Document reference
[10a]

European Sustainable Shipping Forum
7th Plenary Meeting

Brussels, 24 January 2017

Submission from ESSF sub-groups

1. Submission from:

ESSF sub-group on Exhaust Gas Cleaning Systems (EGCS) ☒

2. Sub-group recommendation(s) to the Plenary:

1. To **note** the progress in general of the EGCS sub-group, item 6.1 to this report;
2. To **approve** the revised timeline for finalization of the IMO submission paper on proposed amendments to the *"(2015) Guidelines for Exhaust Gas Cleaning Systems (resolution MEPC. 259(68))*", item 4 to this report;
3. To **note** the further progress in development of the above mentioned submission (item 6.2 to this report) and to **recall**:
   a. the invitation to the members of the Plenary to **consider** co-sponsoring of the IMO submission, item 6.3 to this report;
   b. the progress on cooperation with the U.S. EPA, item 6.4 to this report;
4. To **note** the information on alternative EGCS technologies; item 6.5 to this report;
5. To **note** the final Report on the results of the questionnaire regarding waste from scrubbers, item 6.6, and Annex 2 to this report;
6. To **note** the progress with the EGCS washwater sampling campaigns being undertaken by EGCSA/EUROSHORE and Carnival, item 6.7 to this report; to **encourage** sludge sampling analysis as a second step; and to **support** the development of IMO submission papers;
7. To **endorse the proposed way forward** on development of the operational non-compliance guidelines and potential amendments to the EGCS guidelines and/or the 2009 MARPOL Annex VI port state control guidelines, item 6.8 to this report;
8. To **note** the progress on development of draft guidelines for discharge of EGR bleed off water, item 6.9 to this report; and
9. To **endorse** further activities, item 6.10 to this report.

3. **Required action(s) to be considered by the ESSF Plenary based on sub-group recommendation(s):**

See above.

4. **Timing of required action(s) in view of upcoming deadlines and critical requirements:**

It is to be noted that the dates for the 71st meeting of the IMO Marine Environment Protection Committee (MEPC 71) have been moved from 8-12 May to 3-7 July 2017 and hence the bulky document submission deadline is now 31 March 2017. With reference to sub-group recommendation 2.2 above, Plenary is requested to note the intention of the EGCS sub-group to communicate the final draft submission of the *"Review of the 2015 Guidelines for Exhaust Gas Cleaning Systems (Resolution MEPC. 259(68))*" to Plenary, by correspondence, on or before 17 February 2017 to account for COM internal procedures and approval by the Shipping Working Party in time to meet the IMO deadline.

5. **Summary of the issue and possible alternative solution(s)**

N/A

6. **Background information**

1. General

Since the last report to Plenary, the sub-group on EGCS has continued its work under the general mandate item 1.2 of the ToR with a view to facilitating the take up of EGCS technologies as alternative emission abatement technologies for compliance with Directive 1999/32/EC, as amended. The sub-group met on 15th September 2016, together with inter sessional correspondence, to further progress the work package items. It should be noted that the workload of the sub-group has increased significantly, in particular regarding the intensification of the washwater sampling and analysis campaigns and the four potential IMO submissions that are in progress. Specific background information to these activities and the sub-group recommendations are detailed below.

2. WP8. Verification and approval of pH criteria – Amendment of the 2015 EGCS Guidelines.

Plenary will recall that further amendments to the IMO EGCS guidelines is not currently a PPR agenda item and that the sub-group had developed a paper for unplanned output to MEPC 69, ref. MEPC 69/19. The MEPC committee approved this unplanned output for the MEPC agenda for the next biennium, at the 69th session and outlined the scope of work for the EGCS guideline revisions to be considered together with matters associated with operational non-compliance (see 6.8 of this report). Plenary will further recall the detailed information on the development of the proposed EGCS guideline amendments submitted as paper 7b to the last Plenary session in June 2016.

In accordance with 2.2.2 of the EGCS sub-group ToR and under the coordination of Finland, the sub-group has continued development of the draft amendments to the IMO (2015) EGCS guidelines to facilitate consistent interpretation and application of same. This has included a total of seventeen discussion rounds, the last of which was concluding at the time of preparation of this progress report. Numerous topics have been discussed at length (refer to the aforementioned paper 7b) and in some areas there remain diverging views and a lack of detailed reference information, for example with respect to washwater PAH and turbidity limits and measurement techniques, nitrate sampling and reporting, system terminology, transient non-compliance, etc. There also remains some concern that the proposed amendments should not be seen as being outside the IMO scope of work.

The ESSF Plenary is invited to note the progress on this topic and to note and support the timeline for preparation of the final IMO submission detailed under item 4 of this report.

3. Co-sponsoring of the IMO submission paper concerning draft amendments to the IMO 2015 EGCS guidelines.

As previously reported, rules regarding co-sponsoring say that all third parties interested to co-sponsor submission of a paper lying within the EU competence, as in the case of the revision of the IMO EGCS Guidelines, should express their intention in advance. Information about this will be communicated to the Council, gathering all EU Member States, together with the final draft. After the paper having been agreed amongst all Member States (possibly revised by them), all interested co-sponsors will then be asked whether they are still interested in co-sponsoring the submission. If so, they will be listed in the heading of the submission.

Of note on this matter is that only IMO members or Non-Governmental international Organisations (NGOs), which have been granted consultative status within IMO, can co-sponsor submissions to IMO. Such ESSF members are requested to kindly consider co-sponsoring the submission.

4. Cooperation with the U.S. EPA (Environmental Protection Agency)

Plenary will recall previous intention for the United States Environmental Protection Agency (EPA) to engage in a dialogue with the EU regarding the proposed IMO EGCS guideline amendments. We are pleased to report that the EPA have joined the EGCS correspondence group and have provided valuable input to the discussions. It is the EGCS sub-group's and Commission's belief that cooperation, regardless of whether it will result in a potential joint submission or simply in a consultation of the draft, will have a positive effect on avoidance of duplicated work by the U.S. and EU on this matter. The ESSF Plenary is invited to note the further progress on this topic.

5. Alternative EGCS Technologies and Innovation

The opportunity was taken at the 10th EGCS sub-group meeting to invite speakers from two parties that are involved in projects utilising alternative EGCS technologies. Interesting presentations were given on the Ecospec cSOx plasma scrubbing pilot project on the “Transtimber” and the Ionada membrane scrubbing technology.

Whilst many of the requirements in the existing IMO guidelines for EGCS systems may be considered generic and applicable to all EGCS systems, it was noted that the guidelines were originally developed around established open and closed loop wet scrubbing systems. Hence the full applicability to new, or novel alternative approaches, in particular with respect to the chemistry of the SOx reduction process, requires careful consideration. The evaluation and support of alternative EGCS technologies is foreseen as an EGCS sub-group activity and may necessitate the development of specific guidance for approval and implementation. The ESSF Plenary is invited to note the activity on this topic.

6. WP2. EGCS Waste handling - Cooperation with the PRF Sub-group.

Plenary will recall that EMSA have coordinated responses from the EGCS sub-group on waste from EGCS. This has been a useful exercise in allowing debate within the group where divergent opinions exist and allowing refinement of the responses over a number of rounds. Information has been provided to the PRF sub-group clarifying closed-loop and open-loop concepts, quantification of typical sludge generation rates, a proposal for hazardous classification of wet scrubber sludge and clarifications on the distinctions between open-loop operation and process water in closed-loop operation with bleed off water held in a dedicated tank. Following the sub-group meeting in September, the report has been further refined and is attached for information, as Annex 2 to this report. The ESSF Plenary is invited to note the final version of the report.

7. WP7. - Washwater discharge criteria

Plenary will recall the detailed information on the EGCS washwater sampling protocol and campaign provided to the January 2016 Plenary session as paper 6b.

EGCSA in association with EUROSHORE have undertaken a washwater sampling campaign from installed EGCS units, initially on 8 ships but intended to extend to 30 ships, covering ‘open loop’, ‘closed loop’ and ‘hybrid’ configurations. The work is the most comprehensive investigation of EGCS washwater discharges undertaken by the maritime industry so far. The analysis of the results achieved thus far is still ongoing but has shown that the quality of the EGCS washwater discharges appears to be well within the limits set by the IMO EGCS guidelines (MEPC.259(68)), as referenced by 1999/32/EC, as amended, for alternative emission abatement technologies.

Plenary will also recall that a parallel sampling campaign is being undertaken by Carnival on 40 cruise ships fitted with ‘open loop’ scrubbers and preliminary results also show washwater discharges well below IMO limits. Carnival has also experimented with further refinement of the EGCS washwater system arrangements with additional post EGCS washwater filtration. The sampling campaign, development and analysis will continue and may be incorporated in the EGCSA/EUROSHORE results in due course.

Germany has also given a brief note on the status of their Sampling & Analysis project, having offered to present the overview of the project to the next ESSF EGCS sub-group meeting.

Having in mind many different on-going initiatives, the EGCSA Washwater sampling & analysis protocol was suggested to be used as a technical guidance document under the title "Washwater Sampling and Analysis Guidelines", by EGCSA to the sub-group at the last meeting. Following the suggestion from one of the sub-group members, and the general agreement of the sub-group, the subject document should be further improved in order to produce a submission to IMO.

The objective for the work shall be, as far as reasonably possible, the harmonization in the approach of different sampling & analysis exercises, mostly in favour of the future comparability of results. In support of this work package item the intention to submit two papers to IMO is to be noted. One submission is intended to cover the latest version of the "Washwater Sampling and Analysis Guidelines" developed in the EGCS sub-group as an INF paper and a further (non-bulky) submission requesting IMO to consider tasking the PPR sub-committee to develop IMO washwater sampling and analysis guidelines. If successful, it is possible that the sampling guidelines developed in the EGCS sub-group could form the basis of an IMO Circular, thereby encouraging uniform international application of sampling protocols and encouraging the collection of further data.

The ESSF Plenary is invited to note the progress on this topic and support the development of submissions to the IMO.

8. WP9. Operational non-compliance scenarios.

Plenary will recall that the EGCS sub-group had provided feedback to the Norway submission to MEPC 69, ref. MEPC 69/19/2, on operational non-compliance scenarios such as accidental breakdown of the EGCS, monitoring system failure and transitory non-compliance. The MEPC 69 approved this unplanned output for the MEPC agenda at the 69th session and outlined the scope of work for the operational non-compliance guidelines to be considered together with EGCS guideline revisions (see 6.2 of this report) and potential amendments to the 2009 MARPOL Annex VI port state control guidelines.

Furthermore, these aspects have been discussed by the EGCS sub-group during the development of the proposed EGCS guideline revisions with a view to being covered either by separate IMO guidelines or included as an appendix to the proposed EGCS guideline amendments. It is anticipated that this aspect will be addressed by the sub-group, under the coordination of Norway, in a further submission to the IMO. The work will be held by correspondence and at the sub-group's meetings throughout this year, to allow submission to MEPC 71 (July 2017) or PPR5 (early 2018) at the latest. The ESSF Plenary is invited to note the progress on this topic.

9. Exhaust Gas Recirculation (EGR) bleed off.

Plenary will recall that the EGCS sub-group provided feedback to Denmark on their information paper, ref. PPR 3/INF.4, on EGR bleed off water. It is to be noted that the IMO PPR subcommittee further progressed this agenda item as draft guidelines for the discharge of EGR bleed off water which will be considered by MEPC 71. The ESSF Plenary is invited to note the progress on this topic.

