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## HARMFUL AQUATIC ORGANISMS IN BALLAST WATER

### Application for Final Approval of JFE BallastAce<sup>®</sup> that makes use of NEO-CHLOR MARINE<sup>®</sup>

Submitted by Japan

#### SUMMARY

*Executive summary:* This document contains an application for Final Approval of a 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)<sup>1</sup>

*Strategic direction, if applicable:* 2

*Output:* 2.2

*Action to be taken:* Paragraph 9

*Related document:* MEPC 62/2/1, MEPC 62/2/12; MEPC 64/2/1, MEPC 64/2/7; MEPC 66/INF.30; MEPC.169(57) and BWM.2/Circ.13/Rev.3

#### Introduction

1 Regulation D-3.2 of the *International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004*, stipulates that ballast water management systems that make use of Active Substances to comply with the Convention shall be approved by the Organization.

2 Japan herewith submits an application for Final Approval according to the *Procedure for approval of ballast water management systems that make use of Active Substances (G9)* for the JFE BallastAce<sup>®</sup> that makes use of NEO-CHLOR MARINE<sup>®</sup> developed by JFE Engineering Corporation. Procedure (G9) identifies the required information (resolution MEPC.169(57), annex, paragraph 4.2.1), including provisions for risk characterization and

<sup>1</sup> This document is over 20 pages long and, in accordance with paragraph 6.11 of the Committees' Method of Work (MSC-MEPC.1/Circ.5/Rev.1), only the first three pages will be translated into the three working languages, with the annex in English only.

analysis (resolution MEPC.169(57), annex, paragraph 5.3), which, according to section 6, should be evaluated by the Organization. The document in the annex contains the non-confidential part of the manufacturer's application dossier including a summary of the report prepared by the manufacturer of the JFE BallastAce® that makes use of NEO-CHLOR MARINE® according to the Procedure (G9). The complete dossier will be made available to the experts of the GESAMP-BWWG with the understanding that all information shall be treated as confidential.

3 The receiving competent authority in Japan has verified the application dossier and believes it to satisfy the data requirements of Procedure (G9) adopted by resolution MEPC.169(57).

### **Summary of non-confidential information of the JFE BallastAce® that makes use of NEO-CHLOR MARINE®**

4 The BWMS developed by JFE Engineering Corporation went to the GESAMP-BWWG for evaluation after its Basic Approval dossier was submitted in December 2010. The non-confidential dossier was submitted to IMO. In this Basic Approval dossier, the maximum allowable dosage of TRO as Active Substance in the ballast water was set at 20 mg/L TRO as Cl<sub>2</sub>. The GESAMP-BWWG evaluated the dossier and Basic Approval for the JFE BallastAce® that makes use of NEO-CHLOR MARINE® BWMS was granted (MEPC 62/24, paragraph 2.3.4). However, in its application for Final Approval, submitted as document MEPC 64/2/1 in March 2012, the maximum allowable dosage of TRO as Active Substance was halved, i.e. set at 10 mg/L TRO as Cl<sub>2</sub>. After the dossier evaluation, GESAMP-BWWG recommended to MEPC that Final Approval be granted to the JFE BallastAce® that makes use of NEO-CHLOR MARINE® (MEPC 64/2/7) provided that the concerns and issues raised in its review were addressed by the applicant to the satisfaction of the Administration, prior to the issuance of the Type Approval Certificate. Following the decision of MEPC 64 for granting Final Approval of the system, Japan issued the Type Approval Certificate of this BWMS with an approval date of 26 June 2013, which was submitted to IMO (MEPC 66/INF.30).

5 Compared to the already approved version of JFE BallastAce® that makes use of NEO-CHLOR MARINE®, the new version presented here uses 20 mg/L TRO as Cl<sub>2</sub> as stated at Basic Approval, which was granted (MEPC 62/24, paragraph 2.3.4). This Final Approval application also considers the items pointed out by GESAMP-BWWG during the evaluation of the Basic Approval Application and the responses of the applicant.

6 The JFE BallastAce® that makes use of NEO-CHLOR MARINE® system consists of a filter, a dissolving equipment for dissolving NEO-CHLOR MARINE® in water, an injection pump for injecting the NEO-CHLOR MARINE® dissolved solution into the ballast water pipeline, and mixing plate for proper mixing of the aqueous solution of NEO-CHLOR MARINE® with the ballast water. During ballast water discharge, a neutralizer is injected to meet the Maximum Allowable Discharge Concentration (MADC) of TRO as Cl<sub>2</sub>. The neutralizer is sodium sulphite aqueous solution. This Final Approval application was submitted to request approval concerning the use of this BWMS under the following conditions:

- .1 Ballast water to be treated: All kinds of ballast water, not limited to a certain salinity or temperature.
- .2 Ballast water is treated once at uptake.

- .3 The Active Substance is the Preparation consisting of sodium dichloroisocyanurate dihydrate (NaDCC). This substance is immediately converted to sodium hypochlorite (Active Substance) and isocyanuric acid when dissolved in water. The BWMS was designed to use a dosing system to generate TRO levels to in maximum 20 mg/L TRO as Cl<sub>2</sub>.
- .4 No minimum retention time after ballast water treatment and before discharge was set, because during discharge the water is neutralized with sodium sulphite aqueous solution.
- .5 The MADC of TRO as Cl<sub>2</sub>, which will be monitored by TRO sensors, will be 0.1 mg/L.

7 To evaluate the environmental acceptability of the BWMS, three different types of test waters, i.e. fresh, brackish and marine, were used to challenge the BWMS. The potential ecological risks of the treated ballast water were evaluated by an analysis of disinfection by-products (DBP) during whole effluent toxicity (WET) tests with neutralized water.

8 The risk assessment for the crew, the general public, the ship and for the environment were evaluated and the overall results support the suggestion that unacceptable risks are unlikely to occur.

#### **Action requested of the Committee**

9 The Committee is invited to consider this proposal for Final Approval and decide as appropriate.

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**ANNEX**

**NON-CONFIDENTIAL INFORMATION ON THE JFE BALLASTACE® THAT MAKES USE  
OF NEO-CHLOR MARINE® BALLAST WATER MANAGEMENT SYSTEM**

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Appendix 1 – BWMS manual (OMSM)

Appendix 2 – Land-based tests report

Appendix 3 – Known toxicity effects of sodium sulphite

Appendix 4 – Results of DBPs analysis

Appendix 5 – MAMPEC modelling results

Appendix 6 – WET test results

Appendix 7 – Previous JFE corrosion tests conducted for two FAs accepted by GESAMP

Appendix 8 – References

## ABBREVIATIONS USED IN THE TEXT

AF	Assessment Factor
AS	Active Substance
BA	Basic Approval
BCF	Bioconcentration factor
BWMS	Ballast water management system
CAS	Chemical Abstract Service
Cl <sub>2</sub>	Chlorine
CMR	Carcinogenicity, mutagenicity and reproductive toxicity
°C	Degrees Celsius
DBP	Disinfection by-product
DMEL	Derived Minimum Effect Levels
DNEL	Derived No-effect Levels
EPA (US)	Environmental Protection Agency
GESAMP-BWWG	IMO/FAO/UNESCO-IOC/WMO/IAEA/UN/UNDP/UNEP/UNIDO Joint Group of Experts on the Scientific Aspects of Marine Environment Protection – Ballast Water Working Group
GISIS	Global Integrated Shipping Information System (of IMO)
h	Hour
H <sub>2</sub> O	Water
IMO	International Maritime Organization
kg	Kilogram
K <sub>oc</sub>	Organic carbon-water partition coefficient
LOAEL	Lowest Observed Adverse Effect Level
m	Metres
m <sup>3</sup>	Cubic metres
MADC	Maximum Allowable Discharge Concentration
MAMPEC-BW	Marine antifoulant model for PEC calculation for ballast water
MEPC	Marine Environment Protection Committee
mg/kg bw/d	Milligrams per kilogram of body weight per day
mg/L	Milligrams per litre
NaDCC	Sodium dichloroisocyanurate
ND	Not detectable
NOAEL	No Observed Adverse Effect Level
NOEC	No Observed Effect Concentration
PBT	Persistence, Bioaccumulation, Toxicity
PEC	Predicted Environmental Concentration
pH	Potential of hydrogen
pKa	Dissociation constant
PNEC	Predicted No Effect Concentration
P <sub>ow</sub>	Octanol/water partition coefficient
PPE	Personal protective equipment
PSPC	Performance Standard for Protective Coatings
RCR	Risk characterization ratio
SOP	Standard Operating Procedure
TRO	Total residual oxidants
TSS	Total suspended solids
US	United States
USCG	United States Coast Guard
WWCT	Waste water collection tank
µg/L	Micrograms per litre
µm	Micrometre (or "micron")

## 1 INTRODUCTION

In 2003, the JFE Engineering Corporation (Japan) started its operation. The history of JFE Engineering Corporation began when it inherited the steelmaking technology and shipbuilding technology that had been long accumulated by NKK and Kawasaki Steel Corporation. As the fields of work include the development of urban areas, and to protect the environment, JFE became interested to solve one of the greatest problems caused by humans to aquatic environments and this is the unwanted introduction of species. Many, if not most, of these species are introduced by ballast water. In consequence, JFE has developed a ballast water management system (BWMS), which is named JFE BallastAce<sup>®</sup> that makes use of NEO-CHLOR MARINE<sup>®</sup>. The BWMS presented here is a new development based upon earlier developed BWMS by JFE Engineering Corporation.

The JFE BallastAce<sup>®</sup> which makes use of NEO-CHLOR MARINE<sup>®</sup> BWMS, uses the dry granular NEO-CHLOR MARINE<sup>®</sup> manufactured by Shikoku Chemicals Corporation (Japan) as Active Substance and sodium sulphite as neutralizer.

### 1.1 Application history

The BWMS developed by TG Corporation, which is a member of the Toagosei Group (Tokyo, Japan), went to the GESAMP-BWWG for evaluation after the non-confidential Basic Approval dossier was submitted in January 2008 (IMO 2007). The system was named JFE BallastAce<sup>®</sup> that makes use of TG Ballastcleaner<sup>®</sup> and TG Environmentalguard<sup>®</sup> and it was originally planned to use 30 mg/L TRO as Cl<sub>2</sub> based on sodium hypochlorite as Active Substance and sodium sulphite as neutralizer. Basic Approval was granted. JFE Engineering Corporation joined as manufacturer and in 2009, the Final Approval dossier was submitted (IMO 2009b) jointly by the JFE Engineering Corporation as the BWMS manufacturer and TG Corporation as the chemical producer. For this Final Approval, the Active Substance dose was reduced to 20 mg/L TRO as Cl<sub>2</sub> and Final Approval was granted.

JFE Engineering Corporation continued and discovered NEO-CHLOR MARINE<sup>®</sup> (sodium dichloroisocyanurate dihydrate previously used as a disinfectant for swimming pools, food, and drinking water), which replaced the TG Ballastcleaner<sup>®</sup> (sodium hypochlorite). This new BWMS was named JFE BallastAce<sup>®</sup> that makes use of NEO-CHLOR MARINE<sup>®</sup> and JFE Engineering Corporation applied in 2010 for Basic Approval (IMO 2010). In this Basic Approval dossier, the maximum allowable dosage of TRO as Active Substance in the ballast water was set at 20 mg/L TRO as Cl<sub>2</sub>. GESAMP-BWWG evaluated the dossier and Basic Approval for the JFE BallastAce<sup>®</sup> that makes use of NEO-CHLOR MARINE<sup>®</sup> BWMS was granted (IMO 2011, annex 5). However, in its subsequent application for Final Approval, submitted as document MEPC 64/2/1 in 2012, the maximum allowable dosage of TRO as Active Substance was halved, i.e. set at 10 mg/L TRO as Cl<sub>2</sub>. After the dossier evaluation, the GESAMP-BWWG recommended to MEPC that Final Approval be granted to the JFE BallastAce<sup>®</sup> that makes use of NEO-CHLOR MARINE<sup>®</sup> (IMO 2012b) provided that the concerns and issues raised in its review were addressed by the applicant to the satisfaction of the Administration, prior to the issuance of the Type Approval Certificate. The GESAMP-BWWG stated that, to avoid unreasonable risk to the environment, human health, property or resources, the system should be operated with the following restrictions:

- .1 **Maximum allowable dosage of Active Substance** – the maximum allowable dosage of TRO Active Substance is 10 mg/L TRO as Cl<sub>2</sub>; and

- .2 **Maximum allowable discharge concentration of Active Substance** – the maximum allowable discharge concentration (MADC) of the Active Substance TRO is less than 0.2 mg/L TRO as Cl<sub>2</sub>.<sup>2</sup>

These restrictions were followed and Japan issued the Type Approval Certificate for this BWMS with an approval date of 26 June 2013, which was submitted to IMO (2014).

JFE Engineering Corporation continued further to develop BWMS and the JFE BallastAce® that makes use of NEO-CHLOR MARINE® presented here, which uses 20 mg/L TRO as Cl<sub>2</sub> and is based upon the Basic Approval, which was granted earlier (IMO 2011, annex 5) with a maximum allowable dosage of Active Substance set at 20 mg/L TRO as Cl<sub>2</sub>.

Previously, corrosion studies were carried out according to the GESAMP-BWWG recommendations in the report of its eighth meeting (IMO 2009a, section 5.1). During the corrosion tests of the previous Final Approval (IMO 2012a) slight corrosion effects were noted in unpainted carbon steel and zinc-coated steel. Considering this and also that the corrosion studies were not yet finalized at the time GESAMP-BWWG reviewed the dossier, GESAMP-BWWG recommended that the final corrosion report be evaluated by the Administration prior to the issuance of the Type Approval Certificate. As a slight corrosion was documented with the BWMS using 10 mg/L TRO as Cl<sub>2</sub>, we put an emphasis on corrosion tests when working towards the Final Approval of the BWMS using now a maximum TRO dose as 20 mg/L TRO as Cl<sub>2</sub>.

It is also interesting to note that for the previously developed BWMS the dose of Active Substance TRO has been reduced to 10 mg/L as Cl<sub>2</sub> from 20 mg/L as Cl<sub>2</sub> considered at Basic Approval with the aim to reduce the production of DBPs. However, the tests have shown that there is no direct relation between the dose of the Active Substance and the production of halogenated by-products. It was also noted that the maximum concentrations of certain Relevant Chemicals presented in the dossier for Final Approval of the previously developed BWMS have not significantly changed when compared with Basic Approval, e.g. the maximum concentrations of tribromomethane was 292 µg/L 5 days after treatment in neutralized seawater at Final Approval (with TRO dose of 10 mg/L TRO as Cl<sub>2</sub> (NaDCC)) and 320 µg/L 5 days after treatment in neutralized seawater at Basic Approval (with TRO dose of 20 mg/L TRO as Cl<sub>2</sub> (NaDCC)). This means that although the TRO dose was halved, the concentrations of these substances was only ca. 10% different. It was therefore concluded that no linear correlation between Active Substance concentration and formation of halogenated by-products exists. A further impact in this regard may have occurred do to the augmentation used to meet the BWMS full scale test requirements.

## 1.2 Final Approval application

### 1.2.1 Course

For this Final Approval application, responding to the comments from GESAMP-BWWG, the test results of the full-scale land-based testing equipment were used to document the Active Substance and the Relevant Chemicals, set the MADCs, evaluate the chemical composition and toxicity of treated ballast water, and to calculate the Predicted Environmental Concentration (PEC) and PEC/Predicted No Effect Concentration (PNEC) ratios. Please note that also data from previous JFE dossiers were used and this was indicated where relevant.

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<sup>2</sup> At the time of the previous Final Approval dossier review MADC was set as 0.2 mg /L TRO as Cl<sub>2</sub>. This was changed to 0.1 mg/L afterwards and this new Final Approval therefore refers to a MADC of 0.1 mg /L TRO as Cl<sub>2</sub>.

### **1.2.2 Identification of Relevant Chemicals**

Based upon the tests conducted, 21 different Relevant Chemicals were detected in accordance with the list of such substances provided in Circular BWM.2/Circ.13/Rev.3.

The JFE BallastAce® that makes use of NEO-CHLOR MARINE® BWMS uses the dry granular proprietary Preparation NEO-CHLOR MARINE®. The main component of this Preparation is sodium dichloroisocyanurate dihydrate (NaDCC) which is immediately converted to the Active Substance sodium hypochlorite and isocyanuric acid by dissolving in water. It is the sodium hypochlorite that is used as the disinfectant to treat the ballast water at ballast water uptake in this system. Sodium sulphite aqueous solution (overdosed) is used to neutralize prior to discharging any TRO remaining in the treated ballast water after disinfection with the Preparation NEO-CHLOR MARINE®.

### **1.2.3 Quality Assurance and Quality Control**

The required tests were done according to internationally recognized guidelines and using the Good Laboratory Practice (GLP) approach, as a recognized quality assurance system.

During the execution of the various tests associated with the present application, a quality assurance committee was established, which included specialists from each company involved for ensuring the quality assurance and quality control and the structure responsible for the audit, approval, and implementation to implement the tests. The work addressed:

- (A) Implementation of land-based tests according to the Guidelines (G8) requirements (IMO 2016)
- (B) Implementation of land-based tests according to the Procedure (G9) requirements (IMO 2008)
- (C) Practice of chemical tests and chemical analysis
- (D) Practice of toxicity tests using the treated ballast water
- (E) Practice of corrosion test

### **1.2.4 Experts involved in the dossier preparation**

Quality Assurance Project Plan for the whole project (QAPP) is provided in confidential Appendix 0.

All water quality analyses, WET tests and DBPs analysis were performed by accredited laboratories using internationally accepted methods following the principles and requirements of the Guidelines (G8) (IMO 2016) and Procedure (G9) (IMO 2008), as well as in Circular BWM.2/Circ.13/Rev.3.

The required full-scale land-based tests of the BWMS were conducted at the Control Union Water land-based test facility at Texel, the Netherlands. Wageningen University & Research (WUR), Den Helder, the Netherlands, conducted the freshwater alga growth inhibition tests, the chronic freshwater fish and rotifer tests.

Marine and brackish fish larvae and survival tests, mysid acute toxicity tests and alga toxicity tests were done by Scymaris Ltd, Brixham Environmental Laboratory, Devon, England. DBP analyses were performed by SGS Belgium NV, Antwerp, Belgium, and isocyanuric acid was analysed by TLR International Laboratories, Rotterdam, the Netherlands.

The corrosion tests were done by Kawasaki Technology Co. Ltd., Hyogo, Japan.

This dossier was prepared and the PEC/PNEC as well as RCR values were calculated by GCDC, a joint initiative of Dr. Stephan Gollasch (Hamburg, Germany), Prof. Dr. Matej David and Jan David (Korte, Slovenia).

### 1.2.5 PEC calculation and PEC/PNEC ratio estimation

Although this Final Approval dossier was prepared to meet the requirements in Circular BWM.2/Circ.13/Rev.3, where it was required to use MAMPEC-BW 3.0 or newer, we used here the newest available MAMPEC version to calculate the Predicted Environmental Concentration (PEC) of chemicals in the default harbour and the PEC/PNEC ratio estimation, which is MAMPEC-BW 3.1 (Deltares 2017).

