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PREVENTION AND RESPONSE
12th session
Agenda item 7

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EVALUATION AND HARMONIZATION OF RULES AND GUIDANCE ON THE DISCHARGE OF DISCHARGE WATER FROM EGCS INTO THE AQUATIC ENVIRONMENT, INCLUDING CONDITIONS AND AREAS

Data to be used for the calculation of representative emission factors of discharge water from exhaust gas cleaning systems (EGCS)

Submitted by Norway

	SUMMARY
Executive summary:	This document contains data to be used for the development of representative emission factors of discharge water from exhaust gas cleaning systems (EGCS) and provides relevant information regarding the sampling and analysis of the water.
Strategic direction, if applicable:	1
Output:	1.23
Action to be taken:	Paragraph 17
Related documents:	Resolution MEPC.340(77); MEPC.1/Circ.899; MEPC 78/93; MEPC 79/5/1; MEPC 82/5/1, MEPC 82/INF.22; PPR 11/7/5; PPR 12/7/2 and PPR 12/INF.11

Background

1   The Marine Environment Protection Committee (MEPC), at its seventy-eighth session, approved the *2022 Guidelines for risk and impact assessments of the discharge water from EGCS* (MEPC.1/Circ.899), agreeing that the Guidelines would be kept under review in light of experience gained. The purpose of the Guidelines is to provide a unified approach containing procedures that would support Member States to judge whether the introduction of restrictions/conditions of discharge water from EGCS would be needed and justifiable or not.

2   At PPR 11, the Sub-Committee considered emission factors for use in the environmental risk assessment of the discharge water from EGCS with a view to including representative emission factors in a revised version of MEPC.1/Circ.899, so that a consistent environmental load from the use of EGCS would be used in the risk and impact assessments.

3   During the consideration of the proposed representative emission factors provided in documents MEPC 78/9/3 (Germany) and PPR 11/7/5 (ICS and CLIA), discussions were held on the differences in the methodology used for the establishment of emission factors, especially whether the emission factors should be based upon the amount of each substance generated solely by the scrubbing process or if background concentrations (pollutants detected in the inlet water) also should be part of a representative emission factor.

4   The Sub-Committee was not in a position to conclude on these discussions, but invited interested Member States and international organizations to:

        .1   submit relevant data to a future session;

        .2   submit proposals for terms of reference for the re-establishment of the GESAMP Task Team on EGCS to conduct further work on this matter to MEPC 82; and

        .3   consider providing financial contributions to enable the re-establishment of the GESAMP Task Team on EGCS.

5   At MEPC 82, the Working Group on Air Pollution and Energy Efficiency (APEE) considered a proposal of draft terms of reference for the re-establishment of the GESAMP Task Team on EGCS as set out in the annex to document MEPC 82/5/3 (ICS and CLIA). In the ensuing discussions, different suggestions were made, such as to amend the proposed terms of reference to include the determination of emission factors, to consider any other relevant chemical substances in EGCS discharge water in addition to the proposed list of priority hazardous substances, remove the reference to the use of 50% of laboratory detection limits as assigned values for non-detects, and align key terminology and evaluation criteria with the 2022 Guidelines for risk and impact assessments of the discharge water from EGCS.

6   Due to time constraints, the Committee referred the draft terms of reference for the GESAMP Task Team on EGCS to PPR 12 for further consideration, with a view to finalization and providing advice to the Committee accordingly.

7   This document contains data to be used for the development of representative emission factors of discharge water from EGCS and provides relevant information regarding the sampling and analysis of the discharge water that might also be relevant to the work of the GESAMP Task Team on EGCS, together with the considerations provided in documents PPR 12/7/2 (Norway) and PPR 12/INF.11 (Norway).

Discharge water samples

8   Solvang ASA is a Norwegian shipping company specialized in the transport of LPG and petrochemicals. The company has a fleet of 23 ships where 15 of the ships are equipped with EGCS. The standard EGCS configuration consists of one EGCS for the main engine and one for the auxiliary engines and boiler.

9   The discharge water samples presented in this document come from five very large gas carriers (VLGC), three large gas carriers (LGC) and four ethylene carriers. Water samples are taken annually for each ship with an EGCS, including one set in port with two auxiliary engines in parallel and a minimum 75% power (four samples), and one set in transit with main engine at approximately 75% power and two auxiliary engines at 75% power (five samples). In total, 99 samples are presented from inlet water (52 in harbour and 47 in transit) and 146 samples after the scrubber (52 after auxiliary engines in harbour, 47 after auxiliary engine and 47 after main engine in transit). All ships have been using marine residual fuels category RMG-380, in accordance with ISO 8217-2024.

10   All samples have been analysed by ALS, an ISO 17025 accredited laboratory, which also supplied the sampling bottles. The procedure for sampling, preparations and analysis have been carried out consistent with appendix III of the *2021 Guidelines for Exhaust Gas Cleaning Systems* (resolution MEPC.340(77)), including the use of the recommended methods for sample analysis set out in section 2.4 of the Guidelines.

11   The data presented in this document includes inlet seawater (for background) sampled from the seawater strainer ("1" in figure 1) and discharge water after scrubber(s) ("2"in figure 1). After the scrubber, the discharge water goes to a cleaning system which consists of a residence tank and hydrocyclones where soot and other particles, heavier than water, are removed from the discharge water and deposited in the sludge tank, and from there into filter bags which are delivered ashore. Soot and oily particles with a density lower than water (floating on the top), are skimmed off from the top of the residence tank regularly and delivered ashore. Depending on local regulations, for example the United States Vessel General Permit (VGP), the overboard pH can be increased to greater than (>) six in port and in transit.

12   Samples of discharge water after treatment and possible dilution (referred to in section 2.1.2.3 in the 2021 Guidelines) are not presented in this document as such data is not representative to be used as a basis for emission factors, since not all EGCS have such after treatment and the wash water may be diluted at this point.

13   The data set presented in this document includes two samples in "harbour mode" and three samples in "transit mode". The EGCS and the principle set up for sampling is illustrated in figure 1 below.
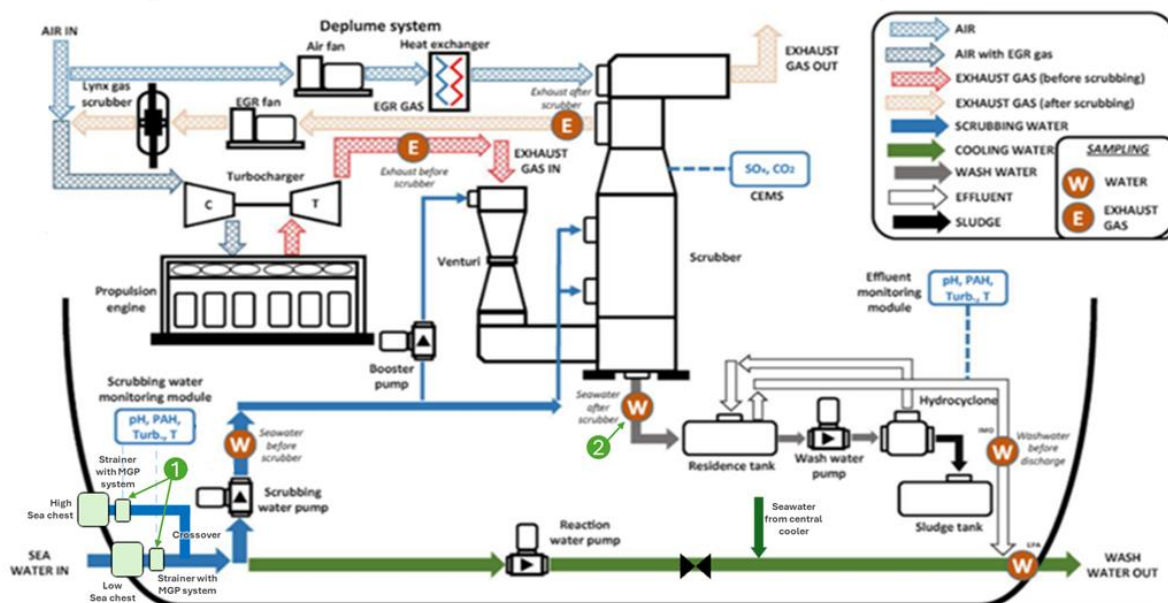

Figure 1: EGCS System and sampling points. The sampling point for the intake seawater is marked "1" and the sampling point after the scrubber but before cleaning of the water is marked "2".