10. Further activities.

The extensive efforts with the proposed amendments to the IMO EGCS guidelines undertaken by the EGCS sub-group, in both the sub-group meeting and by correspondence, represent the most substantive activity of the EGCS sub-group since the last Plenary session. The intention for the next period is to return focus to the residue and washwater sampling campaign (items 6.6 and 6.7 to this report), finalize the ongoing IMO submission papers and assess required activities for the outstanding existing work packages (updated work package table attached as Annex 1 to this report). It has been recognised that the existing work package items do not accurately reflect the current and foreseen sub-group activities. Therefore it is the intention to develop a revised list of proposed work packages within the sub-group for Plenary endorsement at a future session. The ESSF Plenary is invited to endorse this approach.

The next meeting of the EGCS sub-group is planned for 23 February 2017.

List of Annexes:

Annex 1 – Report on the consolidated replies to the PRF Directive questionnaire

Annex 1

EUROPEAN COMMISSION
DIRECTORATE-GENERAL FOR MOBILITY AND TRANSPORT
Directorate D - Logistics, maritime & land transport and passenger rights
D.1 - Maritime transport & logistics

ESSF sub-group on Exhaust Gas Cleaning Systems (ESSF EGCS)

REPORT

Questions for the ESSF Sub-Group on Exhaust Gas Cleaning Systems regarding waste from Scrubbers

Contents

1. 1. INTRODUCTION

The present report contains the relevant analysis and conclusions from the replies to the PRF Questionnaire on waste from Exhaust Gas Cleaning (EGC) systems. The questionnaire was first sent to the ESSF EGCS subgroup in late October 2015, undertaking a process that would end up with a set of consolidated replies reflecting the contribution from approximately 20% of the EGCS subgroup members, and the total number of industry EGCS manufacturer representatives.

An initial background note is provided to draw the context in which the PRF Questionnaire is made and, furthermore, to underline the relevance and timing for the questions now made by the PRF ESSF subgroup, on the particular topic of waste from scrubbers.

The questionnaire is then explained and its structure commented so as to clarify, in the context of the present report, what is the scope of each question. This is considered of particular relevance, in particular with regards to washwater, where its classification, in the context of waste is better clarified by the EGCS subgroup.

Finally, in two main sections, one dedicated to sludge, and another to washwater, the report follows the structure of the questionnaire, with each questions being presented as a sub-section of the report. With the full replies given in Annex-B, the report will focus on the main aspects relating to each question.

In addition to the questionnaire the report also reflects the EGCS ESSF subgroup discussion topics, at its 9th session, on the 10th May 2016. During this meeting further clarifications were made to some of the points where divergent views were found. Replies to the PRF Questionnaire were, at the time, understood as the reflection of the individual expertise of the EGCS subgroup members and not the result of a collective exercise by the whole subgroup.

The subject of waste from EGCS systems, in particular of sludge composition, is an area where investigation is still being undertaken at the ESSF EGCS subgroup. A Sampling and Analysis campaign is currently under way so as to determine the chemical composition, presence and nature of pollutants in several sludge samples, already collected. The sampling & analysis exercises have not yet been finished and none of the preliminary results have yet been validated to the point of being made public by the EGCS subgroup.

On the particular aspect of washwater the present report tries to make the clear distinction between “washwater” (a process fluid of a wet EGC system) and “waste water” (the result of a “bleed-off” or similar saturated water that does not meet the discharge criteria established by the IMO EGCS Guidelines). The first shall not be regarded as waste, provided the criteria for its discharge are met, whereas the second may be eligible for delivery at PRF. The distinction is basically made on the basis of meeting the criteria for discharge, or not. If the washwater resulting from a normal process flow meets the discharge criteria there is, in principle, no technical or legal justification to consider it as “waste”.

2. 2. BACKGROUND

Following from the provisions in regulation 17 of MARPOL Annex VI, governments of each Party undertake to ensure the provision of facilities adequate to meet the needs of ships using its ports, terminals or repair ports for the reception of exhaust gas cleaning residues from an approved exhaust gas cleaning system.;

Through Resolution MEPC.199(62), the International Maritime Organization (IMO) adopted the 2011 Guidelines for Reception Facilities Under MARPOL ANNEX VI, on the 15th July 2011. Administrations were then invited to take the respective guidelines into account when developing and enacting national laws giving force to and implementing provisions set forth in regulation 17 of MARPOL Annex VI. Additionally Parties to MARPOL Annex VI and other Member Governments were requested to bring the guidelines to the attention of port and terminal operators, and any other interested groups, making them the international reference document regarding the specific requirements for port reception facilities on MARPOL Annex VI wastes.

From IMO Guidelines for Reception Facilities under MARPOL Annex VI there are already relevant indications regarding the nature of EGCS residues, with different aspects being covered, such as definitions relevant to EGCS systems/waste, Treatment, disposal and composition of EGCS residues.

It was in this international context that the Commission has recently started an Impact Assessment for a future legislative revision of Directive 2000/59/EC on port reception facilities for ship generated waste and cargo residues ("the PRF Directive"). The roadmap for the revision of the PRF Directive mentions as a possible measure the inclusion of the waste arising from the implementation of MARPOL Annex VI in the scope of the Directive.

In order to develop a better understanding of the operation of EGC systems, and the sludge waste and waste water effluents resulting from such operation, the ESSF EGCS Sub-Group was requested to provide answers to the questionnaire included in Annex-A. The questions go very approximately in accordance to the points covered by the Guidelines for Reception Facilities under MARPOL ANNEX VI. Composition of EGCS waste, typical quantities for different ship types and corresponding modes of operation and other aspects related to additives, their potential toxicity and EGCS sludge waste classification. The requested input, as shown in the present report, is expected to be used in the Impact Assessment for the revision of the PRF Directive.

3.

4. 3. QUESTIONNAIRE

The PRF Questionnaire, entitled *Questions for the ESSF Sub-Group on Exhaust Gas Cleaning Systems regarding waste from Scrubbers* (Annex-A of the present report) was prepared with EMSA support as a cooperation of the two technical secretariats for both PRF and EGCS subgroups. The resulting questionnaire was then sent to these last subgroup members, for comments and suggested modifications that would better suit the nature and scope of such questionnaire. The contributions from the EGCS subgroup has then resulted in a revision of the questionnaire, even prior to any replies being actually received. The timeline followed is shown below, in Figure 1:

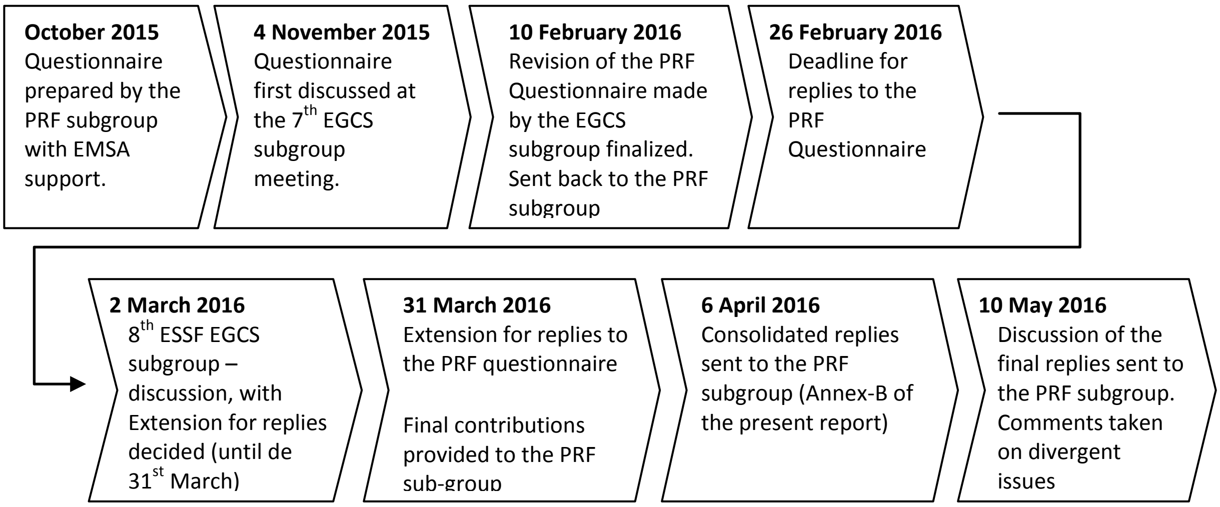


Fig.1 – PRF Questionnaire - Timeline

The questionnaire is essentially divided into 2 (two) parts. A first part is dedicated to sludge waste, with questions focused on aspects related to composition, quantities produced and expected for PRF, additives, toxicity, waste classification, amongst others. A second part of the questionnaire is dedicated to washwater and waste water effluents.

Different members of the EGCS subgroup have expressed concerns, throughout the initial discussions on the scope of the PRF questionnaire, that washwater was being considered as a deliverable waste fluid. This would be an evident misconception of a scrubber working principle. Washwater is, in fact, a work fluid in a system which can operate in different modes, either open-loop (with continuous effluent waste water[1]) or closed-loop (with intermittent washwater discharge).

The questions on washwater include no kind of assumption with regards to a potential classification of EGCS Washwater as waste. The option of delivering process water (washwater, bleed-off water, or other) to port reception facilities is merely considered with the objective of estimating what the potential impact of such delivery would be, especially in terms of required capacity.

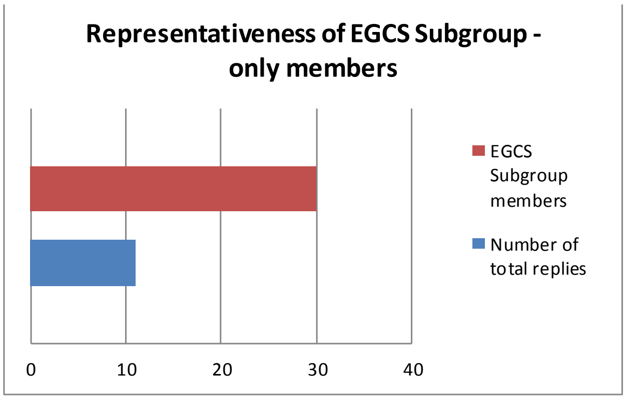
[1] - Compliant with the IMO 2015 EGCS Guidelines – IMO Resolution 259(68)

In terms of representativeness, the questionnaire has been sent out to all the EGCS subgroup members, receiving a total of 11 (eleven) replies, including 2 (two) from EGCS manufacturers not taking part in the ESSF EGCS (with the liaison of EGCSA). Being the EGCS subgroup composed of representatives of 30 (thirty) organizations, plus another 14 (fourteen). 11 replies are representative of approximately 34% of the members and 19% of the extended group. Another measure of representativeness can however be also made by taking into account only the universe of EGCS manufacturer's representatives, and here the percentage was more than 50% of representativeness, with nearly half of the manufacturers' representatives giving their contribution replying to the questions from the PRF subgroup.