### 1.3 Conditions applied to the system

This Final Approval application was submitted to request approval concerning the use of this BWMS under the following conditions:

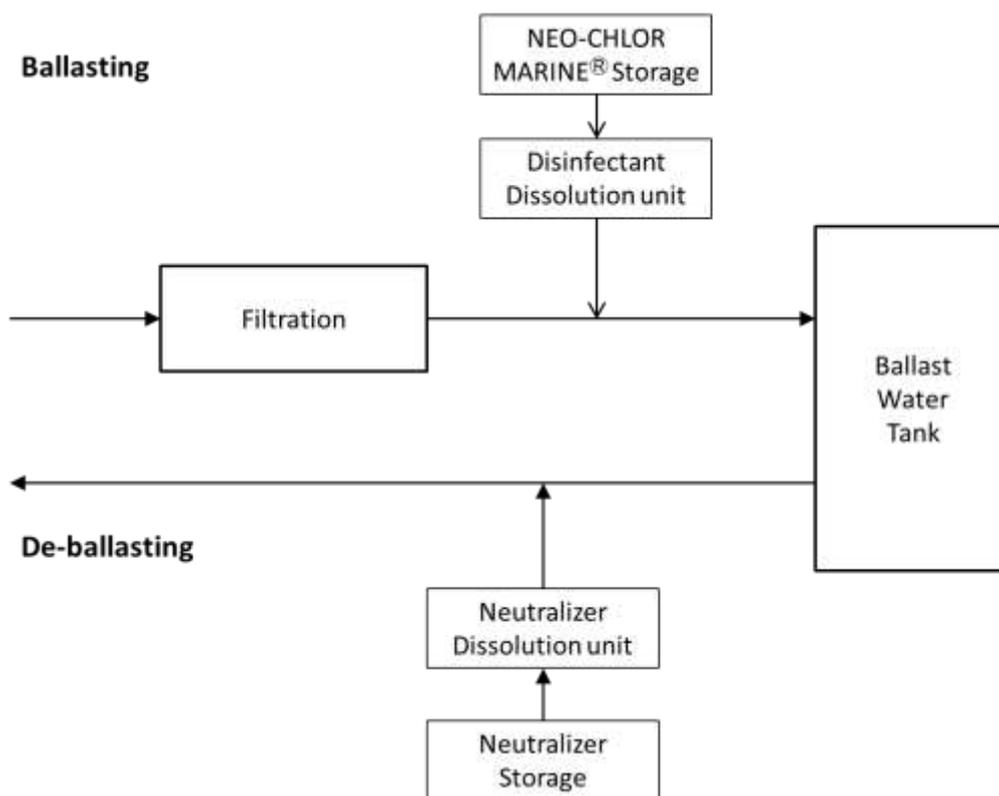
- Ballast water to be treated:  
All kinds of ballast water, not limited by salinity or temperature.
- Number of ballast water treatments:  
Once at water ballast water uptake.
- Preparation and Active Substance concentration to be used:  
The Active Substance is the Preparation consisting of sodium dichloroisocyanurate dihydrate (NaDCC). This substance is immediately converted to sodium hypochlorite (Active Substance) and isocyanuric acid when dissolved in water. JFE has obtained Basic Approval up to a maximum of 20 mg/L TRO as Cl<sub>2</sub> for the BWMS and BWMS was designed to use a dosing system to generate TRO levels to in maximum 20 mg/L TRO as Cl<sub>2</sub>.
- Retention time:  
No minimum retention time after ballast water treatment and before discharge was set. Ballast water can be discharged immediately after treatment as it is neutralized with sodium sulphite aqueous solution.
- Operation of TRO sensor:  
During the discharge operation of ballast water, a TRO sensor monitors the TRO concentration before discharge, and when it detects a TRO concentration of more than 0.07 mg/L, the application of the neutralizer is executed. Furthermore, another TRO sensor monitors the TRO after neutralization with sodium sulphite to ensure that the TRO concentration is 0.1 mg/L or less at the discharge.
- The MADC will be 0.1 mg/L TRO as Cl<sub>2</sub>.

## 2 DESCRIPTION OF THE SYSTEM

The BWMS operation is highly automated. A detailed BWMS description and its control system is provided in this chapter and in confidential Appendix 1.

### 2.1 Overview of the JFE BallastAce® that makes use of NEO-CHLOR MARINE®

The JFE BallastAce® that makes use of NEO-CHLOR MARINE® system consists of a filter, a dissolving equipment for dissolving NEO-CHLOR MARINE® in water, an injection pump for injecting the NEO-CHLOR MARINE® dissolved solution into the ballast water pipeline, and mixing plate for proper mixing of the aqueous solution of NEO-CHLOR MARINE® with the ballast water (Figure 1). During ballast water discharge a neutralizer is injected to meet the MADC of TRO. The neutralizer is sodium sulphite aqueous solution.



**Figure 1: Schematic process diagram of BWMS**

## 2.2 System configuration and main components

### 2.2.1 Concept of the Ballast Water Management System

The JFE BallastAce<sup>®</sup> that makes use of NEO-CHLOR MARINE<sup>®</sup> uses a TRO meter to optimize the consumption of NEO-CHLOR MARINE<sup>®</sup> to adjust the TRO concentration to the set value immediately after its injection into the ballast water. Specifically the number of revolutions at the inverter in the granular chemical feeder of the NEO-CHLOR MARINE<sup>®</sup> dissolving equipment is automatically adjusted.

The feeding rate of NEO-CHLOR MARINE<sup>®</sup> is set so as to have the upper limit of TRO at 20 mg/L at a maximum. When the treated ballast water is discharged (hereinafter referred to as deballasting), the TRO concentration during deballasting is determined by a TRO meter and an aqueous solution of sodium sulphite at the concentration 1.6 times higher than the theoretical amount needed for neutralizing and reducing the TRO is injected by a chemical injection pump into the ballast water line upstream of the ballast pump. In this way proper mixing of the neutralizer during deballasting is ensured. To ensure the complete neutralization in the deballasting water, a TRO meter, which is called supervision TRO meter is further used to monitor the level of TRO.

### 2.2.2 BWMS components and its functions

The flow in normal operation of ballasting and deballasting with JFE BallastAce<sup>®</sup> that makes use of NEO-CHLOR MARINE<sup>®</sup> is illustrated in the piping diagram (see confidential Appendix 1).

A system for operation control and electric control is illustrated in confidential Appendix 1. This system includes a BWMS motor panel, a chemical pump starting panel, and a BWMS control panel. The operation panel is provided with the machine-side operation panel or remote control panel allowing its remote control from the ballast control room.

The remote control panel has the same functions as the machine-side BWMS control panel and is further provided with the function of collecting BWMS operation data and of preparing a report on the operation record requested by Guidelines (G8) (IMO 2016).

The components of the BWMS and their functions are described as follows.

### **(1) Filter**

The filter is included to remove plankton and particles with a size greater than 50 µm in ballast water taken in via sea chests, so that a lower amount of Active Substance has to be used in later treatment steps to eliminate viable plankton and bacteria. Plankton trapped by the filter is returned together with backwash water to the original ballast water uptake sea area. The filter backwash is operated without interrupting the filtering operation. Differential pressure sensors at inlet and outlet of the filter detect the clogging level of the filter element to increase the flow rate of backwash water if needed, thus preventing the filter element from clogging. The backwash line is provided with two motor valves to adapt the flow rate of backwash water and a motor valve is provided one on each at inlet and outlet of the filter.

Another motor valve is provided in the filter system for switching to the bypass line when the treated ballast water is discharged (see confidential Appendix 1).

### **(2) Flow meter**

The maximum feed rate of NEO-CHLOR MARINE® is set at 20 mg/L TRO as Cl<sub>2</sub> concentration. An electromagnetic flow meter is installed for controlling the dosing rate of NEO-CHLOR MARINE®, which is proportional to the flow rate of the ballast water.

### **(3) Supply equipment for NEO-CHLOR MARINE®**

NEO-CHLOR MARINE® filled in a dedicated container, which meets the UN specifications, has to be fed in advance into the chemical hopper of the dissolving equipment for NEO-CHLOR MARINE® described later (see below) before starting the treatment of the ballast water. Since this chemical is reactive, operators have to avoid direct skin contact to the chemical during handling of this chemical.

During the transferring operation of the chemical, a container attachment is attached to the upper part of the dedicated container and moves up and down, flips, and swivels to connect with the dissolving equipment hopper using a stationary feeder. Valves at the side of the dissolving equipment and the container attachment are then opened to drop NEO-CHLOR MARINE® filled in the container into the hopper.

NEO-CHLOR MARINE® is thus transferred in the closed system to the chemical hopper ensuring that the operators have no direct skin contact with the chemical and for a safe operation. Further details are described in Appendix 1.

#### **(4) Dissolving equipment for NEO-CHLOR MARINE®**

NEO-CHLOR MARINE® has to be dissolved in water to form an aqueous solution before it is injected into the ballast water. The NEO-CHLOR MARINE® dissolving equipment, called disinfectant dissolution unit (DDU), consists of a hopper for temporarily storing the Active Substance, a metering feeder for adjusting the charging rate of NEO-CHLOR MARINE® by controlling the number of revolutions so as to keep the TRO concentration in the ballast water constant, the buffer tank for temporarily mixing NEO-CHLOR MARINE® with the dissolving water, the valves for adjusting the water level of the dissolving water in the buffer tank, the motor valves for blocking the feed of the dissolving water when the operation is halted. Resin coated or corrosion resistant materials should be used in those places where the NEO-CHLOR MARINE® or its undiluted solution comes in contact.

#### **(5) Chemical injection pump**

The chemical injection pump is the pump for injecting the aqueous solutions of NEO-CHLOR MARINE® and sodium sulphite into the ballast line. The pump is a diaphragm or gear metering pump. The wetted surface area with an aqueous solution of NEO-CHLOR MARINE® uses pure titanium or protective resin coated material, whereas a wetted surface area with an aqueous solution of sodium sulphite is made of stainless steel or resin. The feed lines for the aqueous solutions of NEO-CHLOR MARINE® and sodium sulphite are equipped with back pressure valves for preventing backflow in the ballast line side and excess flow by pressure drop and with relief valves for preventing a pressure surge of the chemical injection pump.

#### **(6) Mixing plate**

The mixing plate is a thin, round plate that is installed at the downstream of the injector of the ballast pipe. An eddy is generated when the ballast water passes the mixing plate, which will stir and mix the injected disinfectant in a short time. This enhances the killing and disinfecting effects. It also rapidly stirs and mixes the ballast water containing TRO that is to be discharged from the ballast tank and the neutralizer injected into this to accelerate the neutralizing reaction at the time of deballasting.

#### **(7) Control TRO meter**

After the disinfectant is injected into the ballast water at the time of ballasting, this unit measures the TRO concentration after it is stirred and mixed by the mixing plate. This measurement value and the associated ballast water flow rate are fed back to the BWMS control panel, and based on these two values, the disinfectant injection flow rate is automatically controlled to keep the TRO concentration within the set value. Also, at the time of deballasting, the TRO concentration in the ballast water at the ballast tank outlet is measured, and it is used to determine the injection flow rate of the neutralizer required for the associated ballast water flow rate.

#### **(8) Supervision TRO meter**

This is used to monitor the TRO value for ensuring that the TRO of the ballast water after the neutralizer was injected is fully neutralized at the time of deballasting. When the monitored value is about to exceed the limit value for discharging, it increases the neutralizer injection flow rate to ensure complete neutralization.

### **(9) BWMS motor panel**

This panel is a power panel for activating the filter motor, the outlet valve of the filter, the backwash valve of the filter, and sampling pumps.

### **(10) Chemical pump starting panel**

This panel is an electrical power panel for driving the injection pump for the aqueous solution of NEO-CHLOR MARINE® and sodium sulphite.

### **(11) BWMS control panel**

This panel is a control panel for operating the whole electrical apparatuses used in JFE BallastAce® that makes use of NEO-CHLOR MARINE®.

### **(12) BWMS remote control panel**

This panel is a remote control panel with the function equivalent to the BWMS control panel and is provided if needed. A data logger for collecting operation data of the ballast water treatment system requested by IMO and personal computers for preparing reports are equipped along with the remote control panel.

## **2.2.3 Flow of BWMS**

The flow of the ballast water management system is divided into ballasting and deballasting and either one is detailed below along with the drawing of the piping system.

### **2.2.3.1 Flow of BWMS in ballasting**

(1) The ballast water is pumped in from the sea chest by the ballast pump. The seawater passes through the ballast filter, and most of the planktons larger than 50 µm are removed. The plankton organisms removed here are discharged together with the backwash water by the automatic backwash function of the filter into the waters where the ballast water was taken.

(2) The disinfectant is injected by the disinfectant pump into the ballast pipe via the injector, and the plankton organisms and bacteria that passed through the ballast filter are killed and disinfected. The concentration of organic matters is measured by the UV-T unit, and the chlorine concentration necessary for killing them is calculated. The disinfectant is automatically controlled to be the total residual oxidant (TRO) value automatically set.

(3) When the ballast water where the disinfectant was injected passes the mixing plate, a strong turbulence occurs. This rapidly stirs and mixes the disinfectant in a short time, which enforces the killing and disinfecting effects.

(4) The disinfected ballast water is injected into the ballast tank. The residual oxidant present in the ballast water continues to kill living organisms in the ballast tank (Figure 2).

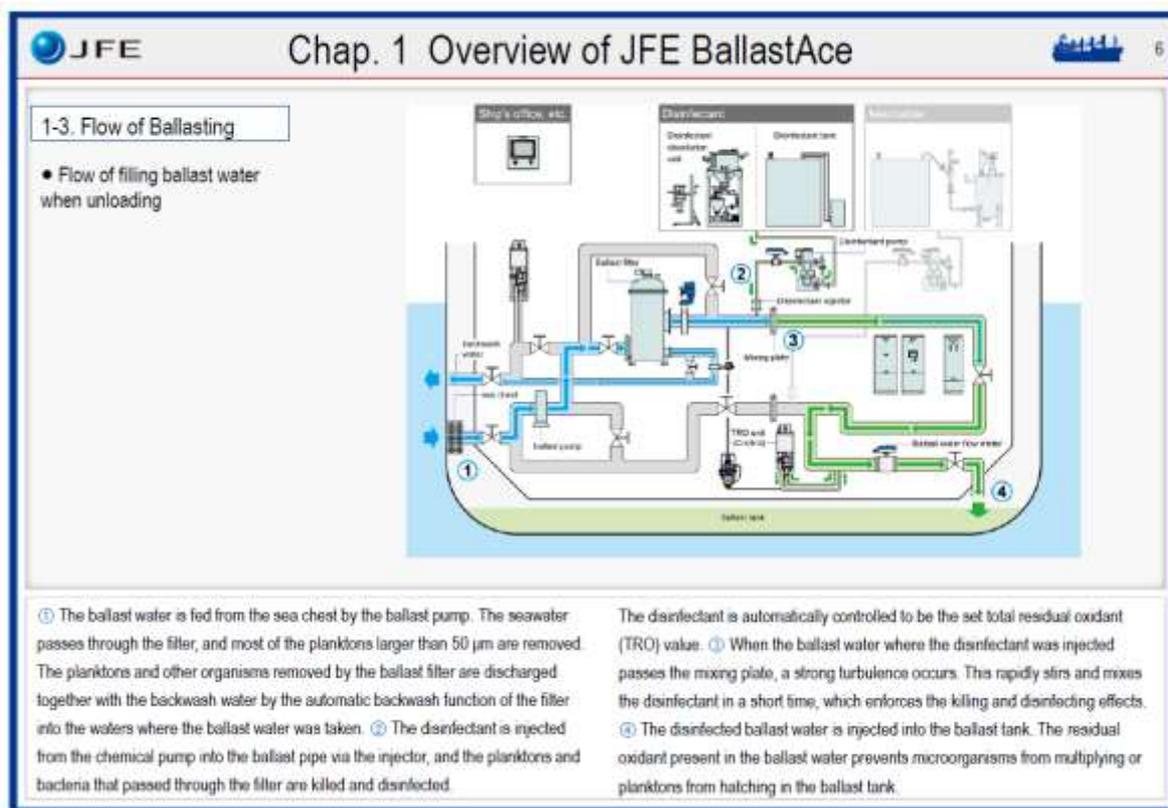


Figure 2: Schematic operation of the BWMS during ballasting

### 2.2.3.2 Flow of BWMS in deballasting

(1) The treated ballast water kept in ballast tanks until the arrival of the ship at the port of discharge contains TRO even though at low concentration. As the treated ballast water does not pass through the filters on discharge and neither through the chemical injection nozzles for the aqueous solution of NEO-CHLOR MARINE® only the pass through neutralizer injection system and two TRO monitor when the ballast pump is activated. Prior to starting the ballast pump an aqueous solution of sodium sulphite is adjusted to a given concentration in advance using the sodium sulphite dissolving equipment. The concentration of the aqueous solution of sodium sulphite is generally adjusted to 10%.

(2) To determine TRO concentration in the treated ballast water during discharge, the sampling pump successively collects samples from the ballast water pipeline. The TRO meter measures the TRO concentration for determining the required injection flow rate of the aqueous solution of sodium sulphite.

(3) The aqueous solution of sodium sulphite is injected at a predetermined flow rate from the chemical injection nozzle provided on the ballast line to completely neutralizing and reducing the residual TRO before the ballast water is discharged from the ship. The maximum allowable discharge concentration (MADC) is set at 0.1 mg /L TRO as Cl<sub>2</sub>, while alarm is activated if 0.1 mg /L TRO as Cl<sub>2</sub> is exceeded (Figure 3).

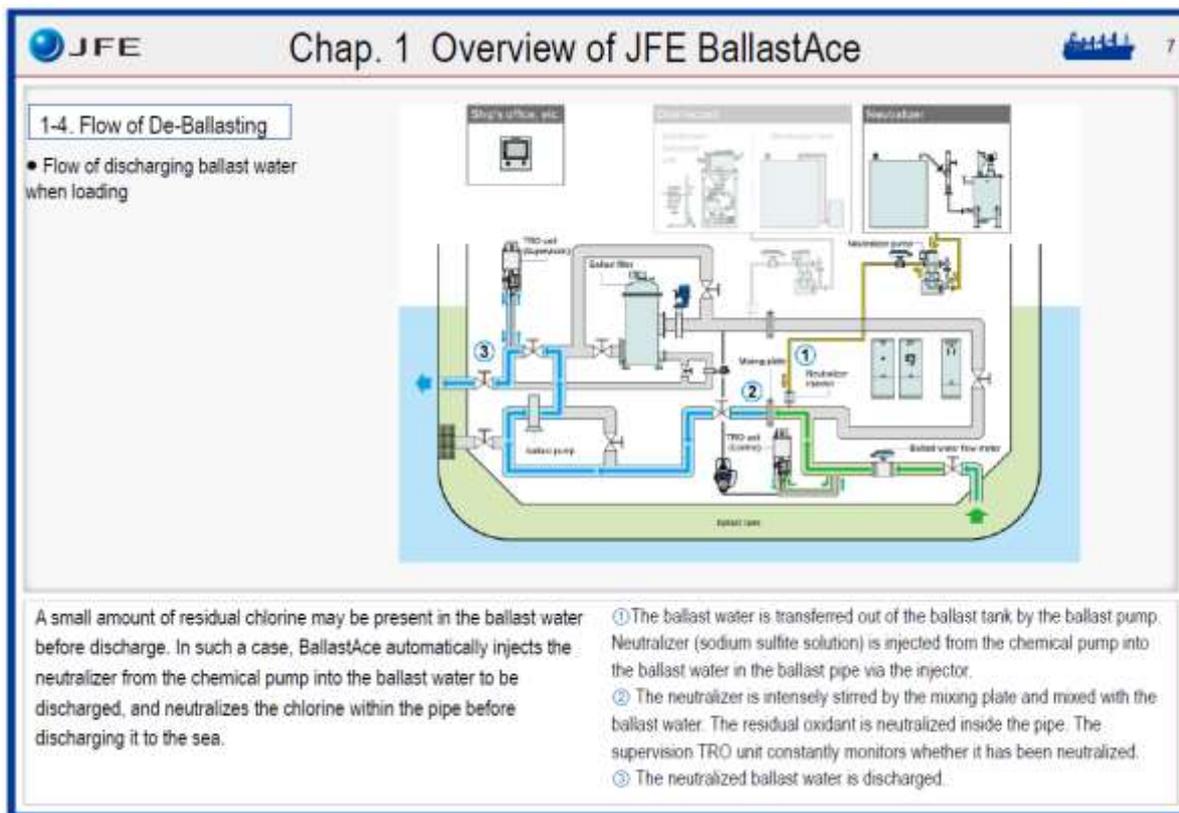
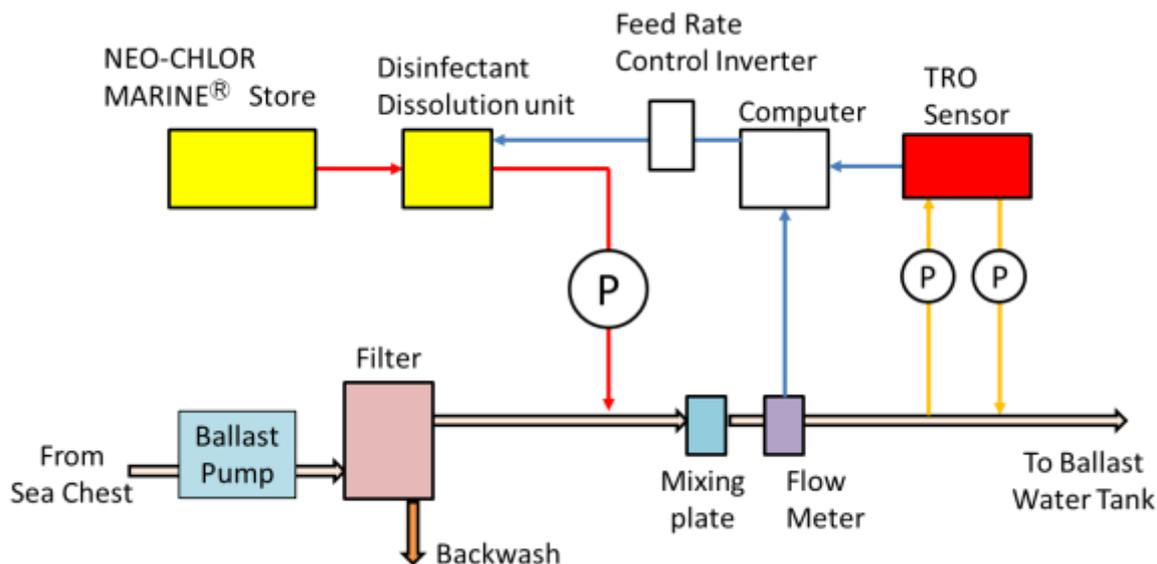


Figure 3: Schematic operation of the BWMS during deballasting

## 2.2.4 Control of chemicals injection

### 2.2.4.1 Control method for chemical injection at ballasting

Figure 4 illustrates the flow of the injection control of NEO-CHLOR MARINE® in ballasting. The TRO meter used for controlling the feed rate of NEO-CHLOR MARINE® in ballasting is a meter sensitive at the TRO concentration range of 0 to 15 mg/L. The feed rate of NEO-CHLOR MARINE® is set at 20 mg /L TRO as Cl<sub>2</sub> at a maximum. The injection control system sets the number of revolutions of the drive motor at the inverter of the rotary feeder using the TRO concentration measured after a set delay time so as to adjust the feeding rate of NEO-CHLOR MARINE® to the set TRO concentration. To prevent NEO-CHLOR MARINE® from injecting an excess volume over the maximum concentration, the upper limit of the number of revolutions is set by calculating the number of revolutions of the drive motor in the injector such that the maximum concentration is obtained using the value determined by the maximum feed rate. To prevent regrowth of organisms and hatching of eggs and/or resting stages of plankton in the ballast water inside the tanks, the TRO in the treated ballast water is not neutralized and reduced until it is discharged.