14   To ensure a representative sample, the engine load and water flow should be stable for several hours prior to sampling. It is also important to collect a representative water sample, and since the water flow after the scrubber is not uniform and 100% mixed, a special sampling lance with the length of the diameter of the pipe had been used to collect the water sample. The pipes from seawater pump are galvanized steel pipes, the scrubber itself is made of

corrosion resistant steel, and all pipes and equipment after the scrubber are made of Glass Reinforced Epoxy (GRE), stainless steel or steel coated with special paint, as copper pipes or brass valves will contaminate the water sample. The water temperature across the EGCS increases by approximately 5°C.

15   The data set and emission factors presented in this document have undergone a Quality Assurance (QA) by SINTEF Ocean and a memo regarding the QA is provided in document PPR 12/INF.11. Considerations regarding the origin of the different substances detected in the samples from discharge water are provided in document PPR 12/7/2.

16   An overview of the data set is presented in table 1 below. The data has been split into samples collected at harbour and during transit, and average concentrations (µg/l) are presented for both inlet water and for discharge water after the EGCS. Emission factors (measured in mg/MWh) representing the net contribution from the scrubbing process are presented for harbour and transit separately. The complete data set with relevant information regarding the ships, calculations and raw data, etc., can be downloaded using this link: https://solvangship.no/environment/scrubber-data

Table 1: An overview of the data set presented in this document. For non-detects, a value of 50% of the detection limit has been used. Barium harbour emission factor was set to Barium transit emission factor due to extreme large variations in ambient seawater in port

Overview				Harbour							Transit										
ELEMENT	LOD	Emission factor Harbour average actual waterflow AE (97.2 m³/MWH) [m³/MWH]	Emission factor Transit average actual waterflow -80% ME (56.4 m³/MWH) -20% AE (95.5 m³/MWH) [m³/MWh]	Average seawater inlet harbour [µg/L]	2σ (95%)	N_tot (N_<LOD)	Average after AE harbour [µg/L]	2σ (95%)	N_tot (N_<LOD)	Average delta AE Harbour based on each sample pair, basis for EF [µg/L]	Average seawater inlet transit [µg/L]	2σ (95%)	N_tot (N_<LOD)	Average after ME [µg/L]	2σ (95%)	N_tot (N_<LOD)	Average delta ME Transit based on each sample pair, basis for EF [µg/L]	Average after AE transit [µg/L]	2σ (95%)	N_tot (N_<LOD)	Average delta AE Transit based on each sample pair, basis for EF [µg/L]
Arsenic	0.50	0	0	3.37 ±5.19		52 (0)	3.19 ±4.89		52 (0)	-0.18	3.10 ±3.96		47 (0)	3.18 ±4.53		47 (0)	0.08	2.91 ±3.45		47 (0)	-0.19
Barium	1.00	9*	9	19.1 ±43.6		47 (0)	22.0 ±50.0		47 (0)	2.95	9.93 ±19.3		42 (0)	10.1 ±22.7		42 (0)	0.17	10.0 ±23.3		42 (0)	0.08
Cadmium	0.05	0	0	0.04 ±0.05		52 (32)	0.03 ±0.04		52 (37)	-0.01	0.03 ±0.04		47 (34)	0.03 ±0.00		47 (36)	0.00	0.03 ±0.00		47 (40)	-0.01
Chromium	0.90	105	225	2.54 ±6.12		52 (23)	3.71 ±7.67		52 (11)	1.08	0.81 ±1.42		47 (27)	4.67 ±7.30		47 (5)	3.49	5.02 ±9.19		47 (7)	3.63
Cobalt	0.20	33	26	0.19 ±0.29		52 (33)	0.51 ±0.97		52 (12)	0.34	0.10 ±0.00		47 (38)	0.57 ±0.94		47 (9)	0.42	0.54 ±0.95		47 (11)	0.38
Copper	1.00	0	18	9.15 ±13.5		52 (1)	9.19 ±10.7		52 (0)	-0.76	6.53 ±9.28		47 (1)	7.38 ±8.83		47 (0)	0.41	6.93 ±7.44		47 (0)	-0.05
Lead	0.50	0	0	0.62 ±1.28		52 (29)	0.34 ±0.38		52 (36)	-0.26	0.55 ±1.17		47 (28)	0.25 ±0.00		47 (37)	-0.30	0.25 ±0.00		47 (41)	-0.32
Mercury	0.02	0	0	0.01 ±0.00		47 (47)	0.01 ±0.01		47 (45)	0.00	0.01 ±0.00		43 (43)	0.01 ±0.00		43 (43)	0.00	0.01 ±0.00		43 (43)	0.00
Molybdenum	0.50	121	118	10.5 ±5.73		52 (0)	11.8 ±6.26		52 (0)	1.25	11.1 ±4.02		47 (0)	13.0 ±5.58		47 (0)	1.75	13.5 ±5.33		47 (0)	2.12
Nickel	0.60	2732	2814	3.56 ±7.51		52 (10)	34.2 ±36.4		52 (0)	28.1	2.92 ±7.40		47 (9)	49.3 ±44.2		47 (0)	46.1	42.4 ±42.4		47 (0)	39.3
Vanadium	0.20	11234	9492	2.61 ±3.08		52 (0)	117 ±129		52 (0)	116	2.19 ±1.49		47 (0)	148 ±133		47 (0)	150	141 ±149		47 (0)	147
Zinc	4.00	0	0	10.1 ±21.5		52 (17)	10.0 ±15.0		52 (9)	-0.93	10.4 ±27.5		47 (18)	10.7 ±19.4		47 (9)	-0.89	8.79 ±12.6		47 (9)	-1.14
Naphthalene	0.03	132	105	0.015 ±0.00		52 (52)	1.374 ±3.35		52 (7)	1.36	0.016 ±0.01		47 (46)	1.723 ±3.37		47 (1)	1.71	1.496 ±5.42		47 (5)	1.48
Acenaphthylene	0.01	2	1	0.005 ±0.00		52 (52)	0.021 ±0.15		52 (45)	0.02	0.005 ±0.00		47 (46)	0.017 ±0.10		47 (37)	0.01	0.006 ±0.01		47 (46)	0.00
Acenaphthene	0.01	4	9	0.005 ±0.00		52 (52)	0.045 ±0.09		52 (21)	0.04	0.005 ±0.00		47 (46)	0.189 ±0.57		47 (10)	0.18	0.058 ±0.14		47 (16)	0.05
Fluorene	0.01	17	29	0.005 ±0.00		52 (51)	0.178 ±0.28		52 (8)	0.17	0.006 ±0.01		47 (46)	0.539 ±0.98		47 (1)	0.53	0.243 ±0.55		47 (4)	0.24
Phenanthrene	0.02	55	96	0.010 ±0.00		52 (52)	0.572 ±0.87		52 (8)	0.56	0.011 ±0.01		47 (46)	1.810 ±3.41		47 (1)	1.80	0.776 ±1.53		47 (4)	0.77
Anthracene	0.01	0	0	0.005 ±0.00		52 (52)	0.005 ±0.01		52 (50)	0.00	0.005 ±0.00		47 (47)	0.014 ±0.07		47 (40)	0.01	0.007 ±0.02		47 (42)	0.00
Fluoranthene	0.01	4	4	0.005 ±0.00		52 (50)	0.043 ±0.11		52 (10)	0.04	0.005 ±0.00		47 (46)	0.072 ±0.14		47 (3)	0.07	0.066 ±0.33		47 (6)	0.06
Pyrene	0.01	4	7	0.006 ±0.01		52 (49)	0.042 ±0.14		52 (16)	0.04	0.005 ±0.00		47 (47)	0.145 ±0.50		47 (7)	0.14	0.048 ±0.15		47 (14)	0.04
Benz(a)anthracene	0.01	0	1	0.005 ±0.00		52 (52)	0.008 ±0.01		52 (42)	0.00	0.005 ±0.00		47 (47)	0.027 ±0.12		47 (25)	0.02	0.009 ±0.02		47 (38)	0.00
Chrysene	0.01	1	4	0.005 ±0.00		52 (51)	0.016 ±0.04		52 (30)	0.01	0.005 ±0.00		47 (47)	0.082 ±0.32		47 (13)	0.08	0.025 ±0.11		47 (28)	0.02
Sum of Benzo(b+j)fluoranthene	0.01	0	1	0.005 ±0.01		49 (48)	0.008 ±0.02		49 (41)	0.00	0.005 ±0.00		44 (44)	0.020 ±0.06		44 (22)	0.01	0.010 ±0.03		44 (36)	0.01
Benzo(k)fluoranthene	0.01	0	0	0.005 ±0.00		52 (52)	0.005 ±0.00		52 (51)	0.00	0.005 ±0.00		47 (47)	0.006 ±0.01		47 (43)	0.00	0.005 ±0.01		47 (46)	0.00
Benzo(a)pyrene	0.01	0	0	0.005 ±0.00		52 (52)	0.005 ±0.00		52 (52)	0.00	0.005 ±0.00		47 (47)	0.009 ±0.03		47 (42)	0.00	0.006 ±0.01		47 (45)	0.00
Dibenz(a.h)anthracene	0.01	0	0	0.005 ±0.00		52 (52)	0.005 ±0.00		52 (52)	0.00	0.005 ±0.00		47 (47)	0.007 ±0.01		47 (44)	0.00	0.005 ±0.00		47 (46)	0.00
Benzo(g.h.i)perylene	0.01	0	0	0.005 ±0.00		52 (52)	0.007 ±0.01		52 (44)	0.00	0.005 ±0.00		47 (47)	0.013 ±0.04		47 (35)	0.01	0.008 ±0.02		47 (39)	0.00
Indeno(1.2.3.cd)pyrene	0.01	0	0	0.005 ±0.00		52 (52)	0.005 ±0.00		52 (52)	0.00	0.005 ±0.00		47 (47)	0.006 ±0.01		47 (45)	0.00	0.006 ±0.01		47 (46)	0.00
Sum of 16 PAH (M1)	0.10	218	258	0.046 ±0.01		52 (50)	2.290 ±4.57		52 (5)	2.24	0.049 ±0.03		47 (45)	4.638 ±8.61		47 (1)	4.59	2.731 ±7.74		47 (2)	2.68
Sum of carcinogenic PAH (M1)	0.04	1	6	0.018 ±0.00		52 (52)	0.031 ±0.07		52 (30)	0.01	0.018 ±0.00		47 (47)	0.135 ±0.56		47 (8)	0.12	0.045 ±0.17		47 (26)	0.03
pH Value	1.00			7.99 ±0.51		52 (0)	3.49 ±2.61		52 (3)	-4.50	8.10 ±0.25		47 (0)	2.95 ±1.23		46 (2)	-5.15	3.40 ±2.20		47 (2)	-4.71