The graphics in figure 2, below, provide a graphical view of the different measures of representativeness of the replies received. In the top graphic the universe of EGCS members is considered whilst in the middle graphic the ESSF EGCS subgroup members and non-members is considered, in an extended ESSF

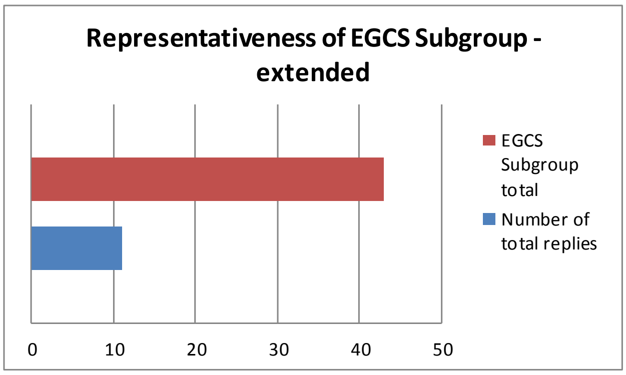
Representativeness of EGCS Subgroup - only members

Number of total replies	11
EGCS Subgroup members	30
% of replies	**37%**



Representativeness of EGCS Subgroup - extended

Number of total replies	11
EGCS Subgroup total	43
% of replies	**26%**



Representativeness of EGCS Manufacturers

Replies from Manufacturers	5
EGCS Subgroup Manufacturers	8
% of replies	**63%**

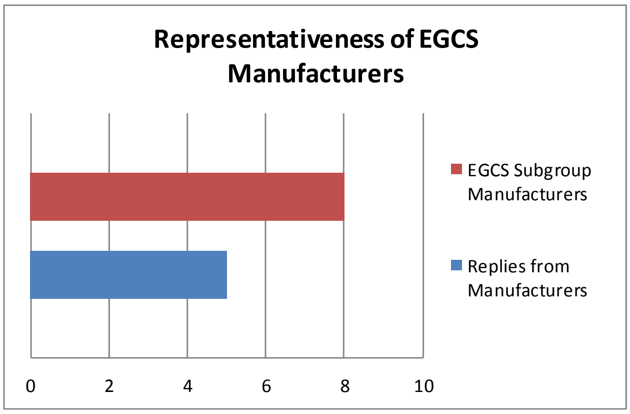


Fig.2 – PRF Questionnaire – Representativeness of replies

Even though the number of replies may seem to have been rather reduced (below 50% even in a members-only universe) the relevance of EGCS manufacturers' representativeness in the replies to the PRF Questionnaire is an important indication in favour of the validity of the whole exercise. With very limited information on the exact composition of EGCS sludge, on technical details of different systems and different operating modes, the contribution from industry is the closest possible approximation of reality with the regards to EGCS waste. In principle, the systems designers and manufacturers' replies are given from a privileged position, foreseeing on technical/engineering grounds, the most probable pollutants in sludge and washwater, already taking into account the potential effect of different alkali additives.

The contribution from EGCSA in distributing further the questionnaire was also very important for the optimization in the number of replies received. Two additional EGCS manufacturers have replied (CR Ocean Technology and Ionada) as a result of EGCSA's redistribution of the questionnaire. Ionada participation brought a different scrubbing technology – membrane scrubbing – presented as a technology with significant differences from the wet scrubbing. The replies were however considered and integrated into this report. In fact, even if technologies other than water based scrubbing are marginal in the EGCS industry, they are important indication of potential alternatives which can, ultimately, represent different resulting waste profiles.

The consolidated replies to the PRF Questionnaire, in Annex-B, represent all the exact written contributions from the different respondents. Some divergent points taken from these replies are further explored in Section 5 of this report.

5. 4. Basic Elements and Operation of EGCS systems

One of the most relevant aspects of the questionnaire exercise was allowing for the opportunity of further providing an insight on the main concepts and principles of exhaust gas scrubbing technology. The main focus is given to wet scrubbing systems, even though one of the replies was received from a manufacturer of membrane scrubbing systems, not operating in a water circulation-based medium. The larger focus of the present questionnaire into wet scrubbing EGC systems is mostly related to the following elements:

- Systems with the largest number of applications and installations onboard vessels, with the large majority of marine EGC systems of the wet scrubbing type;
- Representation of EGC systems' industry/manufacturers in the ESSF EGCS subgroup is exclusively for wet scrubbing systems[2]

The design of marine wet scrubbers or any air pollution control device depends mostly on the size and characteristics of the onboard power and propulsion installation, especially the main engine/generator installation. The intended oil fuel for operation and the ship/engine operating profile are, in addition, also very relevant indicative elements for design of EGC systems. They will be important variables in for the efficiency of the EGC system regarding removal of pollutant SOx elements and Particulate Matter. The versatility of wet scrubbers allow them to be built in numerous configurations, all designed to provide good contact between the liquid and polluted gas stream.

Wet scrubbers remove dust particles by capturing them in liquid droplets. The droplets are then collected, the liquid dissolving or absorbing the pollutant gases. Any droplets that are in the

[2] Ionada contribution for the PRF Questionnaire was the result of EGCSA's redistribution of the document through its member companies. This allowed a company not represented in the EGCS subgroup to also contribute, in Ionada's case with a different technology

scrubber inlet gas must be separated from the outlet gas stream by means of another device referred to as a demister (mist eliminator or entrainment separator). Also, the resultant scrubbing liquid must be treated prior to any ultimate discharge or being reused in the plant.

A wet scrubber's ability to collect small particles is often directly proportional to the power input into the scrubber. Low energy devices such as spray towers are used to collect particles larger than 5 micrometers. To obtain high efficiency removal of 1 micrometer (or less) particles generally requires high energy devices such as *venturi* scrubbers or augmented devices such as condensation scrubbers. Additionally, a properly designed and operated entrainment separator or mist eliminator is important to achieve high removal efficiencies.

Marine wet scrubbers are designed to remove the gaseous pollutant SOx and can, to some extent, remove particulate matter as well. Good gas-to-liquid contact is essential to obtain high removal efficiencies. If the gas stream contains both particle matter and gases, wet scrubbers are generally the only single air pollution control device that can remove both pollutants. A balanced wet scrubber design achieves high removal efficiencies for gases and, in some instances, can achieve high removal efficiency for particulate matter as well.

In general, obtaining high simultaneous gas and particulate removal efficiencies requires that one of them be easily collected (i.e., that the gases are very soluble in the liquid or that the particles are large and readily captured) or by the use of a scrubbing reagent such as lime or sodium hydroxide (caustic soda, NaOH).

As explained above, wet scrubbers are EGC systems mostly based on a composition of fluid flow circulation circuits. The exhaust gases are washed through carefully oriented and adjusted water nozzles, inside a special unit. The water used for washing down the pollutant exhaust stream is typically named “washwater” and has deserved recently much attention both from a regulatory perspective[3] and from an operational point of view, leading to several considerations about its possible discharge in ports or other restricted water bodies, where pollutant concentration might impose stricter limits on washwater discharge.

Figure 3 illustrates the basic components of a marine EGC system:

- An exhaust gas cleaning unit, enabling the exhaust stream from an engine or boiler to be mixed with the washwater – either seawater or freshwater (or both). The exhaust gas cleaning units tend to be enclosed within the funnel area, leading to typical structural retrofit modifications.

- A treatment plant to remove pollutants from the washwater after the scrubbing process. This can take the form of centrifugal separators, chemical treatment within a settling process tank or any other physico-chemical process.

- Sludge handling facilities – sludge removed from the washwater, at the treatment plant must be retained onboard for disposal to port reception facilities. The very specific hazardous classification of EGCS sludge waste, and a better understanding of EGCS sludge waste is a good part of the PRF questionnaire.

Apart from the relevant understanding of EGC systems elements and architecture it is very important to address the different operating modes that wet scrubbers can typically run on. These operating modes are mainly defined by the washwater circuit arrangements, and by the ability to operate the EGC system with, or without, any washwater effluent streams.

[3] Reference to EGCS guidelines

Depending on whether and EGC system can operate with a constantly running new washwater stream discharge, or with a recirculating washwater medium, the systems are said to be operating in open-loop or closed-loop mode, respectively. Some wet scrubbers have the ability to operate in both modes, combining the simplicity of open loop operation with the advantages of a more complex closed-circuit washwater recirculation, especially relevant in circumsatnces where independence from the outer media is important. This can be the case both due to inlet or outlet restrictions:

- Inlet restrictions: in areas where 1) seawater alkalinity is low (affecting the washwater stream scrubbing efficiency and ability to resist to pH variations.); 2) muddy waters or 3) ice-infested waters prone to blockage/clogging of the sea water suctions;

- Outlet restrictions: mostly due to the potential environmental impact of washwater discharges in special sensitive water bodies. Ports and other semi-enclosed areas represent potential fragile ecosystems where washwater discharges are currently being carefully analysed and observed.

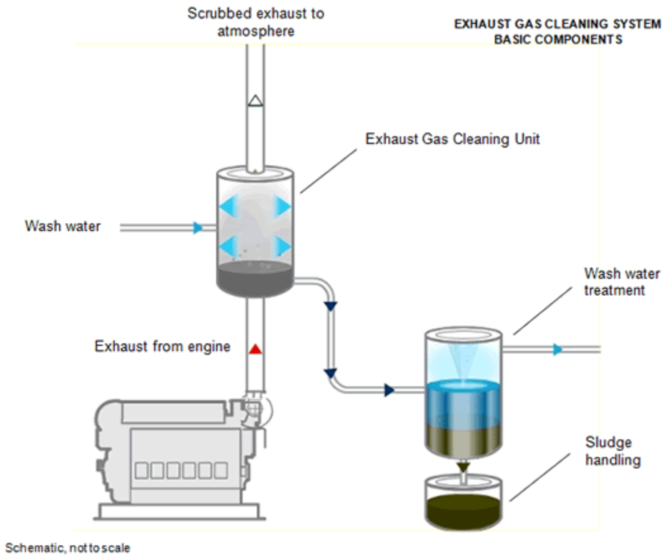


Fig.3 – Exhaust Gas Cleaning System basic components.
(EGCSA, http://www.egcsa.com, 19 June 2016)

For systems operating in open-loop mode (Figure 4, below), the water is taken from the sea, used for scrubbing, treated and discharged back to sea, with the natural chemical composition of the seawater being used to neutralize the results of SO_2 removal, alkalinity being the fundamental parameter affecting seawater buffering capacity. Typically open seawater systems use 45m³/MWh for scrubbing (for a 20MW main engine installation, during one hour at 85% MCR operation, with the scrubber operating in its full capacity, a total of 765m³, approx 785t, of seawater would have passed through the EGC system, the equivalent to 13 trailer tank trucks).

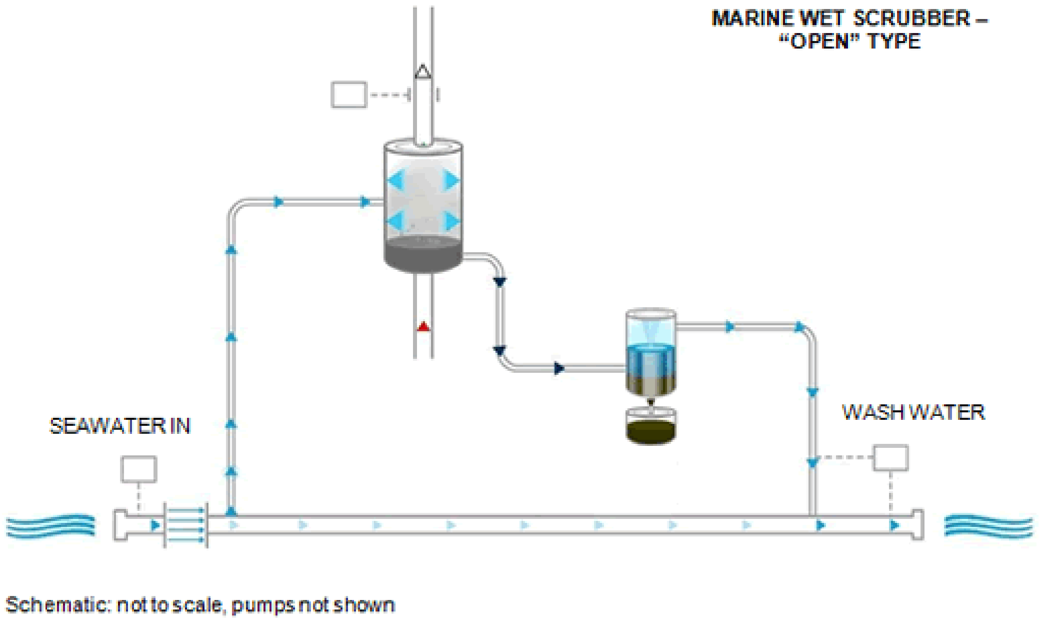


Fig.4 – EGC system in open-loop operation.
(EGCSA, http://www.egcsa.com, 19 June 2016)

For systems operating in closed-loop mode (Figure 5, below), freshwater treated with an alkaline chemical such as caustic soda is used for neutralization and scrubbing. The wash water is then recirculated and any potential losses of washwater in the scrubbing process (mostly due to heating/vaporization in the process) are compensated for. A small quantity of the wash water is bled off to a treatment plant before discharge to sea. Typically closed freshwater systems have a discharge rate of 0.1- 0.3m³/MWh although the system shown can operate with zero discharge for limited periods (for a 20MW main engine installation, during one hour at 85% MCR operation, with the scrubber operating in its full capacity, a total of 1.7m³, approx. 1.75t, of water would have passed through the EGC system. Almost two days of continuous operation would be needed to bleed sufficient water to fill one trailer tank truck).