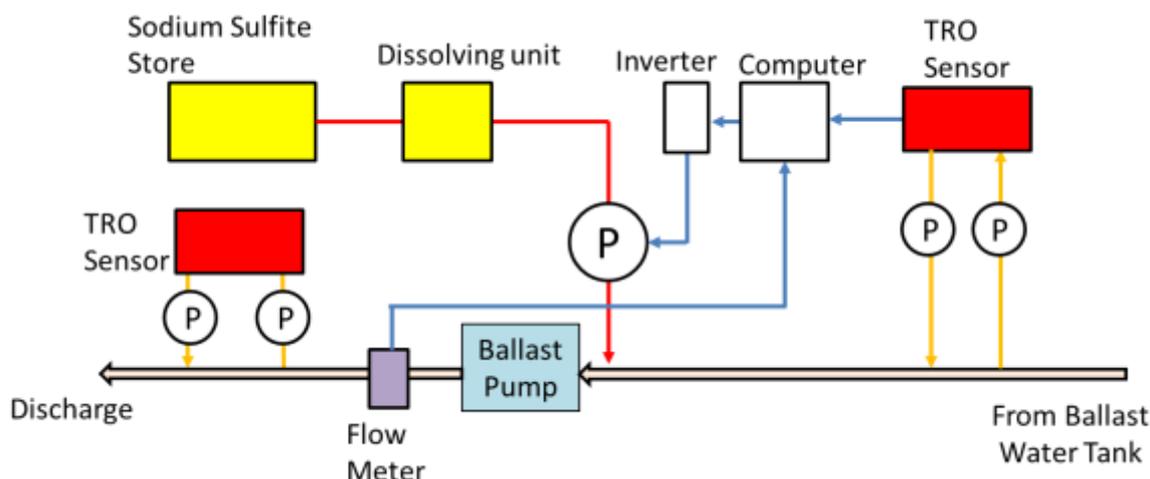
**Figure 4: Injection control of NEO-CHLOR MARINE® during ballasting**

#### 2.2.4.2 Control method for chemicals injection at deballasting

The TRO meter is used to assure the complete neutralization and reduction of the TRO in the ballast water during deballasting. The TRO meter with a sensitivity range of 0 to 15 mg/L of TRO is used to determine the TRO concentration of ballast water in the ballast tanks. The Supervision TRO meter is used to confirm that no TRO exists in the ballast water after neutralization and reduction.

Figure 5 shows a flowchart of the sodium sulphite injection system. Sodium sulphite is dissolved in advance in water to a given concentration of the sodium sulphite solution. The solution is injected by the chemical injection nozzle into the ballast water pipework upstream of the ballast pump so as to adjust the injection rate to completely neutralize and reduce the TRO, of which concentration is determined just after discharge from the ballast tanks. This mixture of the treated ballast water and neutralizer is stirred and mixed when passing through the ballast pump. The rate of neutralization and reduction of the TRO with sodium sulphite is very fast completing the reaction in the ballast water line. Therefore, there is no TRO in the ballast water to be discharged assuring no adverse effects on the ecosystem. In controlling the neutralization of the TRO in the ballast water discharge, the TRO concentration in the ballast water discharge from ballast tanks before neutralization is first determined by the TRO meter followed by injecting sodium sulphite as a neutralizing agent in overdose, i.e. in the amount of 1.6 times the theoretical amount for neutralizing the measured TRO. This volume of sodium sulphite was empirically determined from many test results consistently ensuring the complete neutralization.

The setting condition for operating the present system can be modified any time. Should the TRO value recommended by the GESAMP-BWWG be modified in the future, the current system can fully respond to the modified standard by changing the concentration specified for an alarm activation and the concentration specified for automatic shutdown of the system. If the system is automatically shut down due to, e.g. a sensor malfunction, this is identified and the system restarts after having solved the problems (see confidential Appendix 1).



**Figure 5: Injection control of sodium sulphite during deballasting**

### 2.2.4.3 Actual measurement and monitoring

#### (1) Ballasting

To demonstrate that the TRO concentration during ballasting is controlled within a set value, monitoring data of the system collected when NEO-CHLOR MARINE® were generated during land-based tests (Appendix 2).

#### (2) Deballasting

##### a. Monitoring method

The BWMS is provided with the function of collecting operation data of the system based on Guidelines (G8) (IMO 2016). This system monitors and collects time series data on a water flow rate and an injection rate of an aqueous solution of sodium sulphite indicating the operation condition of the equipment as well as a time series of data on readings by the Control TRO meter for determining the TRO concentration in the treated ballast water and readings by the Supervision TRO meter for confirming the complete neutralization and reduction of TRO.

##### b. Data obtained in monitoring and actual measurement

To demonstrate the TRO is completely neutralized and reduced by controlling the injection of sodium sulphite during deballasting, monitoring data of the system were collected when sodium sulphite was injected in land-based tests (Appendix 2).

## 2.3 Supply chain of chemicals

The Active Substance, NEO-CHLOR MARINE® used in the BWMS is the product manufactured and quality and performance assured by Shikoku Chemicals Corporation and the consigned manufacturers of the said company. A supply chain is established for consistently and reliably supplying the Active Substance from Shikoku Chemicals Corporation and the consigned manufacturers by said company to major seaports in the world.

### **2.3.1 Supply method of chemicals**

The Active Substance is supplied by a chemical supply vessel coming alongside the ship in the port. NEO-CHLOR MARINE® is packaged and supplied by UN approved containers with a proper material quality such as polyethylene or polypropylene.

### **2.4 Amount of Active Substance used**

The amount of NEO-CHLOR MARINE® used is roughly 3,600 kg given the capacity of ballast tanks is 100,000 m<sup>3</sup> for 20 mg/L TRO as Cl<sub>2</sub>.

### **2.5 System and crew safety**

Human exposure to the chemical is unlikely to occur in the normal operation, but could occur in accidental releases. This type of accidents, in which the chemical is released by the BWMS failure, has a potential exposure of crew to NEO-CHLOR MARINE® or sodium sulphite.

If NEO-CHLOR MARINE® in granular form is dropped on the ship's deck, wear a personal protective equipment and recover the chemical in a sealable plastic container.

If NEO-CHLOR MARINE® dissolved in water (converted into a mixture of sodium hypochlorite and isocyanuric acid) is spilled, the spilled solution is neutralized with an aqueous solution of sodium sulphite to flush with water for miscellaneous use into the waste water collection tank (WWCT).

While NEO-CHLOR MARINE® is stable in storage under the normal condition, contact with chemicals such as acids, alkalis, fats, etc. at high concentration generates heat and chlorine. Avoid the storage of chemical substances such as acids, alkalis, etc. near NEO-CHLOR MARINE®. Contact with a small amount of water could generate chlorine. Post a warning sign on a bulletin board near the storage and operation area of NEO-CHLOR MARINE®.

#### **2.5.1 Emergency shutdown and response to power failure**

The emergency shutdown and response to power failure are detailed as follows:

Emergency shutdown: In the event of an emergency requiring shutdown, the injection pump is shut down by the remote control to stop feeding of NEO-CHLOR MARINE® into the ballast water.

Shutdown due to power failure, etc.: In case of power failure, both feed and injection lines for both NEO-CHLOR MARINE® and sodium sulphite are automatically shut down to stop the operation of the whole system and the valves in the pipeline are automatically closed to prevent the chemicals from feeding into the ballast tank and release into the vessel surrounding water area uncontrollably. When the power is recovered for restarting the feed and injection system, the fail-safe device is installed for assuring the restart occurs only after confirming the safe operating condition.

#### **2.5.2 Response to troubles in chemical feed**

When NEO-CHLOR MARINE® or sodium sulphite is fed into the chemical dissolving equipment of ships, wear safety glasses or face protection shields, personal protective equipment, protective gloves, etc. to prevent the crew or operators from chemical exposure and operate the chemical feed according to the handling manual of chemicals on board given in confidential Appendix 1.

### **2.5.3 Response during inspection and repair**

Daily inspection includes any chemical leakage and damage of equipment according to the operation manual (see confidential Appendix 1) for the safety of the crew. When repair is required, wear safety glasses or face protection shields, personal protective equipment, protective gloves, etc., to prevent the crew or operators from chemical exposure and operate the chemical feed according to the handling manual of chemicals on board given in confidential Appendix 1. When personnel other than the crew are involved in the inspection or repair, this person has to be educated on the characteristics of the present equipment and chemicals and the safety for the prevention of chemical exposure.

### **2.5.4 Safety of crew and emergency response**

Possible cases of threatening the safety of crew and its countermeasures are described below.

#### **2.5.4.1 NEO-CHLOR MARINE®**

NEO-CHLOR MARINE® is handled according to the handling manual of chemicals on board (see confidential Appendix 1) in normal operation, in which the safest plan is adopted, but accidents may occur as follows:

- Spill of NEO-CHLOR MARINE® during loading of the chemical to the ship.
- Spill of NEO-CHLOR MARINE® during feeding to the hopper of the dissolving equipment.
- Leak of an aqueous solution of NEO-CHLOR MARINE® from the dissolving equipment or its attachments.

Countermeasures to the above listed cases are described below.

During operation:

(A) When handling the chemical, wear the personal protective equipment and protective clothing and handle the chemical under ventilation.

- Necessary personal protective equipment for operation include safety glasses, face protection shield, chlorine resistant rubber gloves, rubber boots, helmets, and gas mask
- Clothing for operation, wear long sleeve shirts and long trousers with minimum skin exposure. The clothing materials cotton, linen, rayon, polyester, etc. are recommended because of little reactivity with chlorine.

(B) For the safe operation, observe the measures stated in confidential Appendix 1 as well as set up the bulletin board with a warning in the operational area.

When leakages occur:

(C) NEO-CHLOR MARINE® is converted in the presence of water to hypochlorous acid, which corrodes various materials. Small amounts of the chemical leaked from the packing gland of the valve can be recovered by a catch pan such as a tray, etc., followed by neutralization and the storage in WWCT. Wipe clean the spilled area with a dry cloth;

During storage:

- (D) Contact of NEO-CHLOR MARINE® with chemical substances such as acids and alkalis at high concentration may generate chlorine gas. Hence, never store such chemical substances near the area with the potential leakage of NEO-CHLOR MARINE®.
- (E) Store and keep NEO-CHLOR MARINE® below 40°C and away from direct sunlight.

#### **2.5.4.2 Sodium sulphite (neutralizer)**

The neutralizer primarily consists of sodium sulphite and does not belong to any of the categories of dangerous substances under the UN classification system. However, eye, nasal, throat, dermal exposure or inhalation of the substance may result in health problems. To reduce the risk of the crew from leaked chemicals the following countermeasures are implemented.

During operation:

(A) When handling the chemical, wear the personal protective equipment, protective clothing and handle under good ventilation.

- Necessary personal protective equipment for operation include safety glasses, face protection shield, chlorine resistant rubber gloves, rubber boots, helmets, and gas mask
- Clothing for operation includes long sleeve shirts and long trousers with minimum skin exposure.

(B) In the safety manual for the operation, observe the measures stated in Appendix 1 as well as set up a bulletin board with a warning in the operational area.

When leakages occur:

(C) In leaking of an aqueous solution of sodium sulphite, for example, in trace amounts of solution from the gland packing of the valves, use a catch pan such as a tray, etc. to recover the leaked liquid, followed by proper treatment and storage in WWCT. When a substantial amount of the solution is spilled, wash with water and collected in WWCT.

During storage:

(D) Contact of sodium sulphite with acids results in the decomposition and may generate sulphur dioxide gas. Hence, never place acidic substances near the area with the potential leakage of sodium sulphite.

## **2.6 Material Safety Data Sheet (MSDS)**

### **2.6.1 NEO-CHLOR MARINE®**

The material safety data sheet of NEO-CHLOR MARINE® is given in Appendix 1. It contains information to safely handle the chemical substances and to specify appropriate raw materials containing the chemical substances. It is also useful guidance for the safety of the crew involved in handling and storing of the chemical substances.

## 2.7 GHS classification

All Relevant Chemicals considered are included in GISIS, so according to the Methodology (BWM.2/Circ.13.Rev.3, appendix 6), no additional supporting information needs to be submitted by an applicant.

## 3 CHEMICALS ASSOCIATED WITH THE SYSTEM

NEO-CHLOR MARINE® consists of the Active Substance sodium dichloroisocyanurate dihydrate (NaDCC) as a major component. NaDCC is not considered as the Active Substance in this system as it readily decomposes in aqueous solution to produce hypochlorous acid, which is in effect the Active Substance, and isocyanuric acid which is a Relevant Chemical.

### 3.1 PHYSICAL AND CHEMICAL PROPERTIES

#### 3.1.1 Active Substance

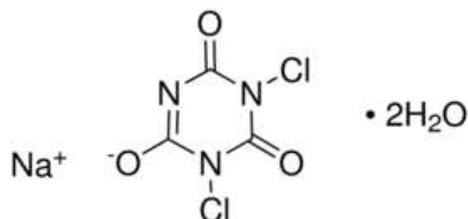
The physical and chemical properties of sodium dichloroisocyanurate dihydrate are shown below.

Chemical Name: Sodium dichloroisocyanurate dihydrate (NaDCC)

IUPAC name: 1,3-dichloro-, 3,5-triazine-, 2,4,6(1H,3H,5H)-trione sodium salt dihydrate

Chemical formula:  $C_3Cl_2N_3NaO_3 \cdot 2H_2O$

Structural formula:



CAS number: 51580-86-0

UN number: 3077 (environmentally hazardous substance, solid, n.o.s.)

Packing group: III

Molecular weight: 255.98

Appearance: White solid granular with slight chlorine odour.

Purity: >99%.

Impurities: Sodium chloride (<1%)

Typical granular size: According to the producers standard >70% of the particles are above 710 µm and less than 2.5% are under 250 µm.

Stabilizers or necessary additives: None.

#### 3.1.2 Neutralizer

The physical and chemical properties of sodium sulphite are presented in Table 1. Sodium sulphite is a hexagonal pillar-shape small crystal or white powder.

**Table 1: Physical and chemical properties of sodium sulphite**

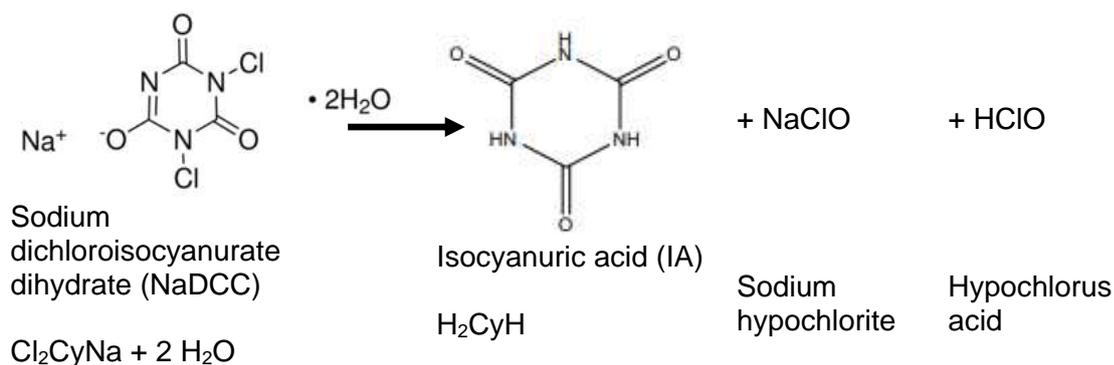
Item	Other chemical
Name of chemical substance	Sodium sulphite
CAS number	7757-83-7
EC number	231-821-4
IMDG class	-
UN number	-
Molar mass (g/mol)	126.04
Chemical formula	Na <sub>2</sub> SO <sub>3</sub>
Purity	Higher than 85 w t%
Melting point (°C)	600
Boiling point (°C)	Convert to Na <sub>2</sub> SO <sub>4</sub>
Flammability (flashpoint for liquids; °C)	Not flammable
Density (20°C; kg/m <sup>3</sup> )	specific gravity 2.68
Vapour pressure (Pa at 20°C)	0 mmHg at ambient T
Relative vapour density (expressed as a ratio by that of air as 1.293 kg/m <sup>3</sup> at 0°C and 105 Pa)	No data available
Water solubility (mg/L, temp; effect of pH)	13.8 g/100 g
pH in solution (under the intended concentration for AS)	>10
Octanol/Water partition coefficient	Log Pow = -7.8
Oxidation-reduction potential (V)	-112 mV
Corrosively to material or equipment	Cannot be classified
Reactivity to container material (only for AS, which needs storage on board)	Not applicable
Auto-ignition temperature, also flash point if applicable (°C)	Not applicable
Explosive properties (narrative)	Not applicable
Oxidizing properties (narrative)	Not applicable
Surface tension (N/m)	75.6 mN/m
Viscosity (Pa·s), Kinetic viscosity (m <sup>2</sup> /s) is also accepted	2.3 mPa·s
Thermal stability and identity of breakdown products (narrative)	Because it is a thermally unstable substance, it is sensitive to air (reacts with oxygen to form sodium sulfate) when heated.

### 3.2 Chemical reactions associated with the system

#### 3.2.1 Identification of Active Substance

##### 3.2.1.1 NEO-CHLOR MARINE®

The disinfection and sterilization agent (tradename: NEO-CHLOR MARINE®) used in this BWMS is sodium dichloroisocyanurate dihydrate as Active Substance. This chemical is converted to sodium hypochlorite, isocyanuric acid (or sodium isocyanurate) and hypochlorous acid in sea, brackish or fresh water according to the following reaction formula (Figure 6). Hypochlorous acid (HClO) and sodium hypochlorite (NaClO) have the disinfection effect.



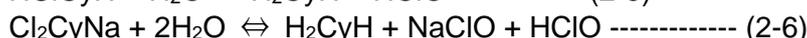
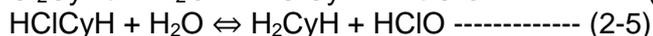
**Figure 6: Molecular formula of sodium dichloroisocyanurate dihydrate (NaDCC) and isocyanuric acid (IA)**

The reaction formulas are illustrated in the equations (2-1)-(2-7). The main reactions are the formulas (2-3) and (2-7). The solubility of isocyanuric acid (2.7 g/L at 25°C) and sodium isocyanurate (146.5 g/L at 26.8°C) in water is much higher than the concentration of these chemicals used in the present BWMS, thus preventing them from precipitation in the treated ballast water.

In fresh water:



or



In seawater or brackish water:

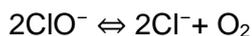


NEO-CHLOR MARINE® is manufactured by the two-step synthesis as illustrated in the following reaction. Isocyanuric acid reacts with sodium hydroxide to yield disodium isocyanurate, which reacts with chlorine to yield dichloroisocyanuric acid, followed by reacting

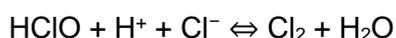
with sodium hydroxide again to crystallize out from the aqueous water high purity sodium dichloroisocyanurate dihydrate (NEO-CHLOR MARINE®). The reaction is carried out in the aqueous solution and purification of the reaction mixture is easy to yield the high purity product.