Action requested of the Sub-Committee

17   The Sub-Committee is invited to consider the information contained in this document and take action as appropriate.

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INTERNATIONAL MARITIME ORGANIZATION

SUB-COMMITTEE ON POLLUTION
PREVENTION AND RESPONSE
12th session
Agenda item 7

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EVALUATION AND HARMONIZATION OF RULES AND GUIDANCE ON THE DISCHARGE OF DISCHARGE WATER FROM EGCS INTO THE AQUATIC ENVIRONMENT, INCLUDING CONDITIONS AND AREAS

Substances contained in discharge water from exhaust gas cleaning systems

Submitted by Norway

SUMMARY	
Executive summary:	This document considers the origin of the substances detected in the samples from discharge water.
Strategic direction, if applicable:	1
Output:	1.23
Action to be taken:	Paragraph 27
Related documents:	MEPC 78/93; MEPC 79/5/1; MEPC 82/5/1, MEPC 82/INF.22; PPR 11/7/5; PPR 12/7/1 and PPR 12/INF.11

Background

1   In document PPR 12/7/1, Norway provided relevant data to be used for the development of representative emission factors of discharge water from EGCS. This document considers the origin of the substances detected in the samples from discharge water in order to provide a better understanding of the data presented on discharge water from EGCS.

2   Norway's understanding is that the substances detected in the discharge water from EGCS can come from:

> .1   the scrubbing process itself where substances present in the fuel oil or resulting from (incomplete) combustion of the fuel are contained in the discharge water;

> .2   the ship's seawater system;

> .3   the ambient water due to pollution or from naturally occurring metals in seawater; and

> .4   the anti-fouling and anti-corrosion system on the ship's hull.

Ship's seawater system

3   A ship's seawater system is crucial for the operation of various onboard systems that rely on seawater such as engine and cargo cooling, air conditioning, firefighting, ballast control and exhaust gas cleaning if the ship is equipped with such a system. As the seawater passes through the ship's seawater system, the composition of the seawater will be altered on its path. The design cooling water flow is based on tropical conditions (32°C), and with lower seawater temperatures the flow may be reduced if the ship is equipped with cooling water flow control.

4   Sea chest: The seawater enters the ship through the sea chest which is covered by antifouling and has several anodes for corrosion protection. On the ships in the Solvang fleet, typically 20 kg to 40 kg of aluminium with a five-year lifespan is used. The aluminium anode loss rate is depending on the coating condition and not on whether the ship has a scrubber or not. From the sea chest, the water goes through a strainer where marine growth protection is added.

5   Strainer: In shipping, there are four main types of Marine Growth Protection System (MGP-system) used in the seawater system: electrolytic system, chemical dosing, ultrasonic system and electro-chlorination. All ships in this study have the electrolytic system where copper and aluminium anodes are used together with electricity to create copper ions, as illustrated in figure 1 below. The size of anodes is given by the maximum flow of the strainers (kg/year), and the lifespan design is three years.
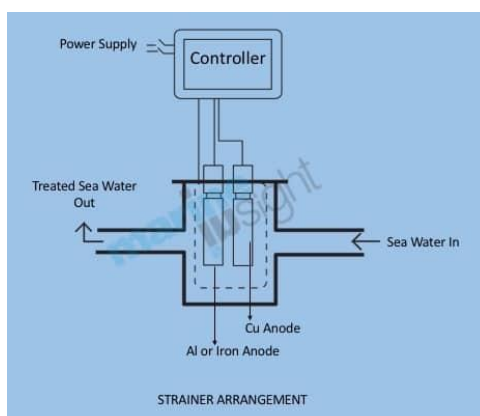

Figure 1: The diagram demonstrates the typical set-up using an electrolytic system for preventing marine growth within the ship's seawater system. Source: Marine Insight

6   As the seawater passes through the electrolytic MGP-system, copper and aluminium will be added to the seawater, depending on the design and flow rate. The release of copper and aluminium in this system is based on the water flow design capacity and not the actual flow through the system. However, the standard system has two settings, eighter full flow or idling. To illustrate how much copper and aluminium will be released from a ship with or without an EGCS, an example from two sister ships in the Solvang fleet is given. Both ships are large gas carriers (LGC), one with an EGCS and one without:

        .1   LGC without an EGCS:

                .1   Seawater to be treated: 1900 m^3/h from either of two strainers:

                        .1   Copper (Cu): 99.8 kg (2 ppb x 1900 m^3/h x 3 years x 24 hours x 365 days x 10^{-6});

        .2   Aluminium (Al): 25 kg (0.5 ppb x 1900 m^3/h x 3 years x 24 hours x 365 days x 10^{-6}); and

        .3   Annual release would be about 33 kg copper and 8 kg aluminium.