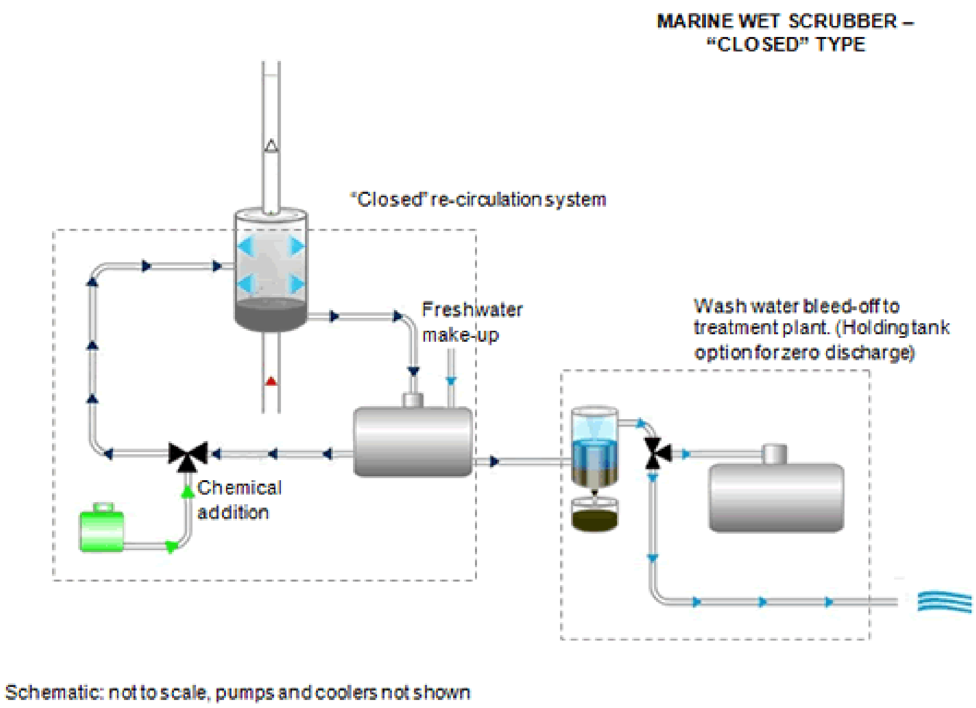


Fig.5 – EGC system in closed-loop operation.
(EGCSA, http://www.egcsa.com, 19 June 2016)

6. 5. Sludge

The part of the PRF questionnaire dedicated to sludge allowed understanding better some relevant points that seemed to be not sufficiently clear, remarkably on the issue of sludge production by EGC systems operating in open loop mode. No evidence could be obtained from the questionnaire regarding sludge production from open-loop scrubbers. Even though this is a concept with many literature and theoretic references and advertisements it is remarkable to note that no manufacturer that replied to the questionnaire has given any indication of sludge production for systems operating in open-loop mode.

Apart from the noticeable point on EGC systems operating in open-loop highlighted above, also the uncertainty about the pollutant components present in sludge is yet to be fully clarified by means of a wide sampling & analysis campaign[4]. Waste Classification is another key point that has much to gain from a better understanding of EGCS sludge composition.

A series of tables, below and through the next pages, contain the consolidated replies relevant to each one of the questions contained in the PRF Questionnaire. The questions have been grouped for the sake of a structured presentation of the replies

Sludge Quantity and Quality

Question from the PRF Questionnaire	**Consolidated replies**
2.1.1 **For the same operating conditions, how much sludge per kWh is typically produced in** **1. Closed loop mode?** **2. Open loop mode?**	REPLIES: **Closed Loop mode** Indication was given by the respondent participants of the following indicative values (they • 1 kg dry matter per MWh • Typically the sludge has a dry matter content of 5 %, which thus gives a sludge rate of 20 kg/MWh. • 0,4 g/kWh (400g/MWh) • 0.000625 kg per kWh (including 36% water that is trapped in the sludge and sent to storage for disposal at) **Open Loop mode** All provided replies and reactions to the PRF Questionnaire have given indication that no sludge was produced by EGC systems operating in open-loop mode. NOTE: The fact that no respondent has indicated the production of sludge comes as a noticeable fact. Open-loop operation diagrams from many existing references feature water treatment and sludge removal. It seems, at least from the received replies, that this is not common practice.
2.1.2 **In hybrid mode, assuming a 50-50% equal share split between the two possible modes of operation (open/closed)?**	• There is no such thing as a Hybrid Mode. • In the way the question is formulated it becomes evident that it will be 50% of the sludge disposal rates indicated in reply to 2.1.1 NOTE: The question, as formulated, is in fact not precise, as indicated by the majority of the respondents. It is common to refer to "hybrid scrubbers" and not to "hybrid-mode". Nevertheless, for cases where two simultaneous streams could be designed, one open and another one in closed circuit, the "hybrid-mode" could apply.
2.1.3 **Please refer now to the production of sludge by open-loop scrubbers. In your opinion, and taking into account available information, is this type of scrubber expected to**	REPLIES: • **Future open loop scrubbers will be able to concentrate some pollutants as sludge**, but at the moment it is hard to predict just how efficiently that can be done. • Many of the scrubber suppliers **do not use water treatment in open loop mode** but if they do, it is a simple hydrocyclone. This

[4] This has been one of the key points still outstanding in the work list of the EGCS sub-group (Work Package 2)

Question from the PRF Questionnaire	Consolidated replies
remain prevalent in the market? In addition to questions 1.1) and 1.2) how do these scrubbers compare in terms of sludge produced?	solution has some treatment capability but it cannot be compared to efficient closed loop water treatment plant • **The main difference between open-loop and closed-loop** is that one operates with large quantities of washwater (challenging any fully effective particle cleaning) and the second has a holding tank with a dedicated cleaning system allowing for effective sludge removal. NOTE: The same note applies as in 2.1.1.

2.1.4
What is typically contained in the sludge waste resulting from scrubber operation in:
1. Closed loop mode?
2. Open loop mode?
	REPLIES:
	Closed Loop:
	• What goes in (fuel, air, lubrication oil, washwater (freshwater + NaOH)) must come out (exhaust gas, bleed-off water, sludge). For the closed loop sludge that would be in headlines:
	  • lubrication oil (will burn but is not flammable)
	  • uncombusted products: soot, hydro carbons (PAH, oil)
	  • ash (salts, minerals)
	
	Open Loop:
	Again here, what comes in (fuel, air, lubrication oil, washwater (seawater)) must go out (exhaust gas, washwater, sludge), and again it is as above, but also sand and sediments originating from the seawater will be extracted as sludge, especially if the ship is operating in stirred up waters or in port areas

2.1.5 **Additives. What additives are used and what is the likely percentage of these ending up in the sludge for both operating modes:** **1. Closed loop mode?** **2. Open loop mode?**	REPLIES: **Closed Loop**: • *Kemira Pax-MP3103M*, which is a coagulant, used in water treatment plants. Approx. 100% of the added substance will end up in the sludge- lubrication oil (will burn but is not flammable) • Polymer 0,1 %. • Water with some Na2SO4 **Open Loop**: (No additives were mentioned)
2.1.6 **For both closed and open loop modes how do the additives added influence the toxicity of the washwater?**	REPLIES: **Closed Loop**: • No toxicity was mentioned **Open Loop**: • No toxicity was mentioned

On the classification of waste

Question from the PRF Questionnaire	Consolidated replies
2.1.7 **How are closed loop sludge and open loop sludge being classified by the port/waste handler?**	REPLIES: **Closed Loop**: • In EU it is the waste treatment company that is responsible for classifying waste, so it would depend on how they perceive the sludge (process it originates from (waste code) + analysis (hazardous/safe)). • **10 01 18 (waste from gas cleaning containing hazardous substances) for closed loop sludge was recommended.** • Swedish ports classify wastes from exhaust gas treatment as hazardous and will require declaration/information about the type and EWC code of the waste to be delivered to a PRF • Same as the sludge cleaned from the engine operation,

Question from the PRF Questionnaire	Consolidated replies
	separator and economizers. It should be handled the same way • **Sludge is classified and treated as oily waste such as purifier sludge and/or used lubricating oil. The main issue in terms of collection and residual value is the content of water in the sludge.** NOTE: Again it noticeable that, departing from the assumption that no sludge is produced by EGC systems operating in open-loop mode, not even the sludge classification is here attempted.
2.1.8 **From the following EWC[5] Codes, for EGCS resulting sludge, which would you select as the most representative? (Please refer to Commission Decision 2000/532/EC, on classification of waste):** • **06 06 02 "wastes containing dangerous sulphides".** • **10 01 18 "wastes from gas cleaning containing dangerous substances".** • **10 01 20 "sludges from on-site effluent treatment containing dangerous substances".** • **13 05 02 "sludges from oil/water separators".** • **13 05 03 "interceptor sludges".** • **13 05 07 "oily water from oil/water separators".** **In addition to the classifications above could any other classification be considered adequate?**	All replies have indicated the following proposed classification as the **10 01 18 "wastes from gas cleaning containing dangerous substances".**

Waste handling and transport

Question from the PRF Questionnaire	Consolidated replies
2.1.9 **What special measures are needed to handle these wastes?**	• The waste is **normally watery and thus contains lots of sodium sulphate (salts)** which might hamper the biological processes in ordinary municipal treatment plants. • Due to the **hazardous nature of the waste** special treatment is needed • appropriate way of destruction of EGCS residues is incineration • Normal practice as used when handling oily sludge from other portions of the ship • Depends on the state of the waste: **liquid** or **solid**. **Solid**: should be collected by appointed waste collector. **Liquid**: (depending on quantity) either by vacuum-truck, or by tanker-barge or in drums. All means of transport should be able to handle this waste via licensed operators and equipment

[5] The EWC is a hierarchical list of waste descriptions established by Commission Decision 2000/532/EC. It is divided into twenty main chapters each of which has a two-digit code between 01 and 20. Most of the chapters relate to industry but some are based on materials and processes. Individual wastes within each chapter are assigned a six figure code. The descriptions and codes within the EWC are a suitable part of the description of your waste so as to comply with your duty of care.