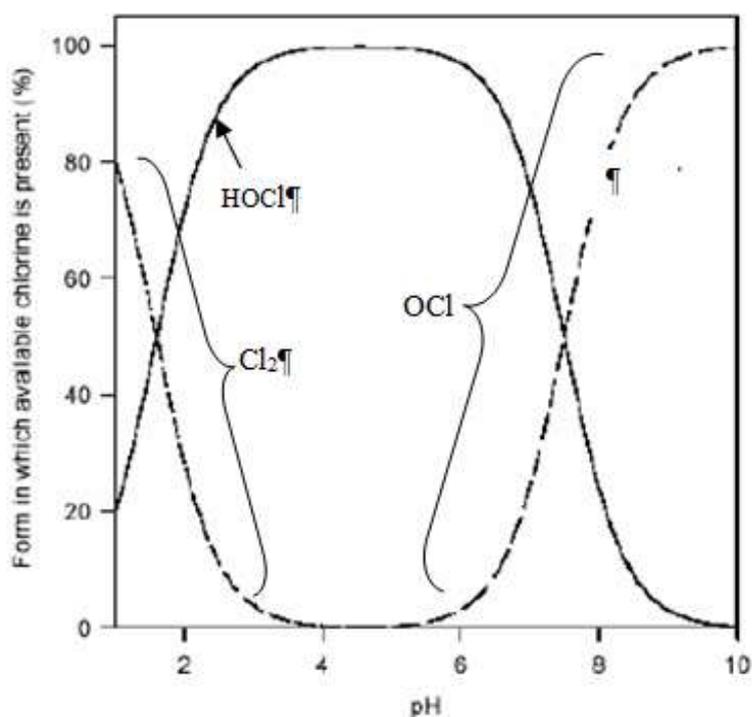
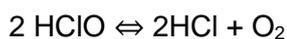
The degradation rate is increased according to the increase in temperature. When the hypochlorite ion concentration is lowered, the degradation rate becomes slower. Under direct sunlight, the degradation reaction of the  $2\text{Cl}^-$  ion and  $\text{O}_2$  is accelerated by the hypochlorite ion.



Further, the hypochlorite ion solution is sensitive to impurities, in particular, to metals (for example, nickel or copper). The hypochlorite ion is changed into chlorine gas and dissolved under acidity conditions of pH 4 or less (Figure 7).



Thus, only the  $\text{ClO}^-$  and the  $\text{HClO}$  are present between pH 4 and pH 11. As a result, the  $\text{HClO}$  is degraded quicker than the  $\text{ClO}^-$  (SIAR: SIDS, 2006).



**Figure 7: Forms of  $\text{ClO}^-$  ion in water at various pH levels**

In addition, hypochlorous acid reacts with nitrogen compounds dissolved in water, such as ammonia, to produce combined chlorine compounds (chloramines). Further, in seawater, hypochlorous acid reacts with hypobromous acid or causes chlorine combined with nitrogen

to undergo a replacement with bromine to produce combined bromine compounds (bromamines). Generally, combined chlorine compounds and combined bromine compounds degrade at slower rates and, therefore, are considered to be weaker oxidizers than hypochlorous acid. Combined chlorine compounds in particular become unstable in proportion to the number of chlorines in their molecules and exist unstably in the environment.



### 3.2.1.2 Effect assessment of isocyanuric acid (including sodium Isocyanurate)

The toxicity data of isocyanuric acid (including sodium isocyanurate) described above confirms that it is not carcinogenic and extremely weak in toxicity. Sodium dichloroisocyanurate has been used as the disinfectant for swimming pool water, in which isocyanuric acid is generated.

People have enjoyed for years to swim in this type of water without generating any hazard to human health. Isocyanuric acid is a white solid powder, very stable, persistent, non-volatile, and water-soluble, but non-bioaccumulative. It is reported that a release of isocyanuric acid 100% to air in the natural environment results in the distribution of 53.3% into the soil and 46.5% into water, respectively.

It is reported that when released 100% into seawater, 99.6% and 0.4% of isocyanuric acid are distributed into water and the sediment, respectively, but none of isocyanuric acid is distributed in air and soil on land (OECD SIDS 1999). However, isocyanuric acid released in seawater reacts with the floating organic substances or sediments to biodegrade relatively fast, indicating it is biodegraded fast enough to assure its safety to human health.

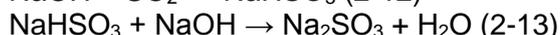
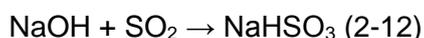
Isocyanuric acid absorbed or ingested by organisms is also excreted from the organisms without accumulation more than 98% of an orally taken dose of isocyanuric acid is excreted unchanged in urine within 24 hours (Allen et al. 1982).

### 3.2.1.3 Sodium sulphite

Sodium sulphite is considered as Other Chemical (OC). The amount of sodium sulphite added and mixed is 1.6 times the theoretical amount required for reducing and completely detoxifying the free chlorine remained in the ballast water after treatment. Unreacted sodium sulphite discharged into seawater reacts with dissolved oxygen to rapidly convert to sodium sulphate.



A general process of manufacturing sodium sulphite involves the injection of sulphur dioxide into sodium hydroxide (illustrated in the reaction below) to yield a sodium bisulphite solution. The mixture is transferred to the neutralization tank to neutralize the ballast water with a sodium hydroxide solution yielding a sodium sulphite solution. The mixture is filtered to eliminate impurities and then chilled with stirring in the crystallization tank to precipitate the crystals, which are separated from the mother liquor, dried and sieved to yield sodium sulphite as the product. The product has no chance to be contaminated with hazardous components.



### 3.3 Identification of chemicals associated with the ballast water management system

This section includes all Active Substance, Relevant Chemical and Other Chemical associated with the system either intentionally or as by-products resulting from the treatment. We like to draw the attention of GESAMP-BWWG to the fact that the present DBP dataset with the 20 mg dosage of TRO/L as Cl<sub>2</sub> provides data for freshwater, brackish water and marine water with water analysed for DBP taken after 5 day holding and after neutralization. However, data before neutralization are lacking. To compensate this data gap datasets generated to apply for former Final Approval were considered. This refers to data from 2009 (WET tests of a 20 mg dosage of TRO/L as Cl<sub>2</sub>) and 2012 (WET tests of a 10 mg dosage of TRO/L as Cl<sub>2</sub>). Both datasets contain DBP results from brackish and marine water. We note that only in two cases, i.e. dibromoacetic acid and tribromomethane, the 2009 dataset shows higher values compared to the 2012 data with half the Active Substance dosage. Further, we observed for most substances an increase in concentration during the 5 day holding time.

#### 3.3.1 Active Substance, Relevant Chemicals and Other Chemicals

Sodium dichloroisocyanuante dihydrate is the active component, but it is very rapidly hydrolyzed upon release in ballast water into hypochlorous acid (or sodium hypochlorite) and sodium isocyanurate (or isocyanuric acid). Sodium sulphite used for neutralization and reduction for eliminating the oxidants remained in the ballast water.

Table 2 provides details of the chemicals analysed for this BWMS with their CAS numbers.

**Table 2: Chemicals analysed for this ballast water management system with their CAS numbers. AS is Active Substance; RC is Relevant Chemical; OC is Other Chemical. Chemicals in grey shading were not detected in any salinity**

Chemical	DL (µg/L)	CAS number	AS, RC or OC
Hypochlorous acid		7790-92-3	AS
Sodium hypochlorite		7681-52-9	AS
1,1,1-trichloroethane	0.2	71-55-6	RC
1,1,2-trichloroethane	0.2	79-00-5	RC
1,1-dibromoethane	1.0	557-91-5	RC
1,1-dichloroethane	1.0	75-34-3	RC
1,2-dibromo-3-chloropropane	1.0	96-12-8	RC
1,2-dichloroethane	1.0	107-06-2	RC
1,2-dichloropropane	1.0	78-87-5	RC
2,4,6-tribromophenol	1.0	118-79-6	RC
Acetaldehyde	1.0	75-07-0	RC
Bromate ion	1.0	15541-45-4	RC
Bromochloroacetic acid	1.0	5589-96-8	RC
Bromochloroacetonitrile	1.0	83463-62-1	RC
Chloral hydrate	1.0	302-17-0	RC
Chlorite	50.0	7758-19-2	RC
Chloropicrin	1.0	76-06-2	RC
Dalapon	0.1	75-99-0	RC

Dibromoacetic acid	1.0	631-64-1	RC
Dibromoacetonitrile	1.0	3252-43-5	RC
Dibromochloroacetic acid	1.0	5278-95-5	RC
Dibromochloromethane	1.0	124-48-1	RC
Dibromomethane	1.0	74-95-3	RC
Dichloroacetic acid	1.0	79-43-6	RC
Dichloroacetonitrile	1.0	3018-12-0	RC
Dichlorobromoacetic acid	1.0	71133-14-7	RC
Dichlorobromomethane	1.0	75-27-4	RC
Dichloromethane	1.0	75-09-2	RC
Formaldehyde	1.0	50-00-0	RC
Isocyanuric acid	20.0	108-80-5	RC
Monobromoacetic acid	1.0	79-08-3	RC
Monobromoacetonitrile	1.0	590-17-0	RC
Monochloroacetic acid	1.0	79-11-8	RC
Monochloroacetonitrile	1.0	107-14-2	RC
Tetrachloromethane	0.2	56-23-5	RC
Tribromoacetic acid	1.0	75-96-7	RC
Tribromomethane	1.0	75-25-2	RC
Trichloroacetic acid	1.0	76-03-9	RC
Trichloroacetonitrile	1.0	545-06-2	RC
Trichloroethene	0.1	79-01-6	RC
Trichloromethane	0.5	67-66-3	RC
Trichloropropane	0.5	96-18-4	RC
Sodium sulphite	500.0	7757-83-7	OC

### 3.3.2 Summary of land-based tests with respect to chemical substances

A summary of all chemicals analysed in the treated ballast water is presented in the tables below, and it includes also undetected substances. A total of 21 Relevant Chemicals were detected. Marine water data are shown in Table 3, brackish water in Table 4 and freshwater in Table 5.

**Table 3: Concentrations of chemicals associated with the ballast water management system. MW is Marine water; D0 is at time 0, D1 at 24h and D5 is 120h of holding time; C is Control water, T is Treated water before neutralization and N is Neutralized treated water. All values are in µg/L**

Chemical	MW-D0-C	MW-D5-C	MW-D0-T	MW-D1-T	MW-D5-T	MW-D5-N
Acetaldehyde	<1	3.0	<1	<1	<1	6.0
Bromate ion	<1	7.0	11.0	12.0	13.2	1.0
Bromochloroacetic acid	1.1	0.4	2.4	13.0	20.0	3.8

Bromochloroacetonitrile	<1	<1	0.8	0.8	0.5	<1
Dalapon	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dibromoacetic acid	0.4	0.8	8.1	9.5	17.1	47.0
Dibromoacetonitrile	<1	<1	3.3	17.6	12.8	<1.0
Dibromochloroacetic acid	<1	<1	1.5	17.8	21.1	32.0
Dibromochloromethane	<1	<1	16.4	51.5	48.1	75.0
Dichloroacetic acid	<1	<1	0.2	1.2	2.7	<1.0
Dichlorobromoacetic acid	0.3	0.5	1.8	12.5	15.6	3.0
Dichlorobromomethane	<1	<1	3.7	5.5	4.9	3.0
Formaldehyde	<1	<1	<1	<1	<1	9.0
Isocyanuric acid	<20	<20	9920.0	9180.0	8310.0	29700.0
Monobromoacetonitrile	<1	<1	<1	<1	<1	51.0
Monochloroacetic acid	<1	<1	<1	<1	<1	<1
Monochloroacetonitrile	<1	<1	0.0	0.0	0.0	2.9
Tribromoacetic acid	0.5	0.6	7.1	57.9	84.9	150.0
Tribromomethane	5.7	7.0	59.2	92.7	283.0	2800.0
Trichloroacetic acid	<1	<1	0.9	4.0	7.7	<1
Trichloromethane	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

**Table 4: Concentrations of chemicals associated with the ballast water management system. BW is Brackish Water; D0 is at time 0, D1 at 24h and D5 is 120h of holding time; C is Control water, T is Treated water before neutralization and N is Neutralized treated water. All values are in µg/L**

Chemical	BW-D0-C	BW-D5-C	BW-D0-T	BW-D1-T	BW-D5-T	BW-D5-N
Acetaldehyde	<1	7.0	<1	<1	<1	5.0
Bromate ion	<1	8.0	1.9	4.6	2.4	1.0
Bromochloroacetic acid	0.7	<1	<1	<1	1.4	3.9
Bromochloroacetonitrile	<1	<1	<1	<1	<1	<1
Dalapon	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dibromoacetic acid	2.2	0.9	9.5	39.4	60.6	38.0
Dibromoacetonitrile	<1	<1	<1	<1	<1	<1
Dibromochloroacetic acid	<1	<1	2.5	2.2	3.2	25.0
Dibromochloromethane	<1	<1	2.4	5.0	8.0	57.0
Dichloroacetic acid	<1	<1	2.0	2.0	1.9	<1.0
Dichlorobromoacetic acid	<1	<1	<1	<1	<1	<1
Dichlorobromomethane	0.1	0.0	0.9	1.5	1.7	2.0
Formaldehyde	<1	<1	<1	<1	<1	<1
Isocyanuric acid	<20	<20	7980.0	7290.0	6780.0	20900.0
Monobromoacetonitrile	<1	<1	<1	<1	<1	1.5
Monochloroacetic acid	0.5	<1	<1	<1	1.5	<1

Monochloroacetonitrile	<1	<1	<1	<1	<1	<1
Tribromoacetic acid	<1	<1	21.3	39.7	48.9	480.0
Tribromomethane	<1	<1	35.9	44.1	86.4	2200.0
Trichloroacetic acid	<1	<1	<1	<1	<1	<1
Trichloromethane	3.0	2.1	5.5	6.9	8.4	<0.5

**Table 5: Concentrations of chemicals associated with the ballast water management system. FW is Freshwater; D5 is 120h of holding time; C is Control water and N is Neutralized treated water. All values are in µg/L**

Chemical	FW-D5-C	FW-D5-N
Acetaldehyde	4.0	4.0
Bromate ion	<1	<1
Bromochloroacetic acid	<1	2.3
Bromochloroacetonitrile	<1	<1
Dalapon	<0.1	6.7
Dibromoacetic acid	<1	<1
Dibromoacetonitrile	<1	<1
Dibromochloroacetic acid	<1	28.0
Dibromochloromethane	<1	54.0
Dichloroacetic acid	<1	5.6
Dichlorobromoacetic acid	<1	57.0
Dichlorobromomethane	<1	74.0
Formaldehyde	4.0	<1
Isocyanuric acid	<20	23300.0
Monobromoacetonitrile	<1	<1
Monochloroacetic acid	<1	<1
Monochloroacetonitrile	<1	<1
Tribromoacetic acid	<1	3.0
Tribromomethane	<1	13.0
Trichloroacetic acid	<1	160.0
Trichloromethane	<0.5	160.0

Chemical analysis of 21 Relevant Chemicals detected in the land-based tests was performed. Relevant Chemicals analyzed include trihalomethanes, bromic acids, haloacetic acids and halonitriles. All Relevant Chemicals detected are included in GISIS (2018) so that no separate data sheets have to be provided. The Other Chemical sodium sulphite is not included in GISIS (2018) and the known toxicity effects of this chemical regarding aquatic plant, invertebrates and fish and other biota is presented in confidential Appendix 3.

For the further risk assessment for human health and the environment, the GESAMP-BWWG selects only the substances that have been detected in a concentration above the detection limit from the table listing all potential by-products produced in ballast water. These substances

should be considered as the Relevant Chemicals for the BWMS. The highest measured values in the ballast tank and in discharged water used for the risk assessment irrespective of the salinity and time of sampling are listed in Table 6.

**Table 6: Selected Relevant Chemicals and maximum concentrations for further risk assessment. Nd means not detected**

Chemical	Maximum concentration (ballast tank) (µg/L)	Maximum concentration (discharged ballast water) (µg/L)
Acetaldehyde	nd	6.0
Bromate ion	13.2	1.0
Bromochloroacetic acid	20.0	3.8
Bromochloroacetonitrile	0.8	nd
Dalapon	nd	6.7
Dibromoacetic acid	60.6	47.0
Dibromoacetonitrile	17.6	nd
Dibromochloroacetic acid	21.1	32.0
Dibromochloromethane	51.5	75.0
Dichloroacetic acid	2.7	5.6
Dichlorobromoacetic acid	15.6	57.0
Dichlorobromomethane	5.5	74.0
Formaldehyde	nd	9.0
Isocyanuric acid	9920.0	29700.0
Monobromoacetic acid	29.5	5.6
Monobromoacetonitrile	nd	51.0
Monochloroacetonitrile	nd	2.9
Tribromoacetic acid	84.9	480.0
Tribromomethane	283.0	2800.0
Trichloroacetic acid	7.7	160.0
Trichloromethane	8.4	160.0

#### 4 CONSIDERATION OF CONCERNS EXPRESSED BY THE GROUP DURING ITS PREVIOUS REVIEW

In this chapter we list the items raised by the GESAMP-BWWG in the summary of their evaluation of the Basic Approval dossier and in the questions they addressed to the applicant.

This Final Approval dossier is based upon the previously granted Basic Approval, as reviewed in the report of the 16th meeting of the GESAMP-Ballast Water Working Group (MEPC 62/2/12, annex 5). We here repeat questions of the GESAMP-BWWG.

### Question 1

**It is noted that the corrosive effect to ballast tanks by use of this proposed BWMS is to be mitigated by specifying effective coatings. What measures are to be recommended to ensure that the ballast water piping is not to suffer extensive corrosion?**

#### Response 1

Modified epoxy coating or painting is recommended for ballast piping for new building ships, but the zinc coating which is usually applied for the ballast piping of existing ships is affected very slightly by the existence of TRO less than 20 mg/L.

#### *Group reaction*

*The Group was satisfied with the response.*

### Question 2

**Throughout the document, the expressions "dissolving equipment" and "dissolution unit" are used. Could you explain what is meant by these expressions? Are they the same thing?**

#### Response 2

The term of "dissolution unit" is used only in Drawings in appendix 7 (page 2) and appendix 9 (page 2). The term of "dissolving equipment" is consistently used in the texts of both the Application and the Summary "dissolution unit" will be replaced with "dissolving equipment" in appendices.

#### *Group reaction*

*The Group was satisfied with the response.*

### Question 3

**Regarding the 'dissolution unit' as identified in appendices 7 and 9 –**

- (a) How is the chemical loaded to the dissolution unit?**
- (b) Is the mixing process manual or is this process fully automatic?**
- (c) Concerning the production of the Active Substance solution to be injected, how is the demand monitored and production in the dissolution unit controlled?**

#### Response 3

- (a) The cartridge-type chemical container for transportation, which is described in 7-1-6-2 of the application (page 147) will be used and it is transported near the inlet of the chemical storage tank by crew. Specifically NEO-CHLOR MARINE® packed in sealed container will be loaded to chemical storage tanks by such as suction-type equipment. Protective measures such as safety glasses, protective mask and protective gloves are used to increase the safety of crew.

- (b) We are planning to use fully automated dissolving equipment.
- (c) Supply of NEO-CHLOR MARINE® to the dissolving equipment is controlled by calculation of flow rate in ballast water main piping and monitored TRO.

*Group reaction*

*The Group noted the response.*

#### **Question 4**

**What is the size of the NEO-CHLOR MARINE® storage unit that is the storage tank between the 'dissolution unit' and the injection pump identified in appendix 7?**

Response 4

In the advance of the development, appendix 7 was revised to exclude storage unit of NEO-CHLOR MARINE® solution as attached.

*Group reaction*

*The Group noted the response.*

#### **Question 5**

**It is noted that the description of the chemical feed equipment given in 7.1.6 and the equipment layout provided in appendix 7 are not the same process. Please provide a full description of the actual process from the chemical storage tank to the injection pump including safety measures incorporated. The function and description of the NEO-CHLOR MARINE® storage unit is not described. What is the function and how critical is the 'unit cooler' identified in the diagram given in appendix 7?**

Response 5

As stated in answer 4, the storage unit was omitted from the drawing in appendix 7. As a consequence, the descriptions in 7-1-6 of both the application and the summary will coincide with the drawing in appendix 7. Then Cooling Unit accompanying Storage Unit is no longer required. The actual process from storage tank to injection pump begins with chemical feeder with variable supply from chemical storage tank and NEO-CHLOR MARINE® is mixed with water in high-speed mixer, where the chemical is completely dissolved as shown in the revised drawing in appendix 9 (page 3). Revised drawing is also attached to the e-mail of these answers. With the safety concern, whole equipment from chemical storage tank through injection pump will be sealed during construction to prevent the crew from contacting chemical granular and solution.