.2   LGC with an EGCS (three of the ships in this data):

    .1   Seawater to be treated: 2200 m^3/h from either of two strainers:

        .1   Copper (Cu): 116 kg (2 ppb x 2200 m^3/h x 3 years x 24 hours x 365 days x 10-6);

        .2   Aluminium (Al): 29 kg (0.5 ppb x 2200 m^3/h x 3 years x 24 hours x 365 days x 10^{-6}); and

        .3   Annual release would be about 39 kg Cu and 9 kg Al.

7   The example above illustrates that a ship with a scrubber, in theory, could release about 15% more copper and aluminium per year than the same ship without a scrubber system. The figure for a given ship will depend on the actual increase in design seawater flow rate compared to a ship without an EGCS. Theoretically, the system gives a fixed anode loss in gram per day independent of actual flow, thus low flow will give high concentration and vice versa. This fact, together with the flow dynamics inside the strainers, explains the large variations in the copper concentration in the inlet water samples.

8   In general, a seawater system does not work at full capacity and by introducing a "smart" control system for the MGP-system it would be possible to reduce the copper and aluminium release by 70% to 80%, i.e. reducing the copper release down to 2 µg/l as per design.

9   An example of "strange" readings and a non-representative sample of intake seawater is shown in figure 2 below. The ship has copper and aluminium electrodes in the MGP-system and aluminium electrodes as corrosion protection. Zinc is not used as a corrosion protection on this ship.

10   On 30 August 2024, **Clipper Enyo** was ready to take water samples from the EGCS and deliver them to the laboratory for analysis. The ship had been idling outside Houston for a month, with low water flow through the strainer. Even though the engine load and water flow had been stable for hours prior to sampling, the zinc, copper and lead had accumulated in the top of the seawater strainer. Measurements of the inlet water showed concentrations of 2020 µg/l of zinc, 299 µg/l of copper, and 590 µg/l of lead, indicating that these elements had not been flushed out. After five hours, the level of these elements was drastically reduced, but still elevated and not representative for the actual flow.

11   It is reasonable to believe that the copper originates from the anodes, where small copper particles are trapped on the inside of the filter mesh, where also larger particles from the seawater are trapped. Norway's understanding is that the particles trapped inside the strainer might be contaminated by lead and zinc, and it takes many hours to stabilize the levels in the seawater system. This seems like a reasonable explanation due to the extensive industrial activity in the Houston region, including petrochemical production, with the result that the waters and sediments in the area contain elevated levels of different heavy metals.
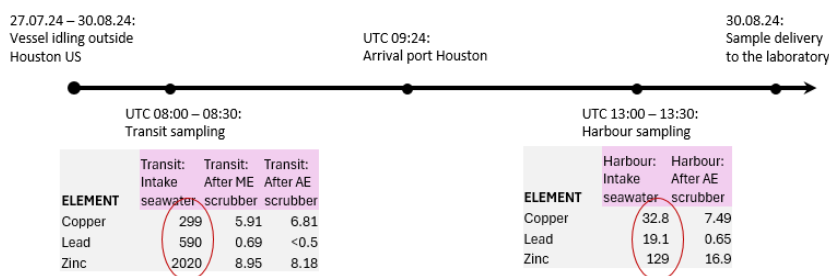
Figure 2: Timeline of the ship Clipper Enyo with elevated concentrations in the inlet water of copper, lead and zinc after idling a month outside Houston.

Substances contained in EGCS discharge water and their origin

12   As described above, the discharge water will contain substances from the scrubbing process, from substances in the ship's seawater system and from substances present in the ambient water. It is also possible that substances come from the ships anti-corrosion and antifouling systems on the ship's hull. However, the release from a ship's hull will be the same for ships with or without an EGCS and is not related to the use of the EGCS.

13   Table 1 below is reproduced from the Report of the GESAMP Task Team on exhaust gas cleaning systems (PPR 7/INF.23) and provides a useful reference when it comes to substances present in the ambient seawater. It should be noted that different ports will have different substances present in different concentrations, depending on historical industrial activities in the ports.

Table 1. Total trace metal concentrations (μg/l) reported in different areas.
From document PPR 7/INF.23

[μg L$_{-1}$]	World Open Ocean			World Coastal waters		Australia Harbour 1		Australia Harbour 2		Mao Minorca Harbour	
Element	min	max	average	min	max	min	max	min	max	min	max
V	1.5	2.0	1.5	-	-	3	8				
Fe	0.001	0.1	0.03	-	-	180	350	8	530	0.07	1.9
Ni	0.1	0.7	0.5	0.9	2.1	0.3	1.9	BDL	9	0.16	0.35
Pb	<0.002	0.03	0.02	1.0	1.5	0.4	55	1	7	0.04	0.5
Zn	0.003	0.6	0.3	12	22	14	67	1	35	0.1	3.9
Cd	<0.001	0.1	0.06	-	-	0.1	0.8	1	7	0.01	0.04
Hg	<0.002	-	0.0004	-	-	-	-	BDL	BDL		
As	1.5	1.9	1.7	0.8	1.5	3.2	8.2	2	8		
Cr	0.2	0.3	0.2	-	-	0.4	1.3	1	2		
Cu	0.03	0.3	0.3	0.9	1.9	0.9	350	1	40	0.1	3.4
Mn	0.004	0.27	0.02	1.1	6.0	6.5	160	1	51		
Al	0.01	1.1	0.5	-	-	-	-	1	1200		
Co	<0.0006	0.001	0.001	-	-	2.2	5	1	2	0.01	0.04
Mo	-	-	10	-	-	-	-	6	13	9.1	14
Ag	<0.001	0.004	0.002	-	-	-	-	BDL	1		
Se	0.04	0.2	0.1	-	-	-	-	1	5		

14   As described in document PPR 12/7/1, all the samples that have been analysed and presented come from ships using residual fuels category RMG-380 according to ISO 8217-2024. These are high sulphur fuel oils (HSFO), having a sulphur content above 0.50% by mass. Ships without an EGCS are expected to use very low sulphur fuel oil outside ECAs (VLFSO, RME 180-0.5 or RMG 380-0.5), a residual fuel with a sulphur content of 0.50% by mass. Inside ECAs, ships without EGCS are expected to use ultra-low sulphur

fuel oil (ULFSO, RME 180-0.1 or RMG 380-0.1), a residual fuel with a maximum sulphur content of 0.10% by mass, or a distillate marine fuel with a maximum sulphur content of 0.10% by mass.