2.1.10 **Are there any special measures needed to transport this waste?**	• No/None • Normal practice as used when handling oily sludge from other portions of the ship.
2.1.13 **How are sludge wastes handled on-board? In case of two sludge streams (open and closed loop sludge) are those mixed? Is close loop sludge mixed with the ship's slop oil?**	• Ship dependent – do not know • **Adm.- sludge from EGCS and ordinary sludge shall not be mixed against MS law to mix hazardous wastes with any other type of waste**. • **Recommendation not to mix** these residues with sludge or with any other type of ship-generated waste • Ports will require information about the type of waste and its EWC-code before it can be delivered to a PRF • **Further treatment of mixed wastes is also complicated**, since it is difficult to separate the hazardous waste from the rest • Although it is the same sludge and contains the same components it is not allowed to be mixed together on board. Scrubber sludge has to be stored separately • **ECGS-waste is already classified by IMO as Annex VI waste. Therefore it may not be mixed with Annex I waste (sludge etc.)**

Delivery to PRF

Question from the PRF Questionnaire	Consolidated replies
2.1.11 **Considering an estimate based on the produced sludge kg per kWh and assumed operation patterns, please comment on** **1. How often may the shipping industry want to deliver this waste to PRF?** **2. How often does the shipping industry actually deliver this waste to PRF?**	• Do not know. Depends on how the ship handles the waste. In IBCs or integrated tanks? • Depends on the tank size. • Once or twice / month • Every few days or weekly • Every port • We need to establish this data based on the produced sludge kg per kWh and operation patterns.
2.1.12 **How much sludge can a ship typically retain on-board (closed and/or open loop sludge)?**	• Ship dependent – do not know • Depends on the tank size. • Totally depending on the ship type, cruisers up to 200 m³, smaller cargo ships 20... 30 m³. • One day to one week based on client preferences
2.1.14 **How much is it costing a ship to deliver this waste to PRF?**	• The waste from EGCS shall be covered by the mandatory delivery obligation. • If covered by the no special fee system, a **differentiation between ships (having the technology installed and those without EGCS) must be allowed**, since it will not be fair to require ships that use cleaner fuel without generating "scrubber waste" to subsidize the waste management for those ships that produce such waste. • abt. 400 €/mt • Disposal costs of about 490 euros per ton. • Depending on quality (metals, contaminants, water, etc) liquid: between €50 - €150, solid: € 325-€350 per m3

Dry Scrubbing

Question from the PRF Questionnaire	Consolidated replies
2.1.20 **How are wastes, derived from dry scrubber technologies, to be classified and how are they disposed of?**	• **Possible EWC Codes could be** **10 01 05 or** **10 01 07** • Hazardous. • Recommend not to use the "used granulate" as fertilizer as suggested by some dry scrubber suppliers • Either will need to be disposed of in dedicated waste treatment plants, or used in for example cement production if those have proper environmental permission to use this product (it thus become a product and is no longer regarded as waste). • Dry scrubbing is still a big unknown - intent was to collect the sulphur and the particulates on to the lime granules and then dispose of the used granules at port. **What to do with the granules?** • quantities of material to be disposed will be extremely large

Miscellaneous

Question from the PRF Questionnaire	Consolidated replies
2.1.15 **Can the EGCS Sub Group provide case studies on how this waste is handled at the present time? (If necessary these can be anonymous).**	• No replies. • NOTE: Would the EGCS subgroup see a possibility in further contributing to this part? Or should this be left exclusively to the PRF subgroup to deal with? • Presentations and possible further discussions with waste handling companies, already with experience with EGCS residues could be possible.
2.1.16 **How many scrubbers are actually installed at the present time?**	• Ask EGCSA • Three SE flagged vessels. • Regarding Langh Tech, 6 hybrid systems. In addition 7 closed loop water treatment systems just being delivered • More than 400 wet scrubbers and 1 dry scrubber have been sold • EGCSA to provide a figure (not done yet) • NOTE: **Would be interesting to provide this figure since we practically have the most relevant part of the EGCS industry in the subgroup**. •
2.1.17 **What is the estimated expected uptake of scrubbers, medium-term and long-term?**	**EGCSA** • This question **requires a survey** of scrubbers in use. This question is only worth assessing if the volumes indicated in question 1 are shown to be significant. It is very likely that scrubber sludge will form only a very small addition to the current oily waste streams landed ashore • **At present ship owners are reluctant to invest in EGCS technology** due to a number of uncertainties. These include fuel price, date of global implementation of the 0.5%S limit and regulatory uncertainty.
2.1.18 **On average how often does a ship using scrubbers call at an EU Port (taking into account seasonal variations)?**	• A rough guess: currently 95% • Many of the vessels that have scrubbers are trading 100% inside the European SECA and thus call EU Ports continuously / daily.
2.1.19 **Is there a geographical bias or port size preference for ships using scrubbers in the EU?**	• A question that **should be directed to shipowners. No effective contributions made to this question**. •

7. 6. WASHWATER AND EFFLUENT WASTE FROM EGCS

The part of the PRF Questionnaire dedicated to washwater has been given considerable discussion before actually agreeing with the formulated questions contained in the PRF Questionnaire, focusing on sludge.

Different members of the EGCS subgroup have expressed concerns, throughout the initial discussions on the scope of the PRF questionnaire, that washwater was being considered as a deliverable waste fluid. This would be an evident misconception of a scrubber working principle. Washwater is, in fact, a work fluid in a system which can operate in different modes, either open-loop (with continuous effluent washwater[6]) or closed-loop (with intermittent washwater discharge or waste water temporary storage, in the form of "bleed off" water – see diagram in Figure 5).

The questions on washwater, as formulated in the PRF Questionnaire, include no kind of assumption with regards to a potential classification of EGCS Washwater as waste. The option of delivering process water (washwater, bleed-off water, or other) to port reception facilities is merely considered with the objective of estimating what the potential impact of such delivery would be, especially in terms of required capacity. In those systems operating in "closed-loop" mode, the contents of the "bleed-off" tank, or holding tank, represent saturated water which, in those cases where recirculation is not possible and the criteria[7] for washwater discharge cannot be met, should be considered as waste water and delivered to Port Reception Facilities, as adequate.

Question from the PRF Questionnaire	Consolidated replies
2.2.1 **On average how much washwater will a ship produce from a scrubber based on normal speeds?**	• Open loop scrubber uses approx. **45 m³/MWh**. A typical RORO ship is installed with a 15 MW engine, which thus will amounts to 675 m³/h of washwater. Reason why ships with pure open loop scrubbers would not collect their washwater • Closed loop scrubbers **bleeds off approx. 0.3 m³/MWh** and for a typical RORO ship that gives us 4.5 m³/h. Operating on average 50% load on a 24-hour basis gives us 54 m³/day. If the average load is higher, the bleed-off containment is higher as if the trip is more than 24 hours long • About 2,5 – 2,8 kg per burnt HFO mt (closed loop) • about 135 ml per kWh NOTE: Typically • Open seawater systems use 45m3/MWh for scrubbing (for a 20MW main engine installation, during one hour at 85% MCR operation, with the scrubber operating in its full capacity, a total of 765m3, approx 785t, of seawater would have passed through the EGC system, the equivalent to 13 trailer tank trucks) • Closed freshwater systems have a discharge rate of 0.1-0.3m3/MWh although the system shown can operate with zero discharge for limited periods (for a 20MW main engine installation, during one hour at 85% MCR operation, with the scrubber operating in its full capacity, a total of 1.7m3, approx 1.75t, of seawater would have passed through the EGC system. Almost two days of continuous operation would be needed to

[6] - Compliant with the IMO 2015 EGCS Guidelines – IMO Resolution 259(68)

[7] IMO 2015 EGCS Guidelines – IMO Resolution 259(68)

	bleed sufficient water to fill one trailer tank truck).
2.2.2 **On average how much washwater will a ship produce from a scrubber when entering a port?**	• Assuming 10% operation in closed-loop mode - For a 15 MW engine that would thus be 0.45 m^3/h. Assuming 30min entering the quayside then the amount would be 0.23 m^3. • About 81 ml per kWh
2.2.3 **On average how much washwater will a ship produce from a scrubber when at berth?**	• Same typical calculation as for the previous question. • Depending on the engine characteristics in operation. • Zero if the engine is off line. Normally the scrubbers have been installed on main engines with only a few applied to generators/auxiliaries.
2.2.4 **What exactly is in the washwater?**	• Soot and particles, heavy metals, oil (as PAH), sulphates. • Studies ongoing to determine the exact composition of washwater. • (a) For open loop scrubbers it is the seawater and sulphates with traces of soot. (b) for closed loop systems the washwater is fresh water with some sodium sulfate and extremely low traces of soot (?) NOTE: **Important to distinguish, for closed-loop operation, between the washwater and bleed-off from that washwater.** Permanent water discharge in "closed-loop" mode is absent of added contaminants since this is only a flow for cooling of the closed-loop water.
2.2.5 **Which pollutants are being accumulated (in which quantities) and where (geographically) are they dispensed into the aquatic environment?**	• **Question understood to be out of scope in the PRF questionnaire** – not a question relevant to PRF. • If the system is operated in open loop mode all the pollutants are washed out to sea at the spot where the vessel is sailing. This means exactly the same pollutants that in closed loop are collected and disposed ashore. • Closed loop scrubbers collect the sulphur emissions and convert them into sodium sulfate. They also collect soot, unburned fuel and black carbon and this is **separated and stored until it is disposed of at a port facility**. The cleaned liquid is discharged anywhere along its travels. Capabilities are provided for short storage should specific ports not allow the cleaned liquid discharge.
2.2.6 **What percentage of the additives that the scrubbers use end up in the wash water? Does this add to the toxicity of the wash water?**	• Approx. 0% (as per 2.1.5) and has thus no toxicity impact on the washwater. • (a) Closed loop scrubbers use NaOH for neutralization of the acid generated by the collection of the SO2 in the scrubber water. **All of the added NaOH converts to Na2SO4 and is discharged with the scrubber water.** This safe practice has been used for land-based scrubbers since the early 1900's and has passed the scrutiny of all the global environmental agencies. • **No additives are used in open loop scrubbers**. These only use seawater and its natural alkalinity to remove and neutralize the SO2.
2.2.7 **Has any research or cost benefit analysis been done to ascertain whether scrubber wash water can be delivered to PRF whilst at berth?**	• No exact replies received.
2.2.8 **How easy is it to store wash water onboard whilst entering and leaving a port and whilst the ship is at berth? Would it be logistically possible to deliver this waste to PRF?**	• **Everything depends on the amount the ship has to contain on board**. If it is a reasonable about it would be no problem. The bleed-off water is easily extracted from the ships tank to shore. • Washwater regardless open or closed mode operation will **contain too many salts for ordinary municipal treatment** plants to cope with it, • **Ports might need to invest in some kind of settling treatment**.

	The pollutants will settle as sediment and float on the surface and when removed, the remaining is clean salty water, which can be discharged to harbour/sea. If it is found that, there is too high levels of certain kinds of metals those can most likely be precipitated by the aid of some kind of coagulant. • Not likely that the closed loop scrubbers would avoid treating the washwater onboard as the loss of freshwater would be too big. Freshwater onboard is a limited resource

8. 7. CONCLUSIONS

- The Questions to the EGCS sub-group on EGCS generated waste aimed at supporting the ESSF sub-group) on Port Reception Facilities, both with details regarding quality and estimated quantities of EGCS waste, and, simultaneously, allowing for an improved understanding of marine scrubbing technology.

- The structure of the PRF Questionnaire, and the questions themselves were shared with the EGCS sub-group well before the period for replies to be submitted. This allowed the scope of the questionnaire to be better adjusted, and the contents within each group of questions to be improved and made coherent within the context of current EGCS technology. This cooperation has proved to be advantageous for both sub-groups.

- The majority of EGCS manufacturers present in EGCS sub-group have replied to the PRF Questionnaire (representativeness above 60%). This can be considered a good indication of the quality of the replies. Sludge and bleed-off water generation are highly specific to each EGC system, also under very specific operational conditions. The knowledge from EGC manufacturers is here fundamental for the quality of the consolidated set of replies.