*Group reaction*

*The Group noted the response.*

#### Question 6

**As NEO-CHLOR MARINE® is in granular form, the Group considers it is very important to have a good description of how the chemical loading is done, the storage conditions and how the aqueous solution is prepared using the powder. Please clarify.**

#### Response 6

As stated in 7-1-6-2 Chemical Storage Tank of the application (page 147), cartridge-type chemical container is used for NEO-CHLOR MARINE® and this will avoid crews to contact directly with the chemical. Regarding the storage condition, it is required to "Store and keep it in the ventilated warehouse for chemicals below 40 degree C and away from direct sunlight" as stated in 7-1-7-7(1)E) of the application (page 151) and also in Item 7. HANDLING AND STORAGE of MSDS in appendix 8 (page 4). Safety measures during dissolution process were described in answer 5.

#### Group reaction

*The Group noted the response.*

#### Question 7

**Please provide information concerning the particle size range of NEO-CHLOR Marine® (granulometry), as this is considered an inhalation hazard and risk.**

#### Response 7

The Company's Standard of Particle Size is such that above 710 um is more than 70% and that of under 250 um is less than 2.5%. This product is granular consisting with larger particles and there are little chances of risks of dust hazard. Furthermore, in addition to the safety measures in Answer 6, it is required to "Wear proper protective equipment" stated in Items 7. and 8. of MSDS in appendix 8 (page 4).

#### Group reaction

*The Group noted the response.*

#### Question 8

**It is noted in Figure 7.1.1 that any leakage is collected in the WWCT. Please explain where and how the WWCT is discharged.**

#### Response 8

As stated in 7-1-4 g. of the application (page 137), in discharging WWCT it is required to "Confirm with the basic free residual chlorine analyser the concentration of residual chlorine in the treated water collected in the WWCT before any treatment. If residual chlorine is detected in the treated water, neutralize it with sodium sulphite." Basically spilled solution of NEO-CHLOR MARINE® is to be neutralized immediately with sodium sulphite as stated in 7-1-4 e. of the application (page 137).

*Group reaction*

*The Group noted the response.*

#### **Question 9**

**Could you clarify the difference between the definitions of "TRO", "FAC" and "FAC monitored by TRO sensor"?**

Response 9

Both "TRO" and "FAC" is defined in "Terms and Definition (Excluding Those Described in Methodology)" of the application (page 1). "TRO" consists of "FAC", Combined Chlorine and other oxidants such as hypobromite ion ( $\text{BrO}^-$ ), which ends up with that "TRO" is always equal to or greater than "FAC". Therefore, monitoring "TRO" in lieu of "FAC" is conservative or safer side. We found that we mistakenly used "FAC" in place of "TRO" at the following text in the application, which might have led to this question. We would like to correct them as follows:

- 2. c (page 13) on line 4 from the top
- 2. e (page 14) on line 3 from the top
- 2. e (page 14) on line 5 from the top
- 2. f (page 14) on line 2 from the top
- 4-1 (page 98) on line 4 from the bottom (free available chlorine).

*Group reaction*

*The Group was satisfied with the response.*

#### **Question 10**

**The Group noted that the dose of FAC (e.g., 20 mg/L) is fixed as mixing ratio, however it is also stated that feedback control of the dose has been developed using a TRO sensor "to monitor a decrease of FAC after injection". In this case, is it possible to exceed the 20 mg/L initial dosage already specified? Could you clarify the purpose and precise working of this feedback control?**

Response 10

There is a built-in limit in the control algorithm on the dosage not to exceed 20 mg/L.

*Group reaction*

*The Group was satisfied with the response.*

#### **Question 11**

**The Group noted that the input of MAMPEC model for isocyanuric acid as 18.34 mg/L is set from theoretical conversion from FAC 20 mg/L. However, the actual concentration of isocyanuric acid measured at NIVA was >70 mg/L after 2 days' holding time. Please explain this inconsistency. Please also provide actual measurement of isocyanuric acid concentrations at CERL.**

#### Response 11

The concentration of Available Chlorine is 55% in NEO-CHLOR MARINE® (sodium dichloroisocyanurate dehydrate, hereafter refer to as  $\text{Cl}_2\text{CyNa} \cdot 2\text{H}_2\text{O}$ ) and, therefore, FAC 20 mg/L is equivalent to  $20 \text{ (mg/L)} / 0.55 = 36.36 \text{ (mg/L)}$  for the concentration of  $\text{Cl}_2\text{CyNa} \cdot 2\text{H}_2\text{O}$ . On the other hand, molecular weights of  $\text{Cl}_2\text{CyNa} \cdot 2\text{H}_2\text{O}$  and Isocyanuric acid (hereafter refer to as  $\text{H}_2\text{CyH}$ ) are 255.98 and 129.1, respectively, and one mole of  $\text{Cl}_2\text{CyNa} \cdot 2\text{H}_2\text{O}$  produces one mole of  $\text{H}_2\text{CyH}$  when solved in fresh water as described in equation (2-6) in 3-1-1 of the application (page 17). Therefore, FAC 20 mg/L ( $\text{Cl}_2\text{CyNa} \cdot 2\text{H}_2\text{O}$  36.36 mg/L) is equivalent to  $36.4 \text{ (mg/L)} * 129.1 / 255.98 = 18.34 \text{ (mg/L)}$  for the concentration of  $\text{H}_2\text{CyH}$  as the theoretical value. Since there are no source or reaction producing  $\text{H}_2\text{CyH}$  and NIVA's measured values are far beyond the above-mentioned theoretical value, we asked NIVA for the explanation to this inconsistency. NIVA admitted this was the first time for them to analyse  $\text{H}_2\text{CyH}$  and stated this irregularity as "We are not able to give a good explanation for the observed discrepancy between I added amount and chemically analysed measurement, except that samples on day 0 and day 2 were measured in a sample that was not neutralized by TG EnvironmentalGuard®. Both TRO analysis and chemical analysis after 5 days indicate that correct amount of SDID was administered." in the paragraph above Table 4 of appendix 11 (page 17). We did not ask CERI to analyse  $\text{H}_2\text{CyH}$  because they had no experiences of that. Therefore, we used 18.34 mg/L as foreseeable maximum concentration for MAMPEC analysis.

#### *Group reaction*

*The Group noted the response.*

#### Question 12

**It is stated that the tests on the ecotoxicity of the simulated ballast water were performed at NIVA in Norway, whereas the analysis of the by-products was carried out at the CERI in Japan. Are these measurements for TRO using DPD method in two different test facilities the same or not? How does this provide the basis for a reliable risk assessment?**

#### Response 12

The concentrations of by-products were analysed in NIVA and Table 6 of appendix 11 (page 41) shows the results. It was our fault not mentioning this table in 6-2-2 Analysis of By-products in Simulated Ballast Water Discharge of the application (page 116). In measurement of TRO, DPD method was used both in NIVA and CERI with the same measuring instrument made by HACH were used. The measured concentrations of the by-products on day 5 in CERI were used for the risk assessment because they are higher than those measured in NIVA.

#### *Group reaction*

*The Group was satisfied with the response.*

**Question 13**

In appendix 10, the data sheets for MAMPEC and EUSES should be presented as promised by the title of the document, but only MAMPEC sheets can be found there. Please send the EUSES data sheets as well.

## Response 13

The data sheet of EUSES is attached to the e-mail of these answers.

*Group reaction*

*The Group was satisfied with the response.*

**Question 14**

**The Group noted that the ecotoxicity test water was prepared by adding sodium dichloroisocyanurate to adjust the chlorine concentration to 20 mg/L. According to the data of toxicity test from appendix 11, the measured chemical concentration of Active Substance was significantly lower than 20 mg/L in treated test water at day 0. Please clarify the intended chemical concentration for ecotoxicity test for the BWMS.**

## Response 14

The concentration of TRO after treatment with  $\text{Cl}_2\text{CyNa} \cdot 2\text{H}_2\text{O}$  depends on water quality especially the contents of organic matters and water temperature. At the time when the tests were conducted in NIVA, TSS was considerably higher than the normal seawater due to containing thicker biomass. In such occasion we have experienced that the decay rate of TRO is fast. The concentration of TRO rapidly drops from the dosage of FAC 20 mg/L on Day 0 can be explained by that FAC reacts with inorganic and organic matters, and other reductants contained in seawater, which behavior is well known for Sodium hypochlorite. The dosage of  $\text{Cl}_2\text{CyNa} \cdot 2\text{H}_2\text{O}$  is to provide FAC concentration of 20 mg/L, which was the targeted concentration. The data of TRO change after dosing  $\text{Cl}_2\text{CyNa} \cdot 2\text{H}_2\text{O}$  to this concentration at four locations in Tokyo Bay is shown below.

**Table: Variation of TRO (in July 2010, measured by DPD method) unit: mg/L**

Area	Addition	After 1.5 hours	After 19 hours	After 4 days
A.Yokosuka	20	13.1	9.0	6.3
B.Pier Daikoku	20	11.3	6.4	4.3
C.Higashi Ougishima	20	8.9	6.5	2.3
D.Tsurumi	20	6.9	2.5	1.3

With this result TRO tends to drop rapidly after dosage in Tokyo Bay with large variation depending on the location and water quality. Similar decreases were also observed when sodium hypochlorite was used and we believe that the feedback control of dosage is necessary and effective.

*Group reaction*

*The Group noted the response.*

## **5 HAZARD PROFILE DATA AND EXPOSURE OF CHEMICALS ASSOCIATED WITH THE BWMS**

This section contains a summary of the hazards to mammals and the environment associated with each chemical associated with or generated by the BWMS.

For the forty-three chemicals most commonly associated with treated ballast water indicated in appendix 6 of Circular BWM.2/Circ.13/Rev.3, no additional properties on physico-chemistry, ecotoxicology and toxicology were submitted. Information substances not included in GISIS (2018) need to be provided. However, our tests revealed that the only substance not included in GISIS (2018) is the neutralizer sodium sulphite and the relevant data are provided in confidential Appendix 3.

The detailed results of the DBP analysis is given in confidential Appendix 4.

The following endpoints were recorded:

- .1 The PNEC were taken from GISIS (2018). This value was used in the environmental risk assessment.
- .2 The Derived No Effect Levels (DNEL) and/or Derived Minimum Effect Level (DMEL) were taken from GISIS (2018) and were used in the human risk assessment.

### **5.1 Predicted No Effect Concentrations (PNEC)**

The below Table 7 summarizes the substances to be included in the aquatic environmental risk assessment and for which PNEC values were required. The PNEC data available in GISIS (2018) were used.

**Table 7: PNEC values of chemicals associated with the BWMS and included in GISIS (2018)**

Chemical	Harbour	Near ship
	PNEC (µg/L)	PNEC (µg/L)
Acetaldehyde	2.2	22.0
Bromate ion	140.0	1400.0
Bromochloroacetic acid	16.0	16.0
Bromochloroacetonitrile	0.7	6.9
Dalapon	11.0	110.0
Dibromoacetic acid	6900.0	6900.0
Dibromoacetonitrile	0.1	0.6
Dibromochloroacetic acid	300.0	300.0

Dibromochloromethane	6.3	270.0
Dichloroacetic acid	23.0	230.0
Dichlorobromoacetic acid	60.0	100.0
Dichlorobromomethane	78.0	78.0
Formaldehyde	5.8	31.0
Isocyanuric acid	320.0	620.0
Monobromoacetic acid	16.0	16.0
Monobromoacetonitrile	23.0	230.0
Monochloroacetonitrile	0.6	0.6
Tribromoacetic acid	14000.0	22000.0
Tribromomethane	96.0	96.0
Trichloroacetic acid	300.0	300.0
Trichloromethane	150.0	150.0

## 5.2 Derived No Effect Levels (DNEL) and/or Derived Minimum Effect Level (DMEL)

DNEL and/or DMEL are based on the appropriate toxicological studies on carcinogenicity, mutagenicity and reproductive toxicity (Procedure (G9) (IMO 2008), paragraph 5.3.12), and each chemical should be scored according to these three items.

Hazard profile data originate from GISIS (2018) and recent GESAMP-BWWG reports. For the human health characterization the mammalian toxicity data are of special importance. This characterization includes a screening on carcinogenic, mutagenic, reproductive toxic and endocrine disruptive properties of each substance. The Relevant Chemicals are scored based upon the appropriate toxicological studies regarding carcinogenicity, mutagenicity and reproductive toxicity. A "yes" was stated if the substance showed the hazard under consideration and a "no" if the substance did not show a hazard under consideration. For some Relevant Chemicals at least one of the hazards, i.e. carcinogenicity, mutagenicity or reproductive toxicity was positive. An exposure to these chemicals should be avoided and general risk mitigation measures were proposed (Appendix 1). This is to minimize exposure to an acceptable level using appropriate extrapolation methods. For the integrated CMR classification a precautionary approach was chosen so that in case at least one of the three components was identified as positive, the CMR integrated classification was also stated as positive (Table 8).

**Table 8: Carcinogenic, mutagenic, and reproductive properties of Relevant Chemicals**

Substance	Carcinogenic (C)	Mutagenic (M)	Reprotoxicity (R)	CMR
Acetaldehyde	NO	NO	NO	NO
Bromochloroacetic acid	YES	NO	YES	YES
Bromochloroacetonitrile	NO	NO	NO	NO
Chloral hydrate	NO	NO	NO	NO
Chloropicrin	NO	NO	NO	NO
Dalapon	NO	NO	NO	NO
Dibromoacetic acid	YES	YES	NO	YES
Dibromoacetonitrile	NO	NO	NO	NO
Dibromochloroacetic acid	NO	NO	NO	NO
Dibromochloromethane	YES	NO	NO	YES
Dichloroacetic acid	YES	NO	NO	YES
Dichloroacetonitrile	NO	NO	NO	NO

Dichlorobromoacetic acid	YES	NO	NO	YES
Dichlorobromomethane	YES	NO	NO	YES
Formaldehyde	YES	NO	NO	YES
Isocyanuric acid	NO	NO	NO	NO
Monobromoacetic acid	NO	NO	NO	NO
Monobromoacetonitrile	NO	NO	NO	NO
Monochloroacetic acid	NO	NO	NO	NO
Monochloroacetonitrile	NO	NO	NO	NO
Monochloroamine	NO	NO	NO	NO
Sodium hypochlorite	NO	NO	NO	NO
Tribromoacetic acid	NO	NO	NO	NO
Tribromomethane	YES	NO	NO	YES
Trichloroacetic acid	NO	NO	NO	NO
Trichloromethane	NO	NO	YES	YES

Eight of the Relevant Chemicals were identified as carcinogenic. These were formaldehyde, bromochloroacetic acid, dibromoacetic acid, dichlorobromoacetic acid, dichloroacetic acid, dibromochloromethane, dichlorobromomethane and tribromomethane. Dibromoacetic acid is probably a non-threshold carcinogenic substance because it is mutagenic. Bromochloroacetic acid and trichloromethane were considered reproductive toxic. For the identified carcinogenic chemicals human risk is calculated on the basis of Derived Minimal Effect Levels (DMEL) as derived from GISIS (2018) (Table 9). However, for some substances no DMELs are available.

The assessment of the carcinogenicity, mutagenicity and reproductive toxicity properties of the Active Substance and the Relevant Chemicals is also relevant for the PBT (Persistence, Bioaccumulation, Toxicity) assessment and this is presented further below.

**Table 9: DNELs and DMELs to be used in the risk assessment for humans. Empty cells in the DMEL column mean that this chemical is not carcinogenic**

Chemical	DNEL Crew (mg/kg bw/d)	DNEL General public (µg/kg bw/d)	DMEL (µg/kg bw/d)
Acetaldehyde	4.2E-01	2.1E+02	
Bromate ion	2.2E-02	1.1E+01	1.1E-01
Bromochloroacetic acid	7.5E-01	3.8E+02	1.3E-01
Bromochloroacetonitrile	1.5E-01	7.5E+01	
Dalapon	1.7E-01	8.4E+01	
Dibromoacetic acid	7.2E-02	3.6E+01	1.3E-01
Dibromoacetonitrile	1.6E-01	8.2E+01	
Dibromochloroacetic acid	3.0E-01	1.5E+02	
Dibromochloromethane	2.1E-01	1.1E+02	1.5E+00
Dichloroacetic acid	1.2E-01	6.0E+01	1.7E+00
Dichlorobromoacetic acid	5.0E+00	2.5E+03	1.7E+00
Dichlorobromomethane	4.0E-02	2.0E+01	2.4E+00
Formaldehyde	2.0E-01	1.0E+02	2.2E-01
Isocyanuric acid	3.1E+00	1.5E+03	
Monobromoacetic acid	7.0E-02	3.5E+01	
Monobromoacetonitrile	8.0E-03	4.0E+00	
Monochloroacetonitrile	8.2E-03	4.1E+00	
Tribromoacetic acid	8.6E-01	4.3E+02	

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Tribromomethane	1.8E-01	8.9E+01	7.7E+00
Trichloroacetic acid	8.6E-01	4.3E+02	
Trichloromethane	2.4E-01	1.2E+02	

### 5.3 Exposure

Two major approaches are relevant for the exposure assessment. Firstly, the substances concentrations assessment in ballast water, the air in the tank above the ballast water, the harbour water and the air above the harbour water are evaluated. Secondly, the human uptake assessment of chemicals from water and air of different intake pathways are evaluated. This includes inhalation, dermal, and oral uptake (see also chapter 8 of this document).

For each chemical detected the maximum values measured in all tests were selected for the risk assessment calculations. The calculations were made according to BWM.2/Circ.13/Rev.3, appendix 4, and by considering a worst-case scenario using MAMPEC-BW 3.1 (Deltares 2017) (see confidential Appendix 5).

#### 5.3.1 Workers

##### 5.3.1.1 Concentration in tank water (crew and/or port State inspection)

To evaluate this exposure pathway the highest concentration of the substances measured before neutralization was used. This exposure refers to in tank cleaning by the crew and tank inspections by port State control workers.

##### 5.3.1.2 Concentration in tank and on deck air (crew and/or port State inspection)

The worst-case scenario for the crew was assumed to be the exposure to in-tank air. This was evaluated based on the highest substance concentration measured before neutralization, which represents in-tank conditions. The absolute temperature is part of the calculation formula to calculate the substance concentration in air inside a ballast tank and we have used 293 K (=20°C). This exposure refers to in tank cleaning by the crew, exposure to the crew on deck and exposure during tank inspections by port State control workers.

##### 5.3.1.3 Port State control sampling

Exposure during sampling refers to aggregated dermal and air inhalation exposures of port State control workers. This work will be done during discharge of the ballast water, i.e. handling ballast water after neutralization.

#### 5.3.2 General public

##### 5.3.2.1 Concentration in seawater (general public)

The harbour water substance concentrations were calculated with the newest available version of the MAMPEC-BW model version 3.1 (Deltares 2017). For the PEC calculation the highest measured substance concentrations in the discharged water were used, i.e. after neutralization.

### 5.3.2.2 Concentration in air above sea (general public)

The substance concentrations in air above sea occur after ballast water discharge. Therefore this was calculated based on the measured substance concentration in the discharged ballast water, which means after neutralization.

### 5.3.3 Predicted Environmental Concentration (PEC)

The Predicted Environmental Concentration (PEC) was calculated using the MAMPEC-BW 3.1 model (Deltares 2017) with the appropriate environment definition and emission input. The results of these calculations were used to estimate the risk to the crew, general public and the environment. The results are presented in Table 10 below.

**Table 10:** PEC from MAMPEC modelling results from the GESAMP-BWWG Model Harbour for the harbour and near ship scenario. (nd = not detected)

Chemical	Cmax harbour MAMPEC (µg/L)	Cmean near ship MAMPEC (µg/L)
Acetaldehyde	2.0E-02	5.6E-03
Bromate ion	1.7E-02	9.0E-03
Bromochloroacetic acid	6.4E-02	3.4E-02
Bromochloroacetonitrile	nd	nd
Dalapon	9.7E-02	4.9E-02
Dibromoacetic acid	8.0E-01	4.2E-01
Dibromoacetonitrile	nd	nd
Dibromochloroacetic acid	5.4E-01	2.9E-01
Dibromochloromethane	8.3E-01	4.0E-01
Dichloroacetic acid	9.5E-02	5.0E-02
Dichlorobromoacetic acid	9.7E-01	5.1E-01
Dichlorobromomethane	7.5E-01	3.5E-01
Formaldehyde	1.8E-02	3.7E-03
Isocyanuric acid	5.0E+02	2.7E+02
Monobromoacetic acid	9.5E-02	5.0E-02
Monobromoacetonitrile	8.5E-01	4.5E-01
Monochloroacetonitrile	2.4E-02	1.0E-02
Tribromoacetic acid	8.1E+00	4.3E+00
Tribromomethane	3.3E+01	1.6E+01
Trichloroacetic acid	2.7E+00	1.4E+00
Trichloromethane	1.5E+00	6.9E-01

### 5.3.4 Concentration of chemicals associated with the BWMS in the atmosphere

It was calculated how humans (crew, port State control and the general public) may be exposed to Relevant Chemicals due to the ballasting and deballasting processes, including a worst-case exposure scenario. Concentrations are presented in Table 11.