Table 1. Measurement of the amounts of heavy metals contained in heavy fuel oil for ships.[*]

		Unit	HSFO 1	HSFO 2	HS HFO （10samples）
Basic Properties	Viscosity	cSt@50°C	278	299	87 ~ 276
	Carbon	% m/m	88.1	85.7	86.6 ~ 87.3
	Hydrogen	% m/m	11.3	11.3	10.3 ~ 12.4
	Nitrogen	% m/m	0.4	0.4	0.09 ~ 0.22
	Sulphur	% m/m	2.6	2.9	0.28 ~ 2.49
Heavy metals	Vanadium	mg/kg	122	121	44 ~ 63
	Nickel	mg/kg	23	22	16 ~ 23
	Iron	mg/kg	16	16	3 ~ 17
	Zink	mg/kg	1	< 1	0 ~ 3
	Lead	mg/kg	< 1	< 1	0
	Copper	mg/kg	< 1	< 1	—
	Cadmium	mg/kg	< 1	< 1	—
	Chromium	mg/kg	< 1	< 1	—
	Arsenic	mg/kg	< 0.5	1	—

15   Paragraphs 16 to 26 below consider the origin of some of the substance in more detail. The concentrations of the relevant substances noted below refer to document PPR 12/7/1 and the data presented therein.

16   Arsenic (As) was detected in all samples. The delta average ($\Delta_{average}$) is around zero which indicates that the scrubber process itself does not contribute to the As detected in the discharge water. According to the dataset, the concentration of As varies depending on physical location. There are differences between harbour (~3.4 µg/l) and transit (~3.1 µg/l). As can be seen in the tables above, As can also be found in small concentrations in seawater and in residual fuel oils.

17   Barium (Ba) is detected in all samples. In transit, $\Delta_{average}$ is close to zero (0.09 µg/l), which indicates that the scrubber process itself does not contribute to the Ba detected in the discharge water. There are also significant differences between harbour (~20 µg/l) and during transit (~10 µg/l) measurements. Though not indicated in table 2 above, Ba is also found in seawater in different concentration depending on depth and location (~5 to 20 µg/l).

18   Cadmium (Cd) is detected in less than 50% of the sample. $\Delta_{average}$ is zero which indicates that the scrubber process itself does not contribute to the Cd found in the discharge water (0.03 µg/l). Cd is used in corrosion protection on steel, so trace amounts can come from parts in the scrubber itself, but the data do not support this. As can be seen in the tables above, Cd can also be found in very small concentrations in seawater and in residual fuel oils.

19   Chromium (Cr) was detected in about 50% of inlet samples and around 80% to 90% after scrubber samples. According to the dataset, the concentration of Cr varies depending on physical location, indicating that the substance is a pollutant in the ambient water. $\Delta_{average}$ is around 1 to 3.5 µg/l which indicates that the scrubbing process or system itself contribute to the Cr detected in the discharge water. Cr is an important component in the making of stainless steel, and since the scrubber itself is made of stainless steel, it is very likely that some of the Cr is coming from the scrubber body. As can be seen in tables 1 and 2 above, Cr can also be found in very small concentrations in seawater and in residual fuel oils.

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[*]   The table is taken from the Report by the expert board for the environmental impact assessment of discharge water from scrubbers (Japan) https://www.mlit.go.jp/common/001327168.pdf

20   Copper (Cu) was detected in nearly all samples. In harbour, the concentration was measured to ~9 µg/l in and out, and in transit ~7 µg/l. This difference can be explained by reduced waterflow in port. $\Delta_{average}$ is around zero which indicates that the scrubbing process itself does not contribute to the Cu detected in the discharge water. As discussed above, the MGP-system is the main contributor to the Cu found in the discharge water, and the concentration varies in time and space, and changes in flow produce large variations in Cu levels. As can be seen in tables 1 and 2 above, Cu can also be found in very small concentrations in seawater and in residual fuel oils.

21   Lead (Pb) was detected in less than 50% of the samples. The average concentration is 0.25 to 0.6 µg/l, and $\Delta_{average}$ is around zero, which indicates that the scrubber process does not contribute to the Pb detected in the discharge water. As can be seen in tables 1 and 2 above, lead can be found in very small concentrations in seawater and in residual fuel oils.

22   Mercury (Hg) is only detected in 2 of 223 samples and the net value is zero. As can be seen in tables 1 and 2 above, Hg can be found in very small concentrations in seawater.

23   Nickel (Ni) was detected in nearly all samples and the concentration of inlet water in harbour is slightly higher than in transit. $\Delta_{average}$ varies from 28 to 50 µg/l, which indicates that the scrubber process is the main contributor to the Ni in the discharge water since Ni is present in a significant amount in residual fuel oils. Ni is also an important component in stainless steel production. As can be seen in tables 1 and 2 above, Ni can also be found in very small concentrations in seawater.

24   Vanadium (V) was detected in all samples with concentration from 2.2 µg/l to 2.6 µg/l in inlet water, and 117 µg/l to 148 µg/l in discharge water. $\Delta_{average}$ shows that the scrubber process is the main contributor to the V in the discharge water since V is present in significant amount in residual fuel oils. V is also used in steel alloys. Though not indicated in table 2 above, V can be found in seawater in different concentrations (~1 to 2 µg/l).

25   Zinc (Zn) was detected in ~75% of all samples and the concentration was measured to ~10 µg/l in both inlet water and discharge water. $\Delta_{average}$ is around zero which indicates that the scrubber process itself does not contribute to the Zn detected in the discharge water. Zn can be found in variable concentrations depending on location, as illustrated in table 1 above, and, in addition, a small amount can also be present in residual fuel oils. The ships in this study are not using zinc for corrosion protection, but aluminium.

26   Polycyclic aromatic hydrocarbon (PAH) is a group of persistent organic compounds that are emitted or discharged during the incomplete combustion of fuel oil, including lubricants. Engine design, maintenance and operation profile would affect the combustion process and the amount of PAH emitted or discharged. In the inlet water, most of the samples are below the detection limit, so the PAHs detected in the discharge water come from the scrubbing process. Sum PAH was 2.29 µg/l in harbour. In transit, the sum of PAH after auxiliary engine scrubber was 5.79 µg/l, and after main engine scrubber 5.75 µg/l.

Action requested of the Sub-Committee

27   The Sub-Committee is invited to consider the information contained in this document and take action as appropriate.

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SUB-COMMITTEE ON POLLUTION
PREVENTION AND RESPONSE
12th session
Agenda item 7

PPR 12/INF.11
22 November 2024
ENGLISH ONLY
Pre-session public release: ☒

EVALUATION AND HARMONIZATION OF RULES AND GUIDANCE ON THE DISCHARGE OF DISCHARGE WATER FROM EGCS INTO THE AQUATIC ENVIRONMENT, INCLUDING CONDITIONS AND AREAS

Quality Assurance (QA) of the data presented in document PPR 12/7/1

Submitted by Norway

SUMMARY	
Executive summary:	The dataset and the emission factors presented in document PPR 12/7/1 (Norway) have undergone a Quality Assurance (QA) by SINTEF Ocean. The annex to this document contains a project memo from SINTEF Ocean regarding the QA.
Strategic direction, if applicable:	1
Output:	1.23
Action to be taken:	Paragraph 3
Related documents:	PPR 12/7/1 and PPR 12/7/2

Background

1   In document PPR 12/7/1, Norway presented data to be used for the development of representative emission factors of discharge water from EGCS) and provided relevant information regarding the sampling and analysis of the water. In document PPR 12/7/2 (Norway), the origin of the substances detected in the samples from discharge water were considered.

2   As noted in document PPR 12/7/1, the dataset and the emission factors presented in that document have undergone a Quality Assurance (QA) by SINTEF Ocean. The annex to this document contains a project memo from SINTEF Ocean regarding the QA.