- The determination of the exact contents of sludge should be the focus of a sampling and analysis campaign, as already scoped under the ESSF EGCS sub-group Work Package 2.

- The “closed loop” and “open loop” operating modes have been better clarified, not only to the PRF sub-group but also amongst the EGCS sub-group members. This has been fundamental not only in the better understanding of sludge production but also with regards to the main differences to be noted between washwater and bleed-off water.

- It was noticed that no EGC system manufacturer that responded to the PRF Questionnaire has indicated the production of sludge from EGC systems when operating in open-loop mode. Taking into account the numerous references to water treatment systems and sludge collection in EGC literature and technical references this came as a surprise as a conclusion in the present report. From the universe of replies to the PRF Questionnaire we can draft the conclusion that, in principle, ships with EGC systems operating in open-loop mode would not have sludge to deliver to PRF.

- It was the opinion of some EGCS members that the Questionnaire appeared too centred on the current situation with EGCS only used to achieve compliance in respect of the European ECA-SOx and potentially the EU ‘at berth’ requirements. Any consideration for sludge and bleed-off/waste water calculations, linked to the operational profile, would in this case be relatively reduced.

  A major influencing factor in this area will be the upcoming reduction in the outside ECA-SOx fuel oil sulphur limit from the current 3.50% max sulphur to 0.50% max sulphur. While this change is set for the EU (EEZ / Pollution Control Zones) to enter into force in on 1st January 2020, it remains to be confirmed that this date will also apply to all other waters world-wide which are not ECA-SOx.

The point here being that with the fuel oil sulphur limits set at 0.10% and 0.50% there will be an ever stronger case for the installation of EGCS – it may be that some EGCS will in fact only be marketed as being 0.50% equivalent capable but in so doing greatly reduce size, cost, wash water requirements etc. – to the point that the EGCS in many cases will be in operation whenever the ship is in service – at sea and in port - which could typically be some 360 days / year.

The result would be that:

a. All EU ports, both inside and outside ECA-SOx, could be faced with a need to receive EGCS residues – see also below

b. The total quantities of those residues would be those resulting from near continuous operation on EGCS

c. The quantity to be landed from any one ship at a time could represent many weeks' /months' worth of operation on EGCS including full sea load on main engines

- Further work for a better understanding of EGCS sludge and bleed-off/waste water generation should encompass the following points (possibly for EGCS sub-group) to follow-up on:

  a. Sludge campaign for sampling & Analysis (already agreed under Work Package 2 of the EGCS WP listing – see Annex-1 of the Progress Report.

  b. Better understanding and exploring of washwater treatment devices, with sludge collection for EGC System operating in Open-loop

  c. Integration of different operational considerations for total sludge estimation.

  d. Possible development of a calculation tool that is capable of sludge and bleed-off estimation including ship/operational based assumptions and variables.

ANNEXES

1. Questions for the ESSF Sub-Group on Sub Group on Exhaust Gas Cleaning Systems regarding waste from Scrubbers.
2. Table with consolidated replies to the PRF Questionnaire on EGCS waste - Consolidated Replies to the PRF Questionnaire on waste from EGCS Systems -6APR2016
3. Work Package 2 – Working Paper - EGCS – Waste handling (contribution from Exhaust Gas Cleaning System Association)

9. ANNEX-1

PRF Questionnaire

Questions for the ESSF Sub-Group on Sub Group on Exhaust Gas Cleaning Systems regarding waste from Scrubbers

EUROPEAN COMMISSION
DIRECTORATE-GENERAL FOR MOBILITY AND TRANSPORT

Directorate D - Logistics, maritime & land transport and passenger rights
D.2 - Maritime safety

Questions for the ESSF Sub-Group on Sub Group on Exhaust Gas Cleaning Systems regarding waste from Scrubbers

1. Background

The Commission has recently started an Impact Assessment for a future legislative revision of Directive 2000/59/EC on port reception facilities for ship generated waste and cargo residues ("the PRF Directive").

The roadmap for the revision of the PRF Directive mentions as a possible measure the inclusion of the waste arising from the implementation of MARPOL Annex VI in the scope of the Directive.

In order to develop a better understanding of the operation of Scrubbers, and the waste and washwater resulting from such operation, the ESSF Scrubber Sub-Group is requested to provide answers to the questions mentioned below (specifying the different ship types where necessary). The requested input, which will be discussed in the next meeting of the ESSF PRF Subgroup, will be used in the Impact Assessment for the revision of the PRF Directive.

Whilst it is obvious that each scrubber will be different and the waste and wash water levels will depend on many parameters including the type of scrubber, its design, the fuel, the actual power output and machinery being scrubbed, general information is needed in order to identify how and to what extent this waste needs to be handled by PRF. If averages cannot be provided, then perhaps a range of values can be given.

2. Questions to the Subgroup on exhaust gas cleaning systems

2.1 Sludge from scrubbers in different modes of operation (open and closed loop) and from hybrid scrubbers

2.1.1. For the same operating conditions, how much sludge per kWh is typically produced in

1. Closed loop mode?
2. Open loop mode?

2.1.2. In hybrid mode, assuming a 50-50% equal share split between the two possible modes of operation (open/closed)?

2.1.3. Please refer now to the production of sludge by open-loop scrubbers. In your opinion, and taking into account available information, is this type of scrubber expected to remain prevalent in the market? In addition to questions 1.1) and 1.2) how do these scrubbers compare in terms of sludge produced?

2.1.4. What is typically contained in the sludge waste resulting from scrubber operation in:

1. Closed loop mode?
2. Open loop mode?

2.1.5. Additives. What additives are used and what is the likely percentage of these ending up in the sludge for both operating modes:
1. Closed loop mode?
2. Open loop mode?

2.1.6. For both closed and open loop modes how do the additives added influence the toxicity of the washwater?

2.1.7. How are closed loop sludge and open loop sludge being classified by the port/waste handler?

2.1.8. From the following possibilities for EGCS resulting sludge which would you select as the most representative? (Please refer to Commission Decision 2000/532/EC, on classification of waste):

a. 06 06 02 "wastes containing dangerous sulphides".

b. 10 01 18 "wastes from gas cleaning containing dangerous substances".

c. 10 01 20 "sludges from on-site effluent treatment containing dangerous substances".

d. 13 05 02 "sludges from oil/water separators".

e. 13 05 03 "interceptor sludges".

f. 13 05 07 "oily water from oil/water separators".

In addition to the classifications above could any other classification be considered adequate?

2.1.9. What special measures are needed to handle these wastes?

2.1.10. Are there any special measures needed to transport this waste?

2.1.11. Considering an estimate based on the produced sludge kg per kWh and assumed operation patterns, please comment on
1. How often may the shipping industry want to deliver this waste to PRF?
2. How often does the shipping industry actually deliver this waste to PRF?

2.1.12. How much sludge can a ship typically retain on-board (closed and/or open loop sludge)?

2.1.13. How is the sludge handled on-board? In case of two sludge streams (open and closed loop sludge) are those mixed? Is close loop sludge mixed with the ship's slop oil?

2.1.14. How much is it costing a ship to deliver this waste to PRF?

2.1.15. Can the EGCS Sub Group provide case studies on how this waste is handled at the present time? (If necessary these can be anonymous).

2.1.16. How many scrubbers are actually installed at the present time?

2.1.17. What is the estimated expected uptake of scrubbers, medium-term and long-term?

2.1.18. On average how often does a ship using scrubbers call at an EU Port (taking into account seasonal variations)?

2.1.19. Is there a geographical bias or port size preference for ships using scrubbers in the EU?

2.1.20. How are wastes, derived from dry scrubber technologies, to be classified and how are they disposed of?

2.2 Wash Water from scrubbers – in different modes of operation (open and closed loop) and from hybrid scrubbers.

(NOTE: The following questions do NOT include any assumption with regards to a potential classification of EGCS Washwater as waste. The option of delivering process water (washwater, bleed-off water, or other) to port reception facilities is merely considered with the objective of estimating what the potential impact of such delivery would be, especially in terms of required capacity.

2.2.1. On average how much washwater will a ship produce from a scrubber based on normal speeds?

2.2.2. On average how much washwater will a ship produce from a scrubber when entering a port?

2.2.3. On average how much washwater will a ship produce from a scrubber when at berth?

2.2.4. What exactly is in the washwater?

2.2.5. Which pollutants are being accumulated (in which quantities) and where (geographically) are they dispensed into the aquatic environment?

2.2.6. What percentage of the additives that the scrubbers use end up in the wash water? Does this add to the toxicity of the wash water?

2.2.7. Has any research or cost benefit analysis been done to ascertain whether scrubber wash water can be delivered to PRF whilst at berth?

2.2.8. How easy is it to store wash water onboard whilst entering and leaving a port and whilst the ship is at berth? Would it be logistically possible to deliver this waste to PRF?

Anna Bobo Remijn
DG MOVE- Unit D.2

10. ANNEX-2

Consolidated Replies to the PRF Questionnaire on waste from EGCS Systems -6APR2016

2.1 Sludge from scrubbers in different modes of operation (open and closed loop) and from hybrid scrubbers	
2.1.21. For the same operating conditions, how much sludge per kWh is typically produced in **1. Closed loop mode?** 2. **Open loop mode?**	ALFA LAVAL **Closed Loop:** 1 kg dry matter per MWh Typically the sludge has a dry matter content of 5 %, which thus gives a sludge rate of 20 kg/MWh. **Open Loop:** None. Alfa Laval open loop scrubbers are currently not fitted with equipment that could generate sludge, as the systems as is complies with the washwater criteria of the EGC Guidelines. We do not find the current technologies of open loop water treatment systems sound and trustworthy. LANGH TECH **Closed Loop:** 0,4 g/kWh **Open Loop:** None. CR OCEAN ENGINEERING **Closed Loop:** 0.000625 kg per kWh (including 36% water that is trapped in the sludge and sent to storage for disposal at port) **Open Loop:** None. IONADA **Closed Loop:** (no reply) **Open Loop:** (no reply) **Membrane Scrubber:** Membrane Scrubbers produce ZERO sludge - The microporous membrane of the ceramic tubes contains the NaOH used to absorb the SOx. The sodium sulphates created by the NaOH and SOx reaction are tanked for regeneration ashore and reused for the next batch delivered to the vessel.