**Table 11: Concentration of chemicals associated with the BWMS in the atmosphere that were used in the risk assessment for humans**

Chemical	Crew		General public	
	Concentration in tank (µg/L)	Concentration in air (mg/m <sup>3</sup> )	Concentration MAMPEC (µg/L)	Concentration in air (mg/m <sup>3</sup> )
Acetaldehyde	0.0	0.0E+00	0.0	7.3E-08
Bromate ion	13.2	5.4E-05	0.0	6.9E-08
Bromochloroacetic acid	20.0	1.3E-05	0.1	4.3E-08
Bromochloroacetonitrile	0.8	4.3E-05	0.0	0.0E+00
Dalapon	0.0	0.0E+00	0.1	2.6E-07
Dibromoacetic acid	60.6	1.1E-05	0.8	1.5E-07
Dibromoacetonitrile	17.6	3.0E-04	0.0	0.0E+00
Dibromochloroacetic acid	21.1	2.3E-06	0.5	5.9E-08
Dibromochloromethane	51.5	2.1E+00	0.8	3.4E-02
Dichloroacetic acid	2.7	9.5E-07	0.1	3.3E-08
Dichlorobromoacetic acid	15.6	5.1E-06	1.0	3.2E-07
Dichlorobromomethane	5.5	4.8E-01	0.8	6.6E-02
Formaldehyde	0.0	0.0E+00	0.0	2.4E-07
Isocyanuric acid	9920.0	3.6E-09	503.0	1.8E-10
Monobromoacetic acid	29.5	8.0E-06	0.1	2.6E-08
Monobromoacetonitrile	0.0	0.0E+00	0.9	1.2E-04
Monochloroacetonitrile	0.0	7.7E-09	0.0	9.2E-09
Tribromoacetic acid	84.9	1.2E-05	8.1	1.1E-06
Tribromomethane	283.0	6.3E+00	33.4	7.4E-01
Trichloroacetic acid	7.7	5.3E-06	2.7	1.9E-06
Trichloromethane	8.4	1.3E+00	1.5	2.3E-01

## 6 WHOLE EFFLUENT TESTING (WET) – (LAND-BASED TEST)

### 6.1 Description of the tests carried out

Toxicity test methods of the ballast water discharge against aquatic organisms are described below. For details, see the results in confidential Appendix 6. The tests were carried out with water generated during full scale biological efficiency testing at the Control Union Water land-based test facility at Texel, the Netherlands and results are available for freshwater, brackish water and seawater.

WET tests integrate the effects of the Active Substance and all Relevant Chemicals that are formed during and after application of the BWMS. WET tests were performed with fresh water, brackish water and marine species, including different algae, invertebrates and fish. Tests were carried out with treated ballast water after 5 days holding time and after neutralization against control water/media. The effluent ballast water was diluted with laboratory or untreated control water to reach nominal concentrations. Where applicable both survival (LC<sub>50</sub>) and growth (EC<sub>50</sub>) effects were tested.

### **6.1.1 Test types**

#### **6.1.1.1 Algae**

##### **6.1.1.2 Freshwater algal growth inhibition test**

The test procedure was based upon ISO 10253 (ISO 2016a) using *Raphidocelis subcapitata* (synonyms include *Selenastrum capricornutum* and *Pseudokirchneriella subcapitata*) as test species. Reported are the 72h NOEC as an indication for chronic effects and the 72h EC<sub>50</sub> as an indication for acute toxicity. Test concentrations of effluent ballast water used were 0 (blank), 31.6, 42.2, 56.2, 75.0 and 100%.

##### **6.1.1.3 Growth inhibition of marine and brackish algae**

Growth inhibition tests followed guideline USEPA OCSP 850.4500 Algal toxicity and were performed using the diatom *Skeletonema costatum*. The 96 h NOEC, LOEC and EC<sub>50</sub> were documented. Test concentrations of effluent ballast water used were 6.25, 12.5, 25, 50 and 100%.

#### **6.1.1.4 Invertebrates**

##### **6.1.1.5 Chronic freshwater rotifer test**

The test procedure was based upon the standard chronic test for the freshwater rotifer *Brachionus calyciflorus* as available from MicroBioTests Inc. Belgium. The chronic population growth tests were conducted with the freshwater rotifer *Brachionus calyciflorus*. Reported are the 2d chronic NOECs (growth). Test concentrations of effluent ballast water used were 0 (blank), 31.6, 42.2, 56.2, 75.0 and 100%.

##### **6.1.1.6 Acute brackish and marine water mysid test**

Tests were carried out with mysid *Americamysis bahia* according to USEPA OCSP 850.1035 to determine acute toxicity. The test species were <24 hours old. The 96 h NOEC, LOEC and LC<sub>50</sub> were documented. Test concentrations of effluent ballast water used were 6.25, 12.5, 25, 50 and 100%.

#### **6.1.1.7 Fish**

##### **6.1.1.8 Chronic and acute freshwater fish test**

The test procedure was based upon OECD guideline 236 (OECD 2013). The chronic tests were conducted with the freshwater fish *Danio rerio*, also known as zebrafish. Reported are the 4d LC<sub>50</sub> (acute effects) and 7d chronic NOECs for hatching and growth (length). Test concentrations of effluent ballast water used were 0 (blank), 31.6, 42.2, 56.2, 75.0 and 100%.

#### **6.1.1.9 Chronic brackish and marine water fish test**

The tests were conducted according to USEPA Method 1004.0 to determine the survival and growth to sheepshead minnow (*Cyprinodon variegatus*). The 7 day NOEC, LOEC and EC<sub>50</sub> were determined. Test concentrations of effluent ballast water used were 6.25, 12.5, 25, 50 and 100%.

#### **6.2 WET test results**

The summary of the results is presented here below in Table 12, the detailed methods and results are presented in the laboratories reports in the confidential Appendix 6.

Table 12: Results from WET tests

Test	Test organism	Salinity (PSU)	Endpoints (%)			References / Guidelines
			NOEC	EC <sub>50</sub>	LC <sub>50</sub>	
Ballast water effluent compared to combined controls (marine/chronic/survival)	<i>Cyprinodon variegatus</i> (fish)	28-30	100		>100	USEPA 2002. Method 1004.0: Sheepshead Minnow, <i>Cyprinodon variegatus</i> , Larval survival and Growth Test; Chronic Toxicity. Excerpt from: Short-term methods for estimating the chronic toxicity of effluents and receiving waters to marine and estuarine organisms.
Ballast water effluent compared to combined controls (marine/chronic/growth)		28-30	100	>100		
Ballast water effluent compared to laboratory water control (marine/acute/immobility)	<i>Americamysis bahia</i> (mysid)	28-30	62.5		>62.5	USEPA 2016. OCSP 850.1035: Mysid Acute Toxicity Test. Ecological Effects Test Guidelines. EPA 712-C-16-011
Ballast water effluent compared to laboratory water control (marine/acute/growth)	<i>Skeletonema costatum</i> (alga)	28-30	6.25	>100		USEPA 2012. Office of Prevention, Pesticides and Toxic Substances, Ecological Effects Test Guideline OPPTS 850.4500: Algal Toxicity.
Ballast water effluent compared to untreated water control (marine/acute/growth)		28-30	25	>100		
Ballast water effluent compared to laboratory water control (marine/acute/yield)	<i>Skeletonema costatum</i> (alga)	28-30	6.25	21.5		USEPA 2012. Office of Prevention, Pesticides and Toxic Substances, Ecological Effects Test Guideline OPPTS 850.4500: Algal Toxicity.
Ballast water effluent compared to untreated water control (marine/acute/yield)		28-30	25	41		
Ballast water effluent compared to combined controls (brackish/chronic/survival)	<i>Cyprinodon variegatus</i> (fish)	10-20	100		>100	USEPA 2002. Method 1004.0: Sheepshead Minnow, <i>Cyprinodon variegatus</i> , Larval survival and Growth Test; Chronic Toxicity.

Test	Test organism	Salinity (PSU)	Endpoints (%)			References / Guidelines
			NOEC	EC <sub>50</sub>	LC <sub>50</sub>	
Ballast water effluent compared to combined controls (marine/chronic/growth)		10-20	100	>100		Excerpt from: Short-term methods for estimating the chronic toxicity of effluents and receiving waters to marine and estuarine organisms.
Ballast water effluent compared to laboratory water control (marine/acute/immobility)	<i>Americamysis bahia</i> (mysid)	10-20	100		>100	USEPA 2016. OCSPP 850.1035: Mysid Acute Toxicity Test. Ecological Effects Test Guidelines. EPA 712-C-16-011
Ballast water effluent compared to laboratory media control (brackish/acute/growth)	<i>Skeletonema costatum</i> (alga)	10-20	25	>100		USEPA 2012. Office of Prevention, Pesticides and Toxic Substances, Ecological Effects Test Guideline OPPTS 850.4500: Algal Toxicity.
Ballast water effluent compared to untreated water control (brackish/acute/growth)		10-20	6.25	>100		
Ballast water effluent compared to laboratory media control (brackish/acute/yield)	<i>Skeletonema costatum</i> (alga)	10-20	25	94.8		USEPA 2012. Office of Prevention, Pesticides and Toxic Substances, Ecological Effects Test Guideline OPPTS 850.4500: Algal Toxicity.
Ballast water effluent compared to untreated water control (brackish/acute/yield)		10-20	<6.25	58.3		
Ballast water effluent compared to controls (freshwater/chronic/growth)	<i>Danio rerio</i> (fish)	0	>100	>100	>100	OECD 2013. OECD guideline 236.
Ballast water effluent compared to controls (freshwater/acute/hatching)		0	>100	>100	>100	OECD 2013. OECD guideline 236.
Ballast water effluent compared to control (freshwater/chronic/growth)	<i>Brachionus calyciflorus</i> (crustacea)	0	>100			MicroBioTests 2018. The test procedure is based upon the standard chronic test for the freshwater rotifer <i>B. calyciflorus</i> as is available from MicroBioTests Inc. Belgium.

Test	Test organism	Salinity (PSU)	Endpoints (%)			References / Guidelines
			NOEC	EC <sub>50</sub>	LC <sub>50</sub>	
Ballast water effluent compared to controls (freshwater/acute/growth)	<i>Raphidocelis subcapitata</i> (alga)	0	>96	>96		ISO 2016a. ISO 10253: Water quality - Marine algal growth inhibition test with <i>Skeletonema</i> sp. and <i>Phaeodactylum tricornutum</i> . 3rd Edition.

### 6.2.1 Marine water tests

For marine chronic tests fish larvae of Sheepshead Minnow (*Cyprinodon variegatus*) were used. Based on survival compared to the laboratory control and untreated water control ( $p < 0.05$ ) the No Observed Effect Concentration (NOEC) was determined to be 100% in both tests.

For marine acute tests the alga *Skeletonema costatum* was used. In this test, growth inhibition was tested. Regarding growth NOEC was determined to be 6.25% in comparison with laboratory control water and 25% in comparison with untreated water control. Further, the  $EC_{50}$  for both tests was  $>100\%$ . Regarding yield NOEC was determined to be 6.25% in comparison with laboratory control water and 25% in comparison with untreated water control. Further, the  $EC_{50}$  in comparison with laboratory control water was 21.5% and 41% in comparison with untreated water control.

For another marine acute test mysids (*Americamysis bahia*) were used and the immobility was evaluated. Compared to the laboratory control water test the NOEC and  $LC_{50}$  were at 62.5%.

### 6.2.2 Brackish water tests

For the brackish water chronic tests fish larvae of Sheepshead Minnow (*Cyprinodon variegatus*) were used. Both growth and survival analyses were conducted. Based on survival compared to the combined controls NOEC was determined to be 100%. Based on growth compared to the combined controls the NOEC was also determined to be 100%. In the chronic test the  $LC_{50}$  was  $>100\%$  and in the chronic tests  $EC_{50}$  was also  $>100\%$ :

For the brackish water acute test the marine alga *Skeletonema costatum* was used for growth rate analyses. Regarding growth NOEC was determined to be 25% for ballast water effluent growth rate inhibition with comparison to laboratory medium control and below 6.25% for ballast water effluent growth rate inhibition with comparison to untreated water control. This was the strongest effect of all species tested in all salinities. However, this effect was small in terms of actual growth inhibition. At 6.25% concentration the growth rate inhibition compared to untreated control water of was only 10.25% albeit statistically significant. Moreover, we consider that the comparison with laboratory control water is more relevant than the comparison with the untreated control water. This is because the untreated control water is simply water that came from the control tank of CUW (i.e. the facility for the land-based tests), and this is solely studied to check for background toxic effects unrelated to the treatment. The appropriate control water is the laboratory control water used to culture *Skeletonema*, which was prepared by Scymaris (i.e. the facility to conduct the toxicity tests) year-round. The *Skeletonema* is most accustomed to this laboratory control water. Further, for both growth tests  $EC_{50}$  for brackish water were above 100%. Regarding yield NOEC was determined to be 25% for ballast water effluent with comparison to laboratory medium control and below 6.25% for ballast water effluent with comparison to untreated water control. The yield test  $EC_{50}$  in comparison to laboratory control was 94.8% and in comparison to untreated water control 58.3%.

For another brackish water test, acute toxicity to mysids (*Americamysis bahia*) was tested. Based on immobility compared to the combined controls the NOEC was determined to be 100% and  $LC_{50}$  was also above 100%.

### 6.2.3 Freshwater tests

For the freshwater chronic test zebrafish (*Danio rerio*) was used. Effects on growth and hatching were tested. All NOEC,  $EC_{50}$  and  $LC_{50}$  were above 100%.

For the freshwater acute tests the freshwater alga *Raphidocelis subcapitata* was used. NOEC and EC<sub>50</sub> were determined to be >96%.

For another freshwater chronic test the freshwater crustacean *Brachionus calyciflorus* was used and the NOEC was determined as >100%.

#### **6.2.4 WET tests summary and conclusion**

WET tests are in use to confirm (or not) toxicity of substances, which are expected because of the physical and chemical properties of substances. WET tests are seen as to deliver valuable and additional information (Tonkes et al. 1999). Here, in freshwater no effect was observed in all three test species. In marine and brackish water, the alga and the mysid showed an effect, which was strongest for the alga. However, and as GESAMP-BWWG stated previously, the resulting toxic effects can be mitigated by dilution in the receiving waters. The Group assumes in this scenario usually a dilution factor of 5, but we believe this is very conservative when considering how much water is in a port(basin) and how much water is discharged from a vessel. We conclude that WET test with diluted discharge water indicate effects (predominantly to algae), but when considering the dilution of the receiving waters, we suggest that risks to the environment are unlikely. This view is supported by the fact that almost all PEC/PNEC and all RCR values were below 1. All but one PEC/PNEC ratio for the harbour scenario were below 1 (i.e. isocyanuric acid was above 1). In the near ship scenario three substances had a PEC/PNEC above 1 and these were isocyanuric acid, tribromomethane and monochloroacetonitrile. However, when applying the Tier 2 concept the latter was below 1 (see below).

### **7 RISKS TO SHIP SAFETY**

This section covers possible damage to the structure of the ship which might be caused by various effects including:

- .1 explosion;
- .2 fire;
- .3 corrosion; and
- .4 noise.

#### **7.1 Explosion**

It is not expected that this BWMS produces hydrogen gas. Therefore, no explosion risk occurs.

#### **7.2 Fire**

NaDCC has no potential for auto-ignition, but the BWMS itself will not cause a fire.

Potential emergency risks are NaDCC decomposition by a fire in the storage or BWMS vicinity. In case a fire occurs in the BWMS vicinity, the following safety measures shall be taken as risks minimization:

- .1 If a fire occurs in a location where NaDCC containers are stored, water has to be sprayed on and around the NaDCC containers to lower the temperature. Fire extinguishing protective gear must be worn, including a self-contained breathing apparatus and equipment provided by the International Convention for the Safety of Life at Sea (SOLAS). For example, this includes gear against the possible presence of toxic gases such as chlorine.

- .2 If a fire occurs in a location where neutralizer containers are stored, powder fire extinguishers are recommended. Fire extinguishing protective gear must be worn, including a self-contained breathing apparatus and equipment provided by SOLAS. For example, this includes gear against the possible presence of toxic gases such as sulphur oxides.
- .3 If a peripheral fire occurs, move the chemicals immediately to another place, which is not affected by the fire.

### **7.2.1 Classified locations**

In routine installations, BWMS will be located in non-classified locations, e.g. on-deck or in the engine room. Should BWMS be located in classified areas, the associated electrical equipment will be rated in accordance with vessel's classification society and the Administration requirements. In addition, the installation, commissioning, maintenance, and repair instructions provide guidance on maintaining electrical protection measures.

### **7.3 Corrosion**

Contact of an aqueous solution of the NEO-CHLOR MARINE® with parts of the ship without anticorrosive treatment other than the storage tanks and pipelines possibly causes and accelerates the corrosion. It has been confirmed in the durability test of the coating film that the present chemical system is not corrosive to ships including pipelines at the concentration of the chemical substances injected into the ballast tanks if epoxy resin linings or corrosion resistant coatings are applied.

In the present system, sodium sulphite reacts only with TRO derived from NEO-CHLOR MARINE® for reduction and dissolved oxygen to be consumed, indicating it does not have any adverse effect on the ships and pipelines for ballasting operations. A stock solution of sodium sulphite absorbs oxygen in air to yield a stable salt of sodium sulphate.

#### **7.3.1 Effect on ballast tanks**

The inner surface of the ballast tanks might be corroded by ballast water containing residual chlorine if the surface is not properly coated with the corrosion resistant paint. Hence, this coating has to be applied on the inner surface of tanks and pipework of the ship in form of epoxy resin or other materials resistant to chlorine and salt water. These surface treatments will prevent the ballast tanks from corrosion.

#### **7.3.2 Effect on outer hull**

During deballasting residual chlorine disappears while slight excess amounts of sodium sulphite remains in the neutralized ballast water. At that time, sodium sulphite acts as a reducing agent for residual chlorine in the treated ballast water. Its reducing power is higher than that of the transition metals such as iron and zinc. Hence, the outer hull constructed with steel is not affected.

#### **7.3.3 Measures related to ballast water treatment equipment**

Locations for the potential chemical leakage are listed in Table 13. Locations such as chemical storage tanks, etc., where the chemical may potentially leak have to be visually checked every day for any leak as well as the following measures have to be implemented.

**Table 13: Locations of potential chemical leak and countermeasures**

Location for potential chemical leak	Cause of leak	Countermeasures
Chemical storage tanks	Tank failure	Handle according to the instruction in MSDS
Chemical dissolving equipment	Failure of pipe connection, fittings and seals	Install coamings. If leaked, wash with water for miscellaneous use
Chemical injection pumps	Failure of pipe connection, fittings and seals	Install coamings. If leaked, wash with water for miscellaneous use
Valves in chemical feed pipeline	Failure of packing glands and joints. Damage of valve body	Use a tray to catch the leaked fluid. If spilled wash with water for miscellaneous use
Pipe joints	Gasket failure. Poor tightening	Use a tray to catch the leaked fluid. If leaked wash with water for miscellaneous use

- a. Install a coaming underneath the chemical injection pump.
- b. Apply a corrosion resistant paint to the inner wall and bottom of the coaming.
- c. Install WWCT to store the wash water used for cleaning NEO-CHLOR MARINE® solution spilled on a floor. Install water outlets near the chemical storage tanks, pumps, and pipelines for water for miscellaneous use, which is used for the neutralization of the spilled fluid.
- d. Neutralize immediately a spilled solution of NEO-CHLOR MARINE® with sodium sulphite.
- e. Treat properly any chemical spilled in the coming and transfer it to the WWCT.
- f. Install a tray at any location for the potential chemical spill such as valves, etc. and direct the treated water for the spilled chemical into the coaming or WWCT.
- g. Confirm with the portable TRO meter the concentration of TRO in the treated water collected in the WWCT before any treatment. If TRO is detected in the treated water, neutralize it with sodium sulphite.

#### **7.3.4 Progress of corrosion and its countermeasures**

NEO-CHLOR MARINE® is injected and dissolved in the ballast water, which is fed through the ballast water pipework into the ballast tanks. Ships carrying ballast water, which contain residual oxidants, enter a port and keep the ballast water until deballasting for cargo loading. The maximum TRO concentration at that time is 20 mg/L TRO as Cl<sub>2</sub>, which is equal to the upper limit of the concentration of NEO-CHLOR MARINE® (based on the TRO concentration) injected into the ballast water treatment system.