Action requested of the Sub-Committee

3   The Sub-Committee is invited to note the information contained in this document in conjunction with documents PPR 12/7/1 and PPR 12/7/2.

***

Project memo

EGCS emission factor evaluation

VERSION		**DATE**	
1.1		26-11-2024	

AUTHOR(S)
Ash Wells
Dag Stenersen

CLIENT(S)	**CLIENT'S REFERENCE**
Solvang ASA	Tor Øyvind Ask

PROJECT NO.	**NO. OF PAGES/APPENDICES:**
302008703	7+ Appendices

Abstract

Sintef Ocean has provided QA of analysis data summarized in an MS excel spreadsheet to enable transparent presentation and handling of data from water analysis from EGCS on ships in the Solvang fleet. The work included checking the data handling, data handling discussion and a spot check of the data. A method to handle outliers was proposed and implemented. Minor issues in spreadsheet cells were detected and corrected. Method of calculating emission factors was evaluated and agreed.
Latest version of the spreadsheet is a transparent and systematic way of calculating emissions factors from EGCS. The spreadsheet is available on Solvang home page.

PREPARED BY		SIGNATURE
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APPROVED BY		SIGNATURE
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PROJECT MEMO NO.	**CLASSIFICATION**
302008703-NOT-2024-1	Unrestricted

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ISO 45001

Document history

VERSION	DATE	Version description
1.0	2024-11-21	Final Version
1.1	2024-11-26	Updated final version. Corrected misprint in ch. 2.

Table of contents

1 Introduction

The purpose of this memo is to outline the work done in providing Quality Assurance (QA) to data handling of a data set present to us by Solvang ASA. This memo only does the check on the data handling, data handling discussion and a spot check of the data, we have not conducted any testing or further analyses of the data.

2 Solvang EGCS discharge water evaluation -Description of procedure

Appendix 3 of the 2021 Guidelines for Exhaust Gas Cleaning System (EGCS) (Resolution MEPC.340(77)) specifies that analysis should be undertaken by ISO 17025-accredited laboratories using EPA, ISO or equivalent test procedures.

The data presented to Sintef are from the following 2 points in the EGCS, see Appendix A.1. for diagram of a typical EGCS. The first sampling point (inlet water) is located on the strainer after the seawater intake (sea chest), this is used to represent seawater. The second sampling point is after the EGC (Exhaust Gas Cleaning) tower but before the water goes into the discharge water cleaning system.

In addition to the sampling points, the ship's activity is noted i.e. the ship was running main or auxiliary engines (ME and AE respectively) and if the ship was in the harbour or not. The following are the different sample conditions:

- Harbour mode: Intake seawater
- Harbour mode: After AE scrubber, but before cleaning
- Transit, full speed: Intake seawater
- Transit, full speed: After ME scrubber, but before cleaning
- Transit, full speed: After AE scrubber, but before cleaning

The samples can be grouped into 2 groups: harbour samples and during voyage (transit) samples. Solvang has taken water samples from each sampling point along the EGCS within a group within a period of time. There is an assumption that this period (within a day) between each water sample is acceptable which will allow direct comparison of the water at each sampling point, i.e. each sampling point demonstrates what is happening to the seawater as it goes through the EGCS scrubbing system (a "snapshot").

Samples from each ship were sent to an ISO 17025 accredited laboratory (ALS Limited) to analyse levels of 41 substances in each sample together with the pH and turbidity of the water sample. The data from the laboratory was compiled into one excel document for calculations and statistics.

3 QA of spreadsheet for emission analysis

The data and calculations were reviewed by: spot checks of data confirmed compliance with accredited analyses reports from ALS and checking the statistical calculations. Comments relating to the spreadsheet were noted in the document.

The following steps were performed to prepare the data for calculations:

1. Copied the raw data to a separate sheet to do calculations and to set any values of limit of detection (LOD) to half the value of the LOD
2. To detect and removed outliers, the Interquartile range (IQR) was applied: For each sampling condition ("harbour seawater intake", "harbour after scrubber before cleaning" etc.) the lower and upper quartiles (Q1 and Q3 respectively) were calculated for each substance. Subtracting Q3 from

Q1 is the IQR. To find the upper threshold, the IQR was multiplied by 1.5 and added to Q3. Any values above this threshold were dismissed as outliers

3. The data was copied again into another sheet and the above method was applied to Cadmium, Chromium, Cobalt, Copper, Lead, Molybdenum, Nickel, Vanadium and Zinc*. For these substances data above the upper threshold calculated in the previous step was removed as they are considered as outliers. The removed data is highlighted and number of removed data was noted**. All other data was kept.

4. These values are copied to the calculation sheet. Within this sheet the paired deltas were calculated

5. For the calculations, the formulae provided by Solvang were used but some of the cell references were changed for consistency of data handling

* From fuel analysis it is acknowledges that nickel and vanadium is the main elements in HFO. But those elements are also present in stainless steel together with Cadmium, Chromium, Cobalt and Molybdenum. Micro particles from scrubber body will contaminate the water samples. Abnormal levels of Copper can be found under special conditions in seawater strainer. Abnormal levels of Lead and Zinc can be caused by accumulation of these elements in the ambient seawater. These substances were chosen for removing outliers as their potential of other sources contaminating the results of the water analysis.

** Some substances had large number of data points below the LOD, this made this method less reliable with them.

4 Calculation of delta

As mentioned in the previous section (*2 Solvang EGCS discharge water evaluation -Description of procedure*), for each sample pair in a group taken on the same day can be used to allow a "snapshot" of the water contents. This assumption allows direct comparison of the water samples at each stage of the EGCS. By making this assumption, the difference between the water out and in, known as the "paired delta" in this report, can be made directly in each period making the "average paired delta" a truer representation of the system than the alternative method ("delta from averages"). The alternative method is to take the average of all samples out and subtract the average of all samples in to find the "delta from averages".

The following steps was taken to find the "average paired delta":

1. From the prepared data created in the calculation sheet (method outlined in previous section), for each given period and condition the delta was calculated by subtracting the values at sample point 2 from sample point 1 (Appendix A.1)

2. 4 averages (mean) and standard deviations were calculated for: paired delta at harbour, paired delta during transit with main engines, paired delta during transit with auxiliary engines, and of all the paired delta

5 Calculation of emission factor

There are discussions regarding guidelines how to calculate the emissions factors. There are two potential methods of calculating the emissions factor: "delta from averages" and "average paired delta". Solvang's collection method allows for both calculations of emissions factors.

Calculating emission factor from "delta from averages" method:

1. Take the averages of substances each day at the *intake* and *after the EGCS but before the cleaning system*
2. Subtract these averages
3. Multiply by the load flow (– if unknown 45 m^3/MWh can be used)

The average paired delta method is above but switching around steps 1 and 2 (see section 2 about "snapshot" assumption):

1. For each sample, subtract the intake values from the values after the EGCS but before the cleaning
2. Take the average of the paired deltas
3. Multiply by the load flow

Solvang calculated their average load flow for the three engine conditions (ME in transit, AE in transit, AE in harbour) from the data obtained on the days the samples.