2.1.22.	**In hybrid mode, assuming a 50-50% equal share split between the two possible modes of operation (open/closed)?**	ALFA LAVAL As per above (2.1.1) LANGH TECH There is no operational mode that is "hybrid" in our scrubber. You either operate it in closed loop or open loop. The name hybrid just comes from the fact that there are both alternatives available – open loop and closed loop (but not these two modes simultaneously. CR OCEAN ENGINEERING 0.0003125 kg per kWh (including 36% water that is trapped in the sludge and sent to storage for disposal at port) IONADA Note of Clarification - Hybrid mode is not commonly designed as partially open loop or partially as closed loop. These systems are either/or - Either 100% Closed Loop or switched to be 100% Open Loop, depending on the vessel's need. The term Hybrid connotes the ability to switch between the two modes.
2.1.23.	**Please refer now to the production of sludge by open-loop scrubbers. In your opinion, and taking into account available information, is this type of scrubber expected to remain prevalent in the market? In addition to questions 1.1) and 1.2) how do these scrubbers compare in terms of sludge produced?**	ALFA LAVAL We believe that future open loop scrubbers will be able to concentrate some pollutants as sludge, but at the moment it is hard to predict just how efficiently that can be done. LANGH TECH Most likely it will be expected in some extent since the lobbying for those system is rather strong. In our opinion closed loop system is recommended. Many of the scrubber suppliers do not use water treatment in open loop mode but if they do, it is a simple hydrocyclone. This solution has some treatment capability but it cannot be compared to efficient closed loop water treatment plant. CR OCEAN ENGINEERING Yes. The amount of exhaust gas "particulates" collected by closed loop, open loop or hybrid scrubbers is the same under all conditions. However, since the closed loop operation collects the sludge into a tank it seems to have more sludge. In reality it is not more. It just contains a large amount of water with the sludge as it goes through the filtering and storage process. In our closed loop system the amount of water contained with the sludge is about 36%. Other systems have a much larger percent of water content. But first of all we need to understand what we consider to be sludge. Scrubbers do not produce "sludge" but actually collect the particulates that are presently sent via the stack to the air (on ships without scrubbers) which then goes to our lungs and then eventually to the sea. These particles are unburned fuel, ash/soot and black carbon from the engine. A large portion is submicron in size and when airborne can cause lung cancer. There is also a large carbon black portion of the particulates collected by the scrubber which if not collected can cause accelerated melting of the ice caps. This situation has been accepted worldwide for as long as engines

	have used liquid fuel. These issues will apply even when ships use low sulphur fuels such as MGO. The only way to eliminate that concern is with scrubbers. When a scrubber is used, the scrubber water captures a large portion of the particulates and removes them from the air. Once wet and converted to wet sludge, the particulates no longer causes a concern to the lungs nor to ice caps. In closed loop operations, the sludge is then disposed of safely at port. IONADA The operation of several open loop scrubbers is based on large volumes of seawater required to complete the SOx reaction. It is very challenging to clean the water to capture the contaminants that compose the sludge. As well, due to the large volumes of seawater required it is impossible to stop the discharge of the missed contaminants and sulphur in the wash water for even short periods. Given the strong trend of Port States to require ZERO discharge in zones extending to littoral waters, it is difficult to see the value of open loop technology moving forward.
2.1.24. What is typically contained in the sludge waste resulting from scrubber operation in: **1. Closed loop mode?** **2. Open loop mode?**	ALFA LAVAL **Closed Loop:** What goes in (fuel, air, lubrication oil, washwater (freshwater + NaOH)) must come out (exhaust gas, bleed-off water, sludge). For the closed loop sludge that would be in headlines: - lubrication oil (will burn but is not flammable) - uncombusted products: soot, hydro carbons (PAH, oil) - ash (salts, minerals) (AL has provided sludge analysis results included in ANNEX-A) **Open Loop:** Again here, what comes in (fuel, air, lubrication oil, washwater (seawater)) must go out (exhaust gas, washwater, sludge), and again it is as above, but also sand and sediments originating from the seawater will be extracted as sludge, especially if the ship is operating in stirred up waters or in port areas. LANGH TECH **Closed Loop:** Oil (PAH), heavy metals, soot, sulphates **Open Loop:** N/A (sand that originates from incoming sea water?) CR OCEAN ENGINEERING **Closed Loop:** Unburned fuel, soot/ask from the engine and some washwater **Open Loop:** Unburned fuel, soot/ask from the engine and some seawater IONADA

	Closed Loop: (no reply) **Open Loop:** (no reply) **Membrane Scrubber:** No sludge is generated. EGCSA Sludge can be related to the sources and fuel consumption/engine operating power. The sources of sludge included the following. EGCSA can provide an estimate of the production of sludge related to fuel consumption/operating power. Work in this regard is being undertaken in the EGCS SG and will be reported shortly. 1. Water – strictly speaking not a sludge but as the process is a wet process using either fresh or sea water there is an inevitable portion of the sludge collection that is water. Water can be removed but this requires further processing and the amount that can be removed is limited to retaining pump ability of sludge. One manufacturer can provide drying technology to create a dry "cake". 2. Products of combustion – In certain technologies some components of exhaust gas solids are removed pre-wet scrubbing. The solids would consist of metallic ash, unburnt, semi burnt and residues of HC combustion (eg oils and sooty materials). In systems where the exhaust gas cleaning is done on a purely wet basis the same materials mentioned in the preceding sentences are removed. In addition HC compounds that are in vapour/gaseous phase which condense above 50degC will also be present. 3. Neutralisation compounds – The primary purpose of scrubbing exhaust gases is to remove oxides of sulphur. The process of neutralization produces salts.. These salts may relate of alkaline compounds in sea water or may relate to neutralization compounds added on board ship (eg Calcium Hydroxide). 4. Sea water debris – Depending on the location the amount of materials both organic and inorganic picked up from the surrounding water can contribute a significant portion of the sludge collected. This element of sludge production is impossible to calculate with any degree of certainty or accuracy.
2.1.25. Additives. What additives are used and what is the likely percentage of these ending up in the sludge for both operating modes: **3. Closed loop mode?** **4. Open loop mode?**	ALFA LAVAL **Closed Loop:** AL uses Kemira Pax-MP3103M, which is a coagulant used in water treatment plants. Approx. 100% of the added substance will end up in the sludge. **Open Loop:** We do not possess this experience, as we do not have open loop washwater cleaning. On a particular note, referring Annex II of the Sulphur Directive, Alfa Laval underlines that NaOH (caustic soda) is not considered to be an "additive". The reason pointed is the differentiated reference to this chemical in the Sulphur Directive (see extract below): *"Wash water resulting from exhaust gas cleaning systems which make use of chemicals, additives, preparations and relevant chemical created in situ", referred to in point 10.1.6.1 of Resolution MEPC.184(59), shall not be*

	discharged into the sea, including enclosed ports, harbours and estuaries, unless it is demonstrated by the ship operator that such wash water discharge has no significant negative impacts on and do not pose risks to human health and the environment. ***If the chemical used is caustic soda it is sufficient that the washwater meets the criteria set out in Resolution MEPC.184(59) and its pH does not exceed 8,0****.* The differentiated reference to "caustic soda" is, in Alfa Laval's understanding, an indication that its impact as a chemical additive is solely on pH control. No impact assessment is required and only the criteria established in the IMO EGCS Guidelines is to be met. LANGH TECH **Closed Loop:** Polymer 0,1 %. **Open Loop:** N/A. CR OCEAN ENGINEERING **Closed Loop:** Water with some Na_2SO_4 **Open Loop:** Seawater with some sulphates. IONADA **Closed Loop:** (no reply) **Open Loop:** (no reply) **Membrane Scrubber:** NaOH is typically used (although potassium hydroxide can be used) EGCSA This is a good question. EGCSA will revert after consulting members.
2.1.26. For both closed and open loop modes how do the additives added influence the toxicity of the washwater?	ALFA LAVAL Closed loop mode: it has no impact on the washwater as it will go to the sludge phase LANGH TECH No toxic additive

	CR OCEAN ENGINEERING The additives neutralize the acidity of the used scrubber seawater and washwater to allow it to safely be discharged and handled IONADA Membrane Scrubber - Zero, there is no wash water discharge
2.1.27. How are closed loop sludge and open loop sludge being classified by the port/waste handler?	ALFA LAVAL **Closed loop sludge:** **In EU it is the waste treatment company that is responsible for classifying waste, so it would depend on how they perceive the sludge (process it originates from (waste code) + analysis (hazardous/safe)). We recommend using waste code 10 01 18 (waste from gas cleaning containing hazardous substances) for closed loop sludge.** SE Swedish ports classify wastes from exhaust gas treatment as hazardous and will require declaration/information about the type and EWC code of the waste to be delivered to a PRF LANGH TECH Closed loop sludge to be treated in appropriate treatment plant. Environmentally hazardous CR OCEAN ENGINEERING In my opinion too much is being made of the "sludge" from scrubbers. In reality it is the same as the sludge cleaned from the engine operation, separator and economizers. It should be handled the same way. PORT OF ROTTERDAM Scrubbers operating in open loop may discharge its effluent into the port of Rotterdam (and other water bodies in the seaports of the Netherlands) IONADA Membrane Scrubber - The Ionada batch system delivers NaOH and retrieves sodium sulphate slates that are returned to our facility to regeneration See Photo 1 Below

		 Photo 1 - Ionada NaOH/Sulphate salt tank being delivered to the vessel EGCSA Experience from EGCSA members is that the sludge is classified and treated as oily waste such as purifier sludge and/or used lubricating oil. The main issue in terms of collection and residual value is the content of water in the sludge.
2.1.28.	**From the following possibilities for EGCS resulting sludge which would you select as the most representative? (Please refer to Commission Decision 2000/532/EC, on classification of waste):** **a. 06 06 02 "wastes containing dangerous sulphides".** **b. 10 01 18 "wastes from gas cleaning containing dangerous substances".** **c. 10 01 20 "sludges from on-site effluent treatment containing dangerous substances".** **d. 13 05 02 "sludges from oil/water separators".** **e. 13 05 03 "interceptor sludges".** **f. 13 05 07 "oily water from oil/water separators".** **In addition to the classifications above could any other classification be considered adequate?**	ALFA LAVAL Waste code: 10 01 18 10: Waste from thermal processes. 01: Wastes from power stations and other combustion plants (except 19). 18: Wastes from gas cleaning containing dangerous substances We regard the combustion of HFO in the marine engine as a thermal process in line with thermal processes of land-based power stations even though the aim of the combustion is mainly propulsion and to a minor degree electricity generation. It thus fits under the category "… other combustion plants." As stated above we recommend using this description as we see it to be the option closest to describing the waste from where it originates. The aim with the scrubbing process (desulphurisation) is to clean the exhaust gasses for sulphur dioxide in line with ordinary land-based desulphurisation systems except that the alkaline substance added consists of sodium hydroxide (NaOH) and not calcium, which is the typical substance. The sludge originating from ordinary land-based desulphurisation systems is explicitly mentioned in the waste list code as 10 01 07, so in that respect there is no conflict; the marine scrubber sludge cannot be confused with the ordinary known sludge. SE The waste shall be classified by the holder of the waste. However, organisation I have been in contact with

	consider b. - 10 01 18 "wastes from gas cleaning containing dangerous substances" as most representative. This classification is also supported by the Swedish Ports organisation. LANGH TECH b. 10 01 18 "wastes from gas cleaning containing dangerous substances". PORT OF ROTTERDAM 10 01 18 looks like most applicable IONADA sulphate salts for regeneration
2.1.29. What special measures are needed to handle these wastes?	ALFA LAVAL The waste is normally watery and thus contains lots of sodium sulphate (salts) which might hamper the biological processes in ordinary municipal treatment plants. SE Due to the hazardous nature of the waste special treatment is needed and it would be carried out by specialized treatment companies. According to the information from one of the treatment companies the appropriate way of destruction of EGCS residues is incineration LANGH TECH None CR OCEAN ENGINEERING Normal practice as used when handling oily sludge from other portions of the ship. PORT OF ROTTERDAM Depends on the state of the waste: liquid or solid. Solid: should be collected by appointed waste collector. Liquid: (depending on quantity) either by vacuum-truck, or by tanker-barge or in drums. All means of transport should be able to handle this waste via licensed operators and equipment. But should be handled as dangerous goods. IONADA Membrane Scrubber - Industry standards for NaOH and sulphate salts. Note this is reusable material NOT waste.

2.1.30.	**Are there any special measures needed to transport this waste?**	ALFA LAVAL No LANGH TECH None CR OCEAN ENGINEERING Normal practice as used when handling oily sludge from other portions of the ship. PORT OF ROTTERDAM See above IONADA Delivery and removal are provided by the Ionada logistics service - all material is contained in Industry Standard Container Tanks
2.1.31.	**Considering an** estimate based on the produced sludge kg per kWh and assumed operation patterns, please comment on **3. How often may the shipping industry want to deliver this waste to PRF?** **4. How often does the shipping industry actually deliver this waste to PRF?**	ALFA LAVAL 1. Do not know. Depends on how the ship handles the waste. In IBCs or integrated tanks? 2. Depends on the tank size. LANGH TECH 1. Once or twice / month 2. Not known CR OCEAN ENGINEERING 1. Every few days or weekly 2. Every port PORT OF ROTTERDAM 1. As many times as it wants IONADA Delivery is set to the shippers desired schedule - one TEU container services 300MT of 3.5% fuel - typically 2 weeks of operation for a 10 MW engine EGCSA EGCSA will revert after consulting members. However we need to be establish this data based on the produced sludge kg per kWh and operation patterns.

2.1.32. How much sludge can a ship typically retain on-board (closed and/or open loop sludge)?	ALFA LAVAL Ship dependent – do not know. LANGH TECH Totally depending on the ship type, cruisers up to 200 m³, smaller cargo ships 20... 30 m³. Our system anyhow produces highly concentrated sludge (practically dry waste) that storing onboard is not a problem. CR OCEAN ENGINEERING One day to one week based on client preferences IONADA Zero sludge is retained
2.1.33. How is the sludge handled on-board? In case of two sludge streams (open and closed loop sludge) are those mixed? Is close loop sludge mixed with the ship's slop oil?	ALFA LAVAL Ship dependent – do not know. SE In our view, sludge from EGCS and ordinary sludge shall not be mixed. Furthermore, it is against Swedish law (16 § Waste regulation, 2011:927) to mix hazardous wastes with any other type of waste. Swedish ports therefore do not recommend mixing these residues with sludge or with any other type of ship-generated waste. Ports will require information about the type of waste and its EWC-code before it can be delivered to a PRF. Further treatment of mixed wastes is also complicated, since it is difficult to separate the hazardous waste from the rest LANGH TECH Sludge is stored in separated container on board CR OCEAN ENGINEERING Our scrubbing system is fully automated and does not require routine handling of the sludge by the crew. The collected particulates go directly from the water cleaning equipment to a storage container. Typically sludge is not collected for open loop systems because the concentrations are very small and can safely pass the water discharge requirements. The sludge storage is only for closed loop systems. Unfortunately no. Although it is the same sludge and contains the same components it is not allowed to be mixed together on board. Scrubber sludge has to be stored separately. Once it is off the ship I believe that it can be mixed and disposed of together. PORT OF ROTTERDAM ECGS-waste is already classified by IMO as Annex VI waste. Therefore it may not be mixed with Annex I waste (sludge etc.)

		IONADA Zero sludge is retained
2.1.34.	**How much is it costing a ship to deliver this waste to PRF?**	ALFA LAVAL Do not know. SE The waste from Exhaust Gas Cleaning systems (EGCS) shall definitely be covered by the mandatory delivery obligation. If covered by the no special fee system, a differentiation between ships (having the technology installed and those without EGCS) must be allowed, since it will not be fair to require ships that use cleaner fuel without generating "scrubber waste" to subsidize the waste management for those ships that produce such waste LANGH TECH abt. 400 €/mt CR OCEAN ENGINEERING I have seen ships pay disposal costs of about 490 euros per ton. PORT OF ROTTERDAM (Depending on quality (metals, contaminants, water, etc) liquid: between €50 - €150, solid: € 325-€350 per m3. IONADA The cost of the NaOH regeneration per kg is below the commercial selling price per kg - therefore no delivery and receiving charges are charged to the customer. EGCSA EGCSA will consult with members and revert
2.1.35.	**Can the EGCS Sub Group provide case studies on how this waste is handled at the present time? (If necessary these can be anonymous).**	ALFA LAVAL It is best to put this task to the ship owners. Our answer would only be a guess LANGH TECH In Finland the sludge is handled and treated by Ekokem http://www.ekokem.com/en/ IONADA The process is under development with an industry leading marine partner specializing in ship consumable support services

2.1.36.	**How many scrubbers are actually installed at the present time?**	ALFA LAVAL Ask EGCSA. SE Three SE flagged vessels. LANGH TECH Regarding Langh Tech, 6 hybrid systems. In addition 7 closed loop water treatment systems just being delivered CR OCEAN ENGINEERING More than 400 wet scrubbers and 1 dry scrubber have been sold with the majority being already installed IONADA There are two vessels with Membrane scrubbers installed since our commercial introduction in 2015. There is a committed order for an additional 10 ships and negotiations are underway for several more. EGCSA This figure can be provided
2.1.37.	**What is the estimated expected uptake of scrubbers, medium-term and long-term?**	ALFA LAVAL Ask EGCSA. CR OCEAN ENGINEERING I believe that scrubbers make the most sense for shipping, not only from an economical and operational perspective when compared to low sulphur fuel (or even retrofitting LNG), but also from an overall environmental perspective. When compared to low sulphur fuels, scrubbers have a smaller CO_2 footprint and significantly reduce the very harmful particulate emissions. IONADA As the only scrubber system able to provide true zero discharge overboard, with a less complex installation and operation we expect Membrane Scrubbing to be the evolution of the technology. EGCSA This question requires a survey of scrubbers in use. This question is only worth assessing if the volumes indicated in question 1 are shown to be significant. It is very likely that scrubber sludge will form only a very small addition to the current oily waste streams landed ashore At present ship owners are reluctant to invest in EGCS technology due to a number of uncertainties. These include fuel price, date of global implementation of the 0.5%S limit and uncertainty surrounding the Marine Fuels Directive and its implementation as applicable to wet EGCS.

2.1.38.	**On average how often does a ship using scrubbers call at an EU Port (taking into account seasonal variations)?**	ALFA LAVAL A rough guess: currently 95% LANGH TECH Many of the vessels that have scrubbers are trading 100% inside the European SECA and thus call EU Ports continuously / daily. IONADA For the ECA based ships that we viable scrubber candidates (at least 50% of the time in an ECA) there are commonly 2 to 5 EU port calls per week
2.1.39.	**Is there a geographical bias or port size preference for ships using scrubbers in the EU?**	ALFA LAVAL Ask shipowners. LANGH TECH No IONADA There is no preference for the Ionada regeneration facilities. EGCSA The majority of ships using scrubbers are on intra EU trades. The preference for scrubbers is based upon the economic benefit versus the alternative. Thus high power and high fuel consumption increases the attractiveness of scrubbers. A low fuel price is a barrier to uptake of scrubbers.
2.1.40.	**How are wastes, derived from dry scrubber technologies, to be classified and how are they disposed of?**	ALFA LAVAL It is hard to see that it should be anything else than “hazardous”, as it would be the same components as trapped in the washwater being deposited on the granulate. Yet, “hazardous” is just an expression of high concentration of specific substances, so if those substances are spread out in a bigger volume or even passes through with the exhaust gas (out into the ambient air), it would of cause not be hazardous. We would recommend not to use the used granulate as fertilizer as suggested by some dry scrubber suppliers. It either will need to be disposed of in dedicated waste treatment plants, or used in for example cement production if those have proper environmental permission to use this product (it thus become a product and is no longer regarded as waste). SE Possible EWC Codes could be 10 01 05 or 10 01 07 CR OCEAN ENGINEERING

	Dry scrubbing is still a big unknown. To date the few dry systems that have been sold have proved themselves to be much less effective than originally marketed. The intent was to collect the sulphur and the particulates on to the lime granules and then dispose of the used granules at port. The open question is what can environmentally and legally be done with the granules that now contain the oils and the metals that are normally in that oil? Would anyone accept that liability in exchange for some residual lime scrubbing value or would they want to charge for the disposal at the same cost as the other wet scrubber costs? If that later is the case then the total disposal cost for dry scrubbers will become astronomical because the quantities of material to be disposed will be extremely large. PORT OF ROTTERDAM (see above)
2.2 Wash Water from scrubbers – in different modes of operation (open and closed loop) and from hybrid scrubbers.	
2.2.9. On average how much washwater will a ship produce from a scrubber based on normal speeds?	ALFA LAVAL It is very difficult to answer the question with relation to speed. It would be better to relate it to ship size and type as this often goes hand in hand with the engine size, which thus enables us to answer the question. Open loop scrubber uses approx. 45 m³/MWh. A typical RORO ship is installed with a 15 MW engine, which thus will amounts to 675 m³/h of washwater. Just looking at this number should give you the answer that ships with pure open loop scrubbers would not collect their washwater. Closed loop scrubbers bleeds off approx. 0.3 m³/MWh and for a typical RORO ship that gives us 4.5 m³/h. Operating on average 50% load on a 24-hour basis gives us 54 m³/day. If the average load is higher, the bleed-off containment is higher as if the trip is more than 24 hours long. Hybrid scrubbers would most likely have less bleed-off water containment. LANGH TECH In Langh Tech system abt 2,5 – 2,8 kg per burnt HFO mt CR OCEAN ENGINEERING our scrubber produces about 135 ml per kWh IONADA Membrane scrubbers produce ZERO wash water
2.2.10. On average how much washwater will a ship produce from a scrubber when entering a port?	ALFA LAVAL Close loop. What would a typical port load be – 10%? For a 15 MW engine that would thus be 0.45 m³/h. How long does it take to entering the quayside – 30 min.? Then the amount would be 0.23 m³. LANGH TECH Langh Tech system can run in zero discharge mode during port operations

	CR OCEAN ENGINEERING About 81 ml per kWh IONADA Membrane scrubbers produce ZERO wash water
2.2.11. On average how much washwater will a ship produce from a scrubber when at berth?	ALFA LAVAL Same calculation as above (2.2.1 and 2.2.2) if you know the engine size and the load. LANGH TECH Nothing if the main engine is not running. CR OCEAN ENGINEERING Zero if the engine is off line. Normally the scrubbers have been installed on main engines with only a few applied to generators/auxiliaries. IONADA Membrane scrubbers produce ZERO wash water
2.2.12. What exactly is in the washwater?	ALFA LAVAL Please refer to the washwater sample campaign performed by EGCSA. The Danish EPA report also holds the answer (“Assessment of possible impacts of scrubber water discharges on the marine environment”). LANGH TECH Soot and particles, heavy metals, oil (as PAH), sulphates.. CR OCEAN ENGINEERING (a) For open loop scrubbers it is the seawater and sulphates with traces of soot. (b) for closed loop systems the washwater is fresh water with some sodium sulfate and extremely low traces of soot IONADA Membrane scrubbers produce ZERO wash water
2.2.13. **Which pollutants are being accumulated (in which quantities) and where (geographically) are they dispensed into the aquatic environment?**	ALFA LAVAL How is this related to PRF? Pollutants can be assessed from information given in 2.2.4. Of cause where the ship is traveling, washwater will be discharged. Really a strange question – is there a deeper meaning, which I have not spotted? LANGH TECH If the system is operated in open loop mode all the pollutants are washed out to sea at the spot where the

		vessel is sailing. This means exactly the same pollutants that in closed loop are collected and disposed ashore. CR OCEAN ENGINEERING Closed loop scrubbers collect the sulphur emissions and convert them into sodium sulfate. They also collect soot, unburned fuel and black carbon and this is separated and stored until it is disposed of at a port facility. The cleaned liquid is discharged anywhere along its travels. Capabilities are provided for short storage should specific ports not allow the cleaned liquid discharge. IONADA Membrane scrubbers retain the pollutants from the exhaust and are disposed of properly ashore in our regeneration process. The system eliminates the transfer the pollutants from the exhaust to the sea.
2.2.14.	**What percentage of the additives that the scrubbers use end up in the wash water? Does this add to the toxicity of the wash water?**	ALFA LAVAL Approx. 0% (as per 2.1.5) and has thus no toxicity impact on the washwater. LANGH TECH Nothing and no. CR OCEAN ENGINEERING (a) Closed loop scrubbers use NaOH for neutralization of the acid generated by the collection of the SO2