Sodium dichloroisocyanurate dihydrate is dissolved in water to generate sodium hypochlorite, which is a corrosive substance. Hence, as compared to use of seawater alone for ballasting, this ballast water system would result in a progress of corrosion in the ballast tanks, pipework, and parts in direct contact with the treated ballast water. Since the structural support of the ballast tanks is also the reinforcing the stability of the ship, corrosion of the ballast tank is an aspect

directly related to the lifetime of a ship. Therefore, JFE conducted corrosion tests with the sodium hypochlorite solution (TG BallastCleaner®) and there was no additional corrosion effect on the epoxy coated steel. Also, it was confirmed that the corrosive effect between sodium hypochlorite and sodium dichloroisocyanurate dihydrate was same by the Anodic polarization test result. Results of these tests were submitted to GESAMP-BWWG as confidential materials to MEPC 60/2/2 in 2009 (with 20 mg/L TRO as Cl<sub>2</sub>) and MEPC 64/2/1 in 2012 (with 10 mg/L TRO as Cl<sub>2</sub>), and are now provided as confidential Appendix 7 to this dossier. Results were found satisfactory to GESAMP-BWWG and Final Approvals were issued.

To quantify this effect on the ballast pipework, which is in direct contact with the ballast water, and on the ballast tanks, corrosion tests with different test panels were conducted. The coating on the test panels was applied in accordance with Table 1 of the Performance Standard for Protective Coatings (PSPC) for dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers (IMO 2006).

In bulk carriers under heavy ballast conditions, seawater is occasionally loaded in cargo holds resulting in a situation that unpainted steel is in contact with the ballast water. Hence, unpainted steel sheets were included for corrosion evaluation in the tests.

GESAMP-BWWG noted that slight corrosion effects have been determined in carbon steel and zinc-coated steel resulting from the use of this BWMS and that the applicant had recommended that the system should be used on ships with effective ballast tank and pipeline coatings. GESAMP-BWWG also recognized that the corrosive effect on steel was small compared to the corrosive effect of natural seawater and appreciated the applicant's precautionary recommendations (IMO 2012b).

#### **7.4 Storage and handling of NaDCC**

NaDCC and the neutralizer shall be stored separately from each other with their product names indicated to avoid mixed storage (see confidential Appendix 1).

If the storage temperature of NEO-CHLOR MARINE® is higher than 45°C, it releases crystal water potentially resulting in self-heating. Therefore, the temperature of the storage space for the Active Substance is kept below 40°C by such countermeasures as installing cooling equipment directly at the storage space or placing the chemical storage space in a cool area. It should further be stored avoiding exposure to moisture, the storage containers should be tightly sealed, and it should not be stored near other chemical substances in a well-ventilated dry place not exposed to direct sunlight.

#### **7.5 Storage of sodium sulphite**

When sodium sulphite is stored in solid form, avoid exposure to moisture, tightly seal the container, and do not store it near other chemical substances in a well-ventilated dry place not exposed to direct sunlight.

#### **7.6 Other measures for crew and BWMS security**

- .1 General system security  
The BWMS program is protected against any possibly unauthorized modifications and data manipulation.

- .2 Emergency shutdown  
Should any abnormal flow rate, pressure or TRO concentration be detected, an alarm will activate simultaneously with an automatic emergency shutdown of the BWMS. A manual shut down of the whole system is enabled when operators on site press the emergency stop button.
- .3 Safe conduct of crew  
NaDCC and the neutralizer have to be handled with care. Chlorine gas may be detected by humans due to odor. This is recognized even at very low concentrations of 0.1 ppm. Therefore personnel should pay close attention to odors during their checks.

### **7.7 Contact with, or inhalation of, process products**

As the countermeasures for preventing NEO-CHLOR MARINE® dust from spreading, a cartridge type container is used for minimizing the effects to the crew. A certain amount of the chemical substance is kept in the cartridge which is brought from the warehouse and fed into the hopper of the chemical dissolving equipment using the dedicated feeder (see confidential Appendix 1).

NEO-CHLOR MARINE® does not contain particulates with a size smaller than 10 µm, which is particularly hazardous to human health.

### **7.8 Noise**

The components of the BWMS produce no or a low level of noise. A potential source of noise includes the chemical dissolving equipment, chemical feed pumps, and filtration equipment. However, both chemical dissolving equipment and chemical feed pumps are not a source of substantial noise because their capacity is too small to cause an adverse effect on human health. The backwash equipment for the filter generates an operating noise, but its noise level is too low to harm human health.

Further, as it is planned to install and operate the BWMS in ships' engine rooms, pump rooms or other appropriate place on board, the surrounding environment in the engine and pump rooms generate a much higher level of noise than the BWMS. Therefore, the noise generated by the BWMS is unlikely to have an effect on the vessel and on the health of crew.

## **8 RISKS TO THE CREW**

The applied risk characterization followed the procedure for human risk assessment of ballast water chemicals in Circular BWM.2/Circ.13/Rev.3, appendix 4. In the risk characterization for human health the exposure levels to which humans are exposed to or may likely be exposed to, are compared with those levels at which no toxic effects from the chemicals are expected to occur.

A quantitative risk assessment may be performed following four steps:

- .1 hazard identification: to characterize the substances of concern and their effects;
- .2 dose (concentration) – response (effect) relation: to establish the relationship between the dose and the severity or the frequency of the effect;
- .3 exposure assessment: to determine the intensity, and the duration or frequency of exposure to an agent; and
- .4 risk characterization: to quantify the risk from the above data.

The Active Substances and 21 Relevant Chemicals were considered for the hazard identification. Hazard profile data are collected originating from GISIS (2018). For human health characterization the mammalian toxicity data are of special importance. This includes a screening on carcinogenic, mutagenic, reproductive toxic and endocrine disruptive properties (see above).

Risks to the crew and/or port State control may be assumed to be associated with:

- .1 delivery, loading, mixing or adding chemicals to the BWMS;
- .2 ballast water sampling;
- .3 periodic cleaning of ballast tanks;
- .4 ballast tank inspections; and
- .5 normal work on deck.

When considering various work operations, it should be assumed that the exposure routes of concern for the crew and/or port State workers will be inhalation and dermal. In this respect, it is assumed that the crew will be exposed by inhalation to the highest concentration of each chemical in the atmosphere above the treated ballast water at equilibrium and by dermal uptake to the highest concentration of each chemical in the treated ballast water.

The exposure assessments were calculated as the typical scenarios required in Circular BWM.2/Circ.13/Rev.3.

**Table 14: Summary of occupational exposure scenarios**

<b>Operations involving the crew and/or port state workers</b>		
<b>Operation</b>	<b>Exposure</b>	<b>Frequency/duration/quantity</b>
Delivery, loading, mixing or adding chemicals to the BWMS	Potential dermal exposure and inhalation from leakages and spills	Solids, dermal: on a case-by case basis. Liquids, dermal: 0.05-0.1 mL /container handled Gases/vapors/dusts, inhalation
Ballast water sampling at the sampling facility	Inhalation of air released	2 hours/day for 5 days/week; 45 weeks/year
	Dermal exposure to primarily hands	2 hours/day for 5 days/week; 45 weeks/year
Periodic cleaning of ballast tanks	Inhalation of air in the ballast water tank	8 hours/day for 5 days/week; 1 event/year
	Dermal exposure to the whole body	8 hours/day for 5 days/week; 1 event/year
Ballast tank inspections	Inhalation of air in the ballast water tank	3 hours/day for 1 day/month
<b>Normal operations carried out by the crew on BWMS</b>		
Normal work on deck unrelated to any of the above	Inhalation of air released from vents	1 hour/day for 6 months/year

The uptake of chemicals by crew can occur via 3 activities: sampling, cleaning and inspection; and via two exposure routes: inhalation and dermal uptake. As recommended by Circular BWM.2/Circ.13/Rev.3, for the dermal uptake during tank cleaning a higher value of body surface compared to the hand exposure during sampling was used. As most of the human body will likely be appropriately covered during tank cleaning, we considered here three times the surface area

of two hands as appropriate to calculate the exposed body surface during tank cleaning. This value is assumed to cover exposure of parts of forearms or even the face of a person.

For the worker exposure situation in the ballast water tank the concentration of each chemical in the atmosphere above the water was calculated using the Henry's Law Constant. The DNEL values were calculated based on the LOAEL or NOAEL divided by an assessment factor (AF) as provided in GISIS (2018).

For the risk assessment in the crew scenarios we added all calculated exposure values (all dermal and all inhalation values) as a worst-case scenario. In summary, all RCRs were found to be below 1 so that no second tier assessment was performed.

### **8.1 Delivery, loading, mixing or adding chemicals to the BWMS**

During supply of the Active Substance and the neutralizer to the vessel no exposure is expected as the substances are delivered in properly sealed containers (see confidential Appendix 1). The Active Substance is delivered and stored in granular form in 25 kg buckets and the neutralizer in powder form in 25 kg craft paper bags or aluminum bags. As the Active Substance is used in granular form with >70% of the particles are above 710 µm and less than 2.5% are under 250 µm an exposure through inhalation is considered unlikely. The neutralizer is used in powder form. The appropriate protective gear to be worn when handling these chemicals to avoid dermal exposure during refilling the BWMS storage tanks of these substances was already described in confidential Appendix 1.

Please note that Circular BWM.2/Circ.13/Rev.3 suggests evaluating the potential dermal exposure of the hands during delivery, loading, mixing or adding chemicals to the BWMS by the UK Predictive Operator Exposure Model (POEM) and the exposure assessments may be done in two tiers. However, this model is not applicable here as it considers the diluted substances in a fluid, but here only granular and powder substances are handled.

The dilution of the Active Substance and the neutralizer is done in an enclosed unit of the BWMS without interference and no contact to the crew. After dilution the Active Substance and neutralizer solutions are kept in storage tanks of the BWMS, also without contact to the crew. We therefore consider that the crew exposure scenarios as outlined in chapters and of this dossier appropriately dealt with this subject. Protection measures for substance spillages are also described in the following chapters and confidential Appendix 1.

### **8.2 Ballast water sampling**

Sampling for port State control inspections will likely be conducted during ballast water discharges as otherwise the sampling event may not generate representative samples for compliance control with the ballast water management standards. This means that the water is sampled after neutralization. As a consequence, for the calculation of inhalation and dermal exposure during sampling, the substance concentration after neutralization was used.

For ballast water sampling all RCR values were calculated as below 1 (Table 15) so that no Tier 2 calculation was performed.

**Table 15: RCR calculation results for port State control officers when conducting ballast water sampling**

Chemical	Scenario (mg/kg bw/d)		Aggregated exposure (mg/kg bw/d)	DNEL (mg/kg bw/d)	RCR tier 1
	Dermal	Inhalation			
Acetaldehyde	8.4E-07	9.1E-09	8.5E-07	4.2E-01	2.0E-06
Bromate ion	1.4E-07	1.7E-09	1.4E-07	2.2E-02	6.4E-06
Bromochloroacetic acid	5.3E-07	1.1E-09	5.3E-07	7.5E-01	7.1E-07
Dalapon	9.4E-07	7.4E-09	9.5E-07	1.7E-01	5.6E-06
Dibromoacetic acid	6.6E-06	3.6E-09	6.6E-06	7.2E-02	9.1E-05
Dibromochloroacetic acid	4.5E-06	1.4E-09	4.5E-06	3.0E-01	1.5E-05
Dibromochloromethane	1.1E-05	1.3E-03	1.3E-03	2.1E-01	6.2E-03
Dichloroacetic acid	7.8E-07	8.1E-10	7.8E-07	1.2E-01	6.5E-06
Dichlorobromoacetic acid	8.0E-06	7.8E-09	8.0E-06	5.0E+00	1.6E-06
Dichlorobromomethane	1.0E-05	2.7E-03	2.7E-03	4.0E-02	6.8E-02
Formaldehyde	1.3E-06	5.2E-08	1.3E-06	2.0E-01	6.6E-06
Isocyanuric acid	4.2E-03	4.5E-12	4.2E-03	3.1E+00	1.3E-03
Monobromoacetic acid	7.8E-07	6.3E-10	7.8E-07	7.0E-02	1.1E-05
Monobromoacetonitrile	7.1E-06	3.1E-06	1.0E-05	8.0E-03	1.3E-03
Monochloroacetonitrile	4.1E-07	4.7E-10	4.1E-07	8.2E-03	5.0E-05
Tribromoacetic acid	6.7E-05	2.8E-08	6.7E-05	8.6E-01	7.8E-05
Tribromomethane	3.9E-04	2.6E-02	2.6E-02	1.8E-01	1.5E-01
Trichloroacetic acid	2.2E-05	4.6E-08	2.2E-05	8.6E-01	2.6E-05
Trichloromethane	2.2E-05	1.0E-02	1.0E-02	2.4E-01	4.2E-02

Indicative risk levels available from internationally recognized bodies may be used to calculate the indicative RCR regarding potential cancer risk in the DMEL approach. Furthermore, the group RCR approach may be applied to the calculation. The group RCR approach is to be applied for substances with a DMEL value, and is described in Circular BWM.2/Circ.13/Rev.3, appendix 4. Indicative risk levels are presented in Table 16.

**Table 16: Indicative RCR calculation results for non-threshold carcinogenic substances for port State control officers when conducting ballast water sampling**

Chemical	Scenario (mg/kg bw/d)		Aggregated exposure (mg/kg bw/d)	DMEL (mg/kg bw/d)	RCR tier 1
	Dermal	Inhalation			
Bromate ion	1.4E-07	1.7E-09	1.4E-07	1.1E-01	1.3E-06
Bromochloroacetic acid	5.3E-07	1.1E-09	5.3E-07	1.3E-01	4.1E-06
Dibromoacetic acid	6.6E-06	3.6E-09	6.6E-06	1.3E-01	5.1E-05
Dibromochloromethane	1.1E-05	1.3E-03	1.3E-03	1.5E+00	8.6E-04
Dichloroacetic acid	7.8E-07	8.1E-10	7.8E-07	1.7E+00	4.6E-07
Dichlorobromoacetic acid	8.0E-06	7.8E-09	8.0E-06	1.7E+00	4.7E-06

Dichlorobromomethane	1.0E-05	2.7E-03	2.7E-03	2.4E+00	1.1E-03
Formaldehyde	1.3E-06	5.2E-08	1.3E-06	2.2E-01	6.0E-06
Tribromomethane	3.9E-04	2.6E-02	2.6E-02	7.7E+00	3.4E-03
<b>SUM</b>					<b>5.5E-03</b>

No RCR was above 1 so that no Tier 2 calculation was needed.

A comparison of the estimated exposure and DNEL, as a chronic effect of a worker by dermal and inhalational route, was shown as the resulting risk characterization ratio (RCR).

### 8.3 Periodic cleaning of ballast tanks

For in-tank exposure calculations regarding inhalation and dermal uptake during cleaning the substance concentrations measured before the neutralization were used as this exposure occurs with unneutralized treated water. For this calculation the highest measured substance concentrations were used. Results are presented in Table 17 and all RCR values were calculated as below 1.

**Table 17: RCR calculation results for the crew when conducting periodic cleaning of ballast tanks**

Chemical	Scenario (mg/kg bw/d)		Aggregated exposure (mg/kg bw/d)	DNEL (mg/kg bw/d)	RCR tier 1
	Dermal	Inhalation			
Bromate ion	1.8E-06	9.0E-07	2.8E-06	2.2E-02	1.3E-04
Bromochloroacetic acid	2.8E-06	2.2E-07	3.0E-06	7.5E-01	4.0E-06
Bromochloroacetonitrile	1.2E-07	7.2E-07	8.4E-07	1.5E-01	5.6E-06
Dibromoacetic acid	8.5E-06	1.9E-07	8.7E-06	7.2E-02	1.2E-04
Dibromoacetonitrile	1.8E-06	3.6E-06	5.4E-06	1.6E-01	3.4E-05
Dibromochloroacetic acid	3.0E-06	3.8E-08	3.0E-06	3.0E-01	1.0E-05
Dibromochloromethane	7.2E-06	3.5E-02	3.5E-02	2.1E-01	1.7E-01
Dichloroacetic acid	3.8E-07	1.6E-08	4.0E-07	1.2E-01	3.3E-06
Dichlorobromoacetic acid	2.2E-06	8.5E-08	2.3E-06	5.0E+00	4.5E-07
Dichlorobromomethane	7.7E-07	8.0E-03	8.0E-03	4.0E-02	2.0E-01
Isocyanuric acid	1.4E-03	6.0E-11	1.4E-03	3.1E+00	4.5E-04
Monobromoacetic acid	4.1E-06	1.3E-07	4.3E-06	7.0E-02	6.1E-05
Monochloroacetonitrile	2.8E-09	1.3E-10	2.9E-09	8.2E-03	3.6E-07
Tribromoacetic acid	1.2E-05	2.0E-07	1.2E-05	8.6E-01	1.4E-05
Tribromomethane	4.0E-05	1.0E-01	1.0E-01	1.8E-01	5.8E-01
Trichloroacetic acid	1.1E-06	8.8E-08	1.2E-06	8.6E-01	1.4E-06
Trichloromethane	1.2E-06	2.1E-02	2.1E-02	2.4E-01	8.7E-02

For non-threshold carcinogenic substances RCRs were calculated and summed up in Table 18. All RCR values were below 1.

**Table 18: RCR calculation results for non-threshold carcinogenic substances for the crew when conducting periodic cleaning of ballast tanks**

Chemical	Scenario (mg/kg bw/d)		Aggregated exposure (mg/kg bw/d)	DMEL (mg/kg bw/d)	RCR
	Dermal	Inhalation			
Bromate ion	1.8E-06	9.0E-07	2.8E-06	1.1E-01	2.5E-05
Bromochloroacetic acid	2.8E-06	2.2E-07	3.0E-06	1.3E-01	2.3E-05
Dibromoacetic acid	8.5E-06	1.9E-07	8.7E-06	1.3E-01	6.7E-05
Dibromochloromethane	7.2E-06	3.5E-02	3.5E-02	1.5E+00	2.3E-02
Dichloroacetic acid	3.8E-07	1.6E-08	4.0E-07	1.7E+00	2.3E-07
Dichlorobromoacetic acid	2.2E-06	8.5E-08	2.3E-06	1.7E+00	1.3E-06
Dichlorobromomethane	7.7E-07	8.0E-03	8.0E-03	2.4E+00	3.3E-03
Tribromomethane	4.0E-05	1.0E-01	1.0E-01	7.7E+00	1.4E-02
<b>SUM</b>					<b>4.1E-02</b>

#### 8.4 Ballast tank inspections

As for periodic tank cleaning, ballast tank inspectors are exposed to unneutralized treated water. Therefore, the highest measured substance concentrations were used here as well. All RCR values were calculated as below 1 and the detailed results are presented in Table 19 and for non-threshold carcinogenic substances in Table 20.

**Table 19: RCR calculation results for the crew/PSC when conducting ballast tank inspections**

Chemical	Scenario (mg/kg bw/d)	DNEL (mg/kg bw/d)	RCR tier 1
	Inhalation		
Bromate ion	9.0E-07	2.2E-02	4.1E-05
Bromochloroacetic acid	2.2E-07	7.5E-01	3.0E-07
Bromochloroacetonitrile	7.2E-07	1.5E-01	4.8E-06
Dibromoacetic acid	1.9E-07	7.2E-02	2.6E-06
Dibromoacetonitrile	4.9E-06	1.6E-01	3.1E-05
Dibromochloroacetic acid	3.8E-08	3.0E-01	1.3E-07
Dibromochloromethane	3.5E-02	2.1E-01	1.7E-01
Dichloroacetic acid	1.6E-08	1.2E-01	1.3E-07
Dichlorobromoacetic acid	8.5E-08	5.0E+00	1.7E-08
Dichlorobromomethane	8.0E-03	4.0E-02	2.0E-01
Isocyanuric acid	6.0E-11	3.1E+00	1.9E-11
Monobromoacetic acid	1.3E-07	7.0E-02	1.9E-06
Monochloroacetonitrile	1.3E-10	8.2E-03	1.6E-08
Tribromoacetic acid	2.0E-07	8.6E-01	2.3E-07
Tribromomethane	1.0E-01	1.8E-01	5.8E-01
Trichloroacetic acid	8.8E-08	8.6E-01	1.0E-07
Trichloromethane	2.1E-02	2.4E-01	8.7E-02

**Table 20: RCR calculation results for non-threshold carcinogenic substances for the crew when conducting ballast tank inspections**

Chemical	Scenario (mg/kg bw/d)	DMEL (mg/kg bw/d)	RCR tier 1
	Inhalation		
Bromate ion	9.0E-07	1.1E-01	8.2E-06
Bromochloroacetic acid	2.2E-07	1.3E-01	1.7E-06
Dibromoacetic acid	1.9E-07	1.3E-01	1.4E-06
Dibromochloromethane	3.5E-02	1.5E+00	2.3E-02
Dichloroacetic acid	1.6E-08	1.7E+00	9.3E-09
Dichlorobromoacetic acid	8.5E-08	1.7E+00	5.0E-08
Dichlorobromomethane	8.0E-03	2.4E+00	3.3E-03
Tribromomethane	1.0E-01	7.7E+00	1.4E-02
<b>SUM</b>			<b>4.0E-02</b>

### 8.5 Normal work on deck

The BWMS is remotely operated so that no on deck work is needed except for loading the chemicals onto the ship (see above and confidential Appendix 1 for details of handling the chemicals on board). An error in operation or incident during the chemical loading could occur in any circumstance. Hence, it is important to educate and train the crew for the safety using the instruction manuals (see confidential Appendix 1) and MSDS provided by the chemical manufacturer in order to assure them to be 100% safe (see confidential Appendix 1).