1. For each date of samples, Solvang obtained the flow (m^3/h) and engine load (kW) under each condition (harbour or transit, and main or auxiliary engine)
2. For the auxiliary engine conditions the engine load is corrected by multiply by 0.95 (generator efficiency)
3. The following two methods of obtaining emissions factors in the "Overview" sheet:

   Harbour average actual waterflow AE:

   a) The sum of flow of AE at harbour was divided by the sum of the engine load AE at harbour to obtain the load flow
   b) This load flow was multiplied by the average paired delta under AE in harbour condition

   Transit average actual waterflow:

   a) The ship's engine load and load flow were recorded for each sample taken, the load flow was divided by the engine load * 1000 to get m^3/MWh for sample
   b) The above values were multiplied by the corresponding paired delta to get the emission factor from paired delta
   c) All the emission factors from ME in transit was averaged, likewise with the AE in transit
   d) To get the scenario of a typical transit use of the ship's engines, the average for ME in transit was multiplied by 0.8 and the average for AE in transit was multiplied by 0.2
   e) These two values were added together

Waterflow through system

The waterflow of seawater during each test was recorded together with the power generated, which allowed for calculation of cubic metre of seawater per mega-watt hours (m^3/MWh). This value was used together with net value on each element to calculate emission factors. The average water flow for main

engine (all test included) was recorded to 56.4 m^3/MWh, (data to be available on Solvang home page[i]). The water flow corresponds to 75 % engine and scrubber load.

For the auxiliary engines, the average waterflow is ca. 96 m^3/MWh, which is more than double of design of the EGCS. This means the AE scrubber shall handle 3 auxiliary engines (plus the boiler), the full power is ∼4 - 5 MW, but in real life it is difficult to produce more than 1.5-2 MW with 2 auxiliary engines at 75 % power.

The design of EGCS flow is 45m^3/MWh, which is as much as half the flow when using the auxiliary engines. By using real averaged water flow in the emission factor calculations, the obtained values are higher which are considered more accurate for the calculations in concern.

6 References

1 IMO MEPC.1/Circ.89910 June 2022. 2022 GUIDELINES FOR RISK AND IMPACT ASSESSMENTS OF THE DISCHARGE WATER FROM EXHAUST GAS CLEANING SYSTEMS

2 IMO PPR 11/7/5 December 2023. EVALUATION AND HARMONIZATION OF RULES AND GUIDANCE ON THE DISCHARGE OF DISCHARGE WATER FROM EGCS INTO THE AQUATIC ENVIRONMENT, INCLUDING CONDITIONS AND AREAS. Submitted by ICS and CLIA

3 IMO MEPC 78/9/3 April 2022. Unified and representative emission factors for environmental risk assessment of the discharge water from exhaust gas cleaning systems. Submitted by Germany

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[i] https://solvangship.no/environment/scrubber-data
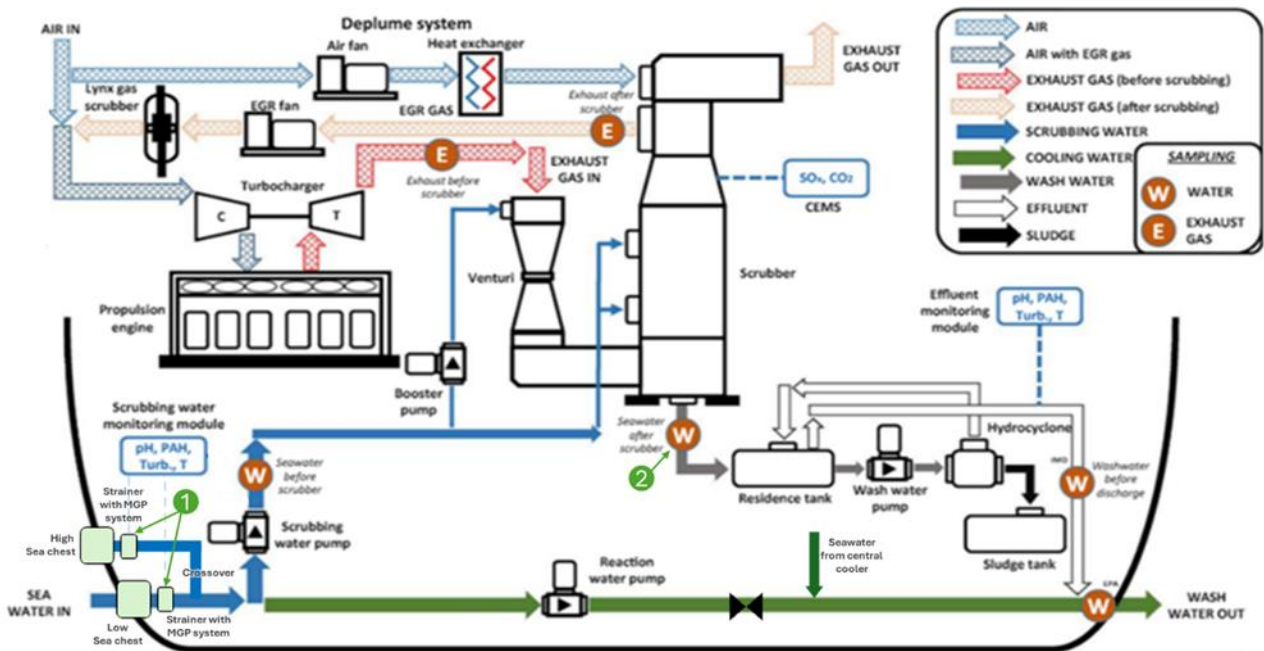
A Appendices

A.1 EGCS Diagram

Figure 1: EGCS and Sampling Points:

1 is the sampling point of the intake seawater; 2 is the sampling point after the scrubber but before cleaning of the water.

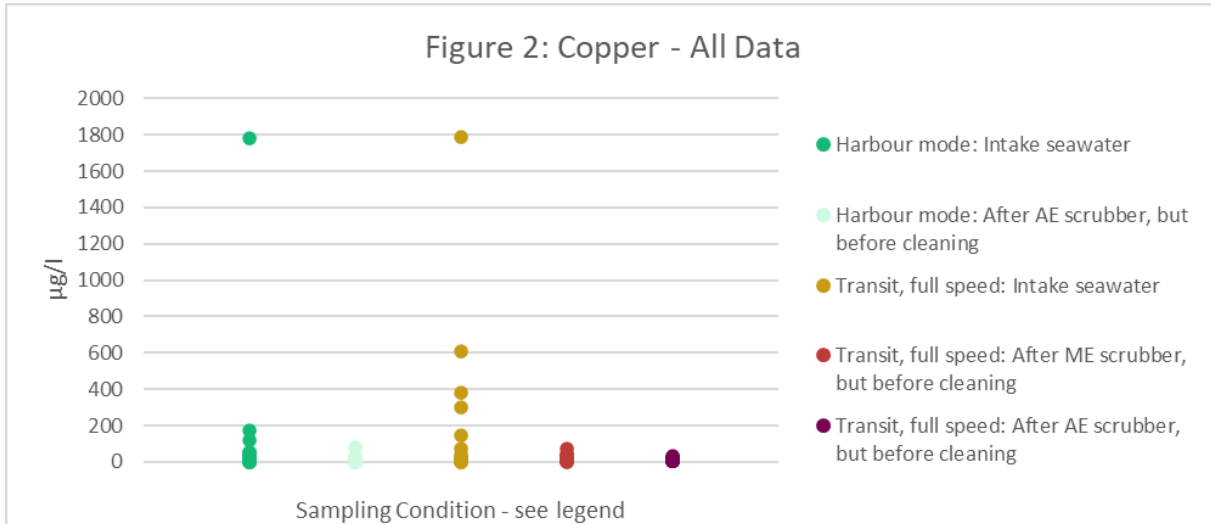*Source: provided by Solvang*

A.2 Graphs of Copper from Data Set

Figure 2: Copper – All Values

The graph shows all the values of copper under the different conditions
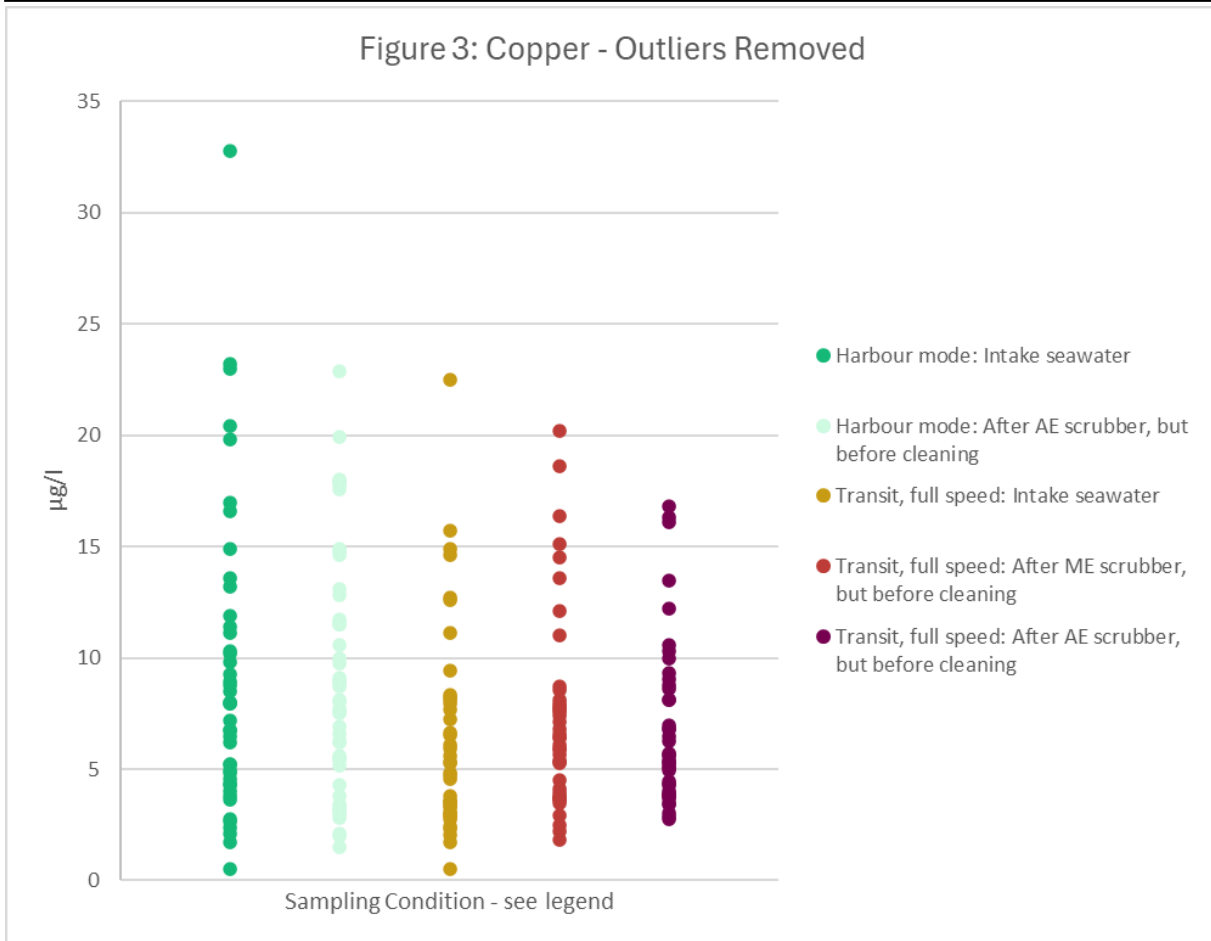

Figure 3: Copper – With the Outliers Removed using the IQR Method

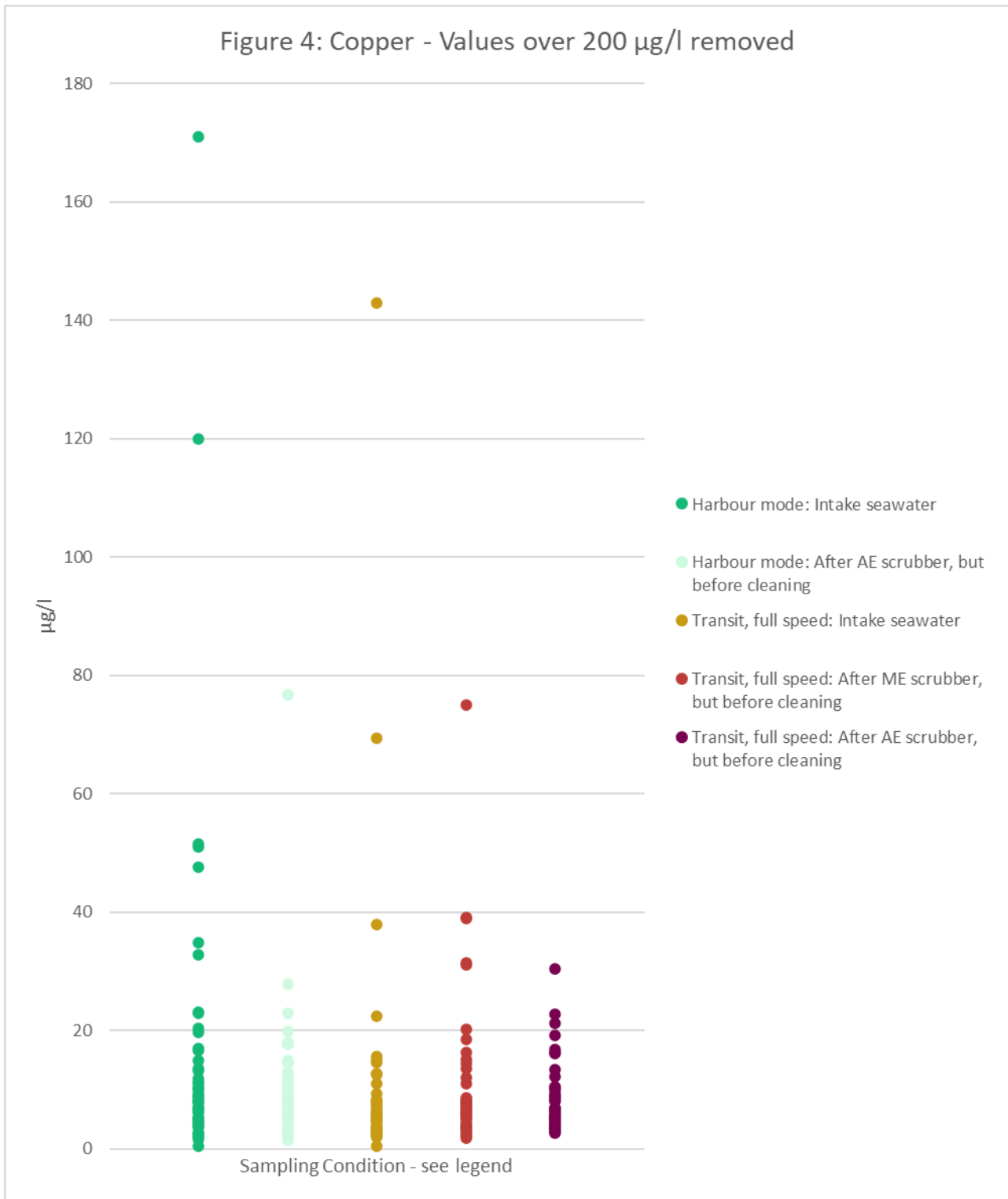*The graph shows the values of copper retained after applying the IQR method for removing outliers.*

Figure 4: Copper - Values over 200 µg/l removed

Total removed data points 5. The graph shows the majority of the data is below 10µg/l, thus the outliers removed by IQR method are outliers.