For normal work on deck all RCR values are calculated as to be below 1 (Table 21 and Table 22).

**Table 21: RCR calculation results for the crew when conducting normal work on deck**

Chemical	Scenario (mg/kg bw/d)	DNEL (mg/kg bw/d)	RCR tier 1
	Inhalation		
Bromate ion	1.1E-08	2.2E-02	5.1E-07
Bromochloroacetic acid	2.8E-09	7.5E-01	3.7E-09
Bromochloroacetonitrile	9.1E-09	1.5E-01	6.0E-08
Dibromoacetic acid	2.3E-09	7.2E-02	3.2E-08
Dibromoacetonitrile	4.5E-08	1.6E-01	2.8E-07
Dibromochloroacetic acid	4.7E-10	3.0E-01	1.6E-09
Dibromochloromethane	4.4E-04	2.1E-01	2.1E-03
Dichloroacetic acid	2.0E-10	1.2E-01	1.6E-09
Dichlorobromoacetic acid	1.1E-09	5.0E+00	2.1E-10
Dichlorobromomethane	1.0E-04	4.0E-02	2.5E-03
Isocyanuric acid	7.6E-13	3.1E+00	2.4E-13
Monobromoacetic acid	1.7E-09	7.0E-02	2.4E-08
Monochloroacetonitrile	1.6E-12	8.2E-03	2.0E-10

Tribromoacetic acid	2.5E-09	8.6E-01	2.9E-09
Tribromomethane	1.3E-03	1.8E-01	7.3E-03
Trichloroacetic acid	1.1E-09	8.6E-01	1.3E-09
Trichloromethane	2.6E-04	2.4E-01	1.1E-03

**Table 22: RCR calculation results for non-threshold carcinogenic substances for the crew when conducting normal work on deck**

Chemical	Scenario (mg/kg bw/d)	DMEL (mg/kg bw/d)	RCR tier 1
	Inhalation		
Bromate ion	1.1E-08	1.1E-01	1.0E-07
Bromochloroacetic acid	2.8E-09	1.3E-01	2.2E-08
Dibromoacetic acid	2.3E-09	1.3E-01	1.8E-08
Dibromochloromethane	4.4E-04	1.5E+00	2.9E-04
Dichloroacetic acid	2.0E-10	1.7E+00	1.2E-10
Dichlorobromoacetic acid	1.1E-09	1.7E+00	6.3E-10
Dichlorobromomethane	1.0E-04	2.4E+00	4.2E-05
Tribromomethane	1.3E-03	7.7E+00	1.7E-04
<b>SUM</b>			<b>3.4E-04</b>

## 9 RISKS TO THE GENERAL PUBLIC

In general, a risk characterization is the procedure to compare the exposure levels to which humans are exposed or likely to be exposed with those levels at which no toxic effects from the chemicals are expected to occur. To calculate PEC the highest measured substance concentration in the discharged water, i.e. after neutralization, was used.

Risks to the general public are most likely to occur as a result of:

- .1 recreational activities, swimming in seawater contaminated with treated ballast water where exposure may be via ingestion (accidental swallowing), inhalation and dermal contact; and
- .2 ingestion of seafood which has been exposed to chemical by-products in the treated ballast water.

The risk to the general public from the oral, dermal and inhalator exposure of chemical by-products was calculated according to the guidance in Circular BWM.2/Circ.13/Rev.3, appendix 4, and summed up as aggregated exposure.

For the dermal uptake calculation during swimming a human with a body weight of 60 kg was used as this value was also indicated in Circular BWM.2/Circ.13/Rev.3 as the default value in other calculations. Here the MAMPEC results were based upon the highest substance concentrations found (irrespective of salinity) after the neutralization as a worst-case scenario. The exposure scenarios for swallowing seawater and oral uptake by seafood were described and were also

based on the highest discharged concentrations of substances. The exposure scenarios for the general public are summarized in Table 23.

**Table 23: Summary of exposure scenarios for the general public**

<b>Situations in which the general public might be exposed to treated ballast water containing chemical by-products</b>		
<b>Situation</b>	<b>Exposure</b>	<b>Duration/quantity</b>
Recreational activities in the sea	Inhalation of chemicals partitioning into the air above the sea	5 events of 0.5 hours/day for 14 days of the year
	Dermal exposure to chemicals whilst swimming in the sea	5 events/day for 14 days of the year
	Swallowing of seawater contaminated with treated ballast water	5 events of 0.5 hours/day for 14 days of the year
Eating seafood exposed to treated ballast water	Oral consumption	Once or twice/day equivalent to 0.188 kg
Aggregated exposure (through swimming and consumption of seafood)		

Further, the aggregated exposure was summarized. DNEL in chronic effect on the general public and the resulting RCR ratios are presented in Table 24. Aggregation is the sum of the general public exposure during swimming (oral, dermal and inhalation) and the consumption of seafood.

**Table 24: RCR calculation results for the general public**

Chemical	Scenario 10.1.1 and 10.1.2 (µg/kg bw/d)				Aggregated exposure (µg/kg bw/d)	DNEL (µg/kg bw/d)	RCR tier 1
	Swimming			Consumption of seafood			
	Oral	Dermal	Inhalation	Oral			
Acetaldehyde	2.1E-05	3.2E-07	3.8E-09	2.0E-04	2.2E-04	2.1E+02	1.1E-06
Bromate ion	1.8E-05	2.7E-07	3.6E-09	1.1E-05	2.8E-05	1.1E+01	2.6E-06
Bromochloroacetic acid	6.7E-05	1.0E-06	2.3E-09	6.4E-04	7.1E-04	3.8E+02	1.9E-06
Dalapon	1.0E-04	1.6E-06	1.3E-08	9.1E-04	1.0E-03	8.4E+01	1.2E-05
Dibromoacetic acid	8.3E-04	1.3E-05	7.6E-09	5.0E-04	1.3E-03	3.6E+01	3.7E-05
Dibromochloroacetic acid	5.6E-04	8.8E-06	3.0E-09	5.4E-03	6.0E-03	1.5E+02	4.0E-05
Dibromochloromethane	8.6E-04	1.3E-05	1.8E-03	1.8E-02	2.1E-02	1.1E+02	1.9E-04
Dichloroacetic acid	9.9E-05	1.5E-06	1.7E-09	1.2E-04	2.2E-04	6.0E+01	3.7E-06
Dichlorobromoacetic acid	1.0E-03	1.6E-05	1.7E-08	9.7E-03	1.1E-02	2.5E+03	4.3E-06
Dichlorobromomethane	7.8E-04	1.2E-05	3.4E-03	1.1E-02	1.6E-02	2.0E+01	7.8E-04
Formaldehyde	1.8E-05	2.8E-07	1.3E-08	1.6E-04	1.8E-04	1.0E+02	1.8E-06
Isocyanuric acid	5.2E-01	8.1E-03	9.6E-12	7.9E-01	1.3E+00	1.5E+03	8.8E-04
Monobromoacetic acid	9.9E-05	1.5E-06	1.3E-09	3.0E-05	1.3E-04	3.5E+01	3.7E-06
Monobromoacetonitrile	8.9E-04	1.4E-05	6.5E-06	1.3E-02	1.4E-02	4.0E+00	3.6E-03
Monochloroacetonitrile	2.5E-05	3.9E-07	4.8E-10	2.3E-04	2.5E-04	4.1E+00	6.1E-05
Tribromoacetic acid	8.5E-03	1.3E-04	5.9E-08	6.4E-02	7.2E-02	4.3E+02	1.7E-04
Tribromomethane	3.5E-02	5.4E-04	3.9E-02	1.3E+00	1.3E+00	8.9E+01	1.5E-02
Trichloroacetic acid	2.8E-03	4.4E-05	9.7E-08	8.5E-03	1.1E-02	4.3E+02	2.6E-05
Trichloromethane	1.6E-03	2.4E-05	1.2E-02	2.1E-02	3.5E-02	1.2E+02	2.9E-04

An indicative risk level may be used to calculate an indicative RCR regarding potential cancer risk. These values can be used to estimate a risk dose based on the probability of increased cancer incidence over a lifetime and may be regarded as a DMEL for the general public (Table 25).

**Table 25: RCR calculation results for non-threshold carcinogenic substances for general public**

<b>Chemical</b>	<b>Aggregated exposure (µg/kg bw/d)</b>	<b>DMEL (µg/kg bw/d)</b>	<b>Indicative RCR tier 1</b>
Bromate ion	2.8E-05	1.1E-01	2.6E-04
Bromochloroacetic acid	7.1E-04	1.3E-01	5.5E-03
Dibromoacetic acid	1.3E-03	1.3E-01	1.0E-02
Dibromochloromethane	2.1E-02	1.5E+00	1.4E-02
Dichloroacetic acid	2.2E-04	1.7E+00	1.3E-04
Dichlorobromoacetic acid	1.1E-02	1.7E+00	6.3E-03
Dichlorobromomethane	1.6E-02	2.4E+00	6.5E-03
Formaldehyde	1.8E-04	2.2E-01	8.3E-04
Tribromomethane	1.3E+00	7.7E+00	1.7E-01
<b>SUM</b>			<b>2.2E-01</b>

Table 25 shows, no RCR value above 1 was calculated for the general public scenario and therefore no Tier 2 calculation was prepared.

## 10 RISKS TO THE ENVIRONMENT

### 10.1 Assessment of Persistence (P), Bioaccumulation (B) and Toxicity (T)

The PBT properties were reviewed based on the half-life, bioconcentration factor (BCF) or Log  $K_{ow}$ , the chronic NOEC values and a toxicity assessment according to the GHS classification for each chemical (Procedure (G9) ( resolution MEPC.169(57)), paragraph 6.4) considering the information provided in GISIS (2018). The PBT properties of all substances detected were covered in GISIS (2018) and no Relevant Chemical detected fulfilled all three the PBT criteria. Please note that for some substances the persistence could not be evaluated as GISIS (2018) does not provide half-life data for all chemicals. However, for all chemicals where the half-life is unknown at least one other parameter was not met so that no Relevant Chemicals was found to meet all three criteria.

Circular BWM.2/Circ.13/Rev.3, appendix 6, i.e. the list of chemicals most commonly associated with treated ballast water for which no additional data need to be provided, does not list isocyanuric acid. However, Circular BWM.2/Circ.13/Rev.3 recommends that applicants make use of the latest version of GISIS (2018), and in GISIS (2018) isocyanuric acid is included. We therefore assume that the GESAMP-BWWG holds sufficient information from the literature on physico-chemical, ecotoxicological and toxicological properties and we provide no additional supporting information here for this substance.

### 10.2 Calculation of PEC/PNEC ratios

For the evaluation of a potential risk to the environment, the concentration of substances after neutralization is relevant, i.e. the water which is released from the vessel into the aquatic environment. The Predicted Exposure Concentrations (PEC) and No Effect Concentrations (PNEC) after chronic exposure in the harbour and acute exposure near ship were derived. The PEC values were calculated as stated above. The risk is calculated here by taking the PEC/PNEC ratios. The general and near ship PNEC values were taken from GISIS (2018), so that the relevant Assessment Factors are already addressed.

All but one PEC/PNEC ratios for the harbour scenario were below 1. The exception was calculated for isocyanuric acid with a value of 1.57. In the near ship scenario three substances had a PEC/PNEC above 1 and these were isocyanuric acid with a value of 9.92, tribromomethane with a value of 5.97 and monochloroacetonitrile with a value of 1.01. In the Tier 2 scenario with a risk mitigation factor of 0.95 the latter substance was below 1, while isocyanuric acid and tribromomethane resulted in values as presented in Table 26.

**Table 26: PEC/PNEC ratios, those >1 are grey highlighted**

Chemical	Harbour			Near ship		
	PEC	PNEC	PEC/PNEC	PEC	PNEC	PEC/PNEC
	(µg/L)	(µg/L)	(-)	(µg/L)	(µg/L)	(-)
Acetaldehyde	2.0E-02	2.2	9.1E-03	1.2E+00	22.0	5.5E-02
Bromate ion	1.7E-02	140.0	1.2E-04	2.1E-01	1400.0	1.5E-04
Bromochloroacetic acid	6.4E-02	16.0	4.0E-03	7.9E-01	16.0	4.9E-02
Dalapon	9.7E-02	11.0	8.8E-03	1.4E+00	110.0	1.3E-02
Dibromoacetic acid	8.0E-01	6900.0	1.2E-04	9.7E+00	6900.0	1.4E-03

Dibromochloroacetic acid	5.4E-01	300.0	1.8E-03	6.6E+00	300.0	2.2E-02
Dibromochloromethane	8.3E-01	6.3	1.3E-01	1.5E+01	270.0	5.7E-02
Dichloroacetic acid	9.5E-02	23.0	4.1E-03	1.2E+00	230.0	5.0E-03
Dichlorobromoacetic acid	9.7E-01	60.0	1.6E-02	1.2E+01	100.0	1.2E-01
Dichlorobromomethane	7.5E-01	78.0	9.7E-03	1.5E+01	78.0	1.9E-01
Formaldehyde	1.8E-02	5.8	3.0E-03	1.8E+00	31.0	5.8E-02
Isocyanuric acid	5.0E+02	320.0	1.5E+00	6.2E+03	620.0	9.4E+00
Monobromoacetic acid	9.5E-02	16.0	5.9E-03	1.2E+00	16.0	7.3E-02
Monobromoacetonitrile	8.5E-01	23.0	3.7E-02	1.1E+01	230.0	4.6E-02
Monochloroacetonitrile	2.4E-02	0.6	4.1E-02	5.9E-01	0.6	9.6E-01
Tribromoacetic acid	8.1E+00	14000.0	5.8E-04	9.9E+01	22000.0	4.5E-03
Tribromomethane	3.3E+01	96.0	3.5E-01	5.7E+02	96.0	5.7E+00
Trichloroacetic acid	2.7E+00	300.0	9.0E-03	3.3E+01	300.0	1.1E-01
Trichloromethane	1.5E+00	150.0	1.0E-02	3.3E+01	150.0	2.2E-01

### 10.2.1 Comments regarding isocyanuric acid

OECD SIDS (1999) reported that isocyanuric acid is not readily biodegradable (OECD 301C: 0% after 14d) and it is stable in water. Direct photodegradation is not expected because isocyanuric acid has no absorption band for UV. Isocyanuric acid was used in swimming pool water to lower the rate of photochemical reduction of chlorine, hypochlorous acid, and hypochlorite ion (Canelli 1974, Pinto & Rohrig 2003). However, isocyanuric acid biodegrades readily under a wide variety of natural conditions, and particularly well, as experiments have shown, in conventional sewage collection and treatment facilities and in lakes or streams when it comes in contact with a soil bed or other low oxygen or anaerobic conditions, also in saline environments. The overall degradation reaction is a hydrolysis with CO<sub>2</sub> and ammonia being the initial hydrolytic breakdown products (Saldick 1974). This author concludes that biodegradation is higher in environments with lower oxygen content, which may be the case inside ballast tanks when the oxygen is consumed by microorganisms over time or when the ballast water is discharged in ports with anaerobic sediments. Isocyanuric acid is further biodegraded by bacteria to CO<sub>2</sub> and biuret (Cook et al. 1985). In addition, Wojtowicz (2001) showed the oxidation of isocyanuric acid with hypochlorite. In summary, isocyanuric acid is under certain circumstances degradable, and it is used commonly for swimming pool treatment as a stabilizer of chlorine. It is generally classified as non-toxic to humans<sup>3</sup> (Kuznesof 2003, Huthmacher & Most 2012) and more than 98% of an orally taken dose of isocyanuric acid is excreted unchanged in urine within 24 hours (Allen et al. 1982). For all stated above, we believe that the calculated isocyanuric acid PEC/PNEC value above 1 is not critical.

### 10.2.2 Comments regarding tribromomethane

The chemical analysis of the neutralized ballast water, i.e. the water the environment, port State control and general public will be exposed to, revealed tribromomethane concentrations in the worst-case scenario as PEC near ship of 570 µg/L and in the more realistic scenario of the harbour PEC was 33 µg/L. This PEC harbour value is below the value set in the WHO (2004) for drinking water, which gives the acceptable tribromomethane content as <100µg/L so that no mitigation

<sup>3</sup> Non-toxic (acute oral and dermal), non-irritating to the skin, and essentially non-irritating to the eye. However, inhalation of the dust, contact with the eye, and ingestion should be avoided.

measures seems to be needed for concentrations as found in PEC harbour. This view is confirmed by the fact that all RCRs are below 1.

Other studies analyzing DBP in BWMS tests found higher tribromomethane concentrations also in BWMS which got Final Approval (Werschkun et al. 2012, 2014, David et al. 2018). Further, Circular BWM.2/Circ.13/Rev.3 stated that an assessment of secondary poisoning of substances is redundant if the absence of bioaccumulation potential can be demonstrated (BCF < 500 L/kg wet weight for the whole organism at 5% fat). Although tribromomethane is relatively persistent and both toxic and irritant to mammals (GISIS 2018), the BCF of tribromomethane is 12.1 (GISIS 2018) so that we believe this substance shows no bioaccumulation risk.

Shah et al. 2015 conducted a study to evaluate the water quality parameters influence DBP formation during ballast water treatment. The results from this study indicate that multiple factors influence DBP formation in saline waters, i.e., salinity (especially the bromide concentration), DOM type/concentration, and the oxidant type/dose. A similar study was done by Zhang et al. (2013) who also found that abiotic factors have an influence of the DBP formation.

Here, the test water for the Guidelines (G8) tests, during which the DBP water samples were taken, was augmented to meet the Guidelines (G8) requirements. In our tests *Chlorella* spp. algal powder, which includes a certain amount of lignin, was used to increase the level of DOC (see confidential Appendix 2). Long-term studies at full-scale BWMS test facilities have shown that lignin could be an important precursor for some DBPs and especially trihalomethanes and it was clearly suggested that a relationship between the formation of these DBPs and the presence of lignin occurs (Delacroix et al. 2013). In another study comparing additives to test water, i.e. starch, glucose, sodium acetate, sodium citrate, metamucil, lignin and methylcellulose (IMO 2017), it was observed that when sodium citrate and lignin were injected into the test water, this test water had a relatively higher DBP concentration compared to other additives. It was further observed that, except for sodium citrate, high molecular weight additives caused higher occurrences of DBPs than their low molecular weight counterparts and lignin had the highest molecular weight (528) of all substances tested. Although *Chlorella* spp. have a relatively small lignin content (<2%) (Ververis et al. 2007) this might have had an impact on the formation of tribromomethane compared to other non-lignin containing augmentation. In addition, species in the genus *Chlorella*, have a high carbohydrate content of >50 w/w (Simas-Rodrigues et al. 2015). As per the model developed by Hua & Yeats (2010), amongst other things, a high carbon content results in a situation that the concentration of trihalomethanes increases with increasing total organic carbon (TOC). Therefore, the use of *Chlorella* powder to augment the test water may have considerably contributed to the concentration of tribromomethane in the neutralized ballast water, which may have resulted in so high PEC/PNEC near ship ratio.

Further, the location of the test cite in the Wadden Sea with rain water runoffs may have had its influence on DBP formation as here the natural lignin content may be relatively high. Griffioen et al. (2016) report findings from earlier studies on sediment and suspended matter in the Dutch waters Lake IJsselmeer/Lake Ketelmeer and Haringvliet/Hollands Diep that the sediment is dominated by carbohydrates (including polysaccharides), proteins, lignin and peptides. This is based upon samples taken when algal blooms were abundant. The high lignin content is possibly due to naturally occurring detritus of terrestrial plants with a high amount of lignin (Schubert & Telesh 2016). Therefore, the test site may face a higher lignin content as assumed in a worst-case scenario. In addition, water from Lake IJsselmeer was used as test water and sediment from the Wadden Sea contributed to augment the TSS levels in the test water. These activities may have even further increased the lignin concentration in the test water thereby resulting in unrepresentatively high contents of DBPs, including tribromomethane.

It should be noted also that Delacroix et al. (2013) found in their study that there seemed to be no clear indication that the measured DBPs concentrations affected the algal toxicity neither for individual DBPs (tribromoacetic acid, dibromochloromethane, chlorate, monobromoacetic acid and tribromomethane) nor for the sum of all DBPs. For all stated above, we believe that the calculated tribromomethane PEC/PNEC value above 1 is not critical.

### 10.3 Determination of retention time

As a neutralization step is included, the system requires no minimum retention time.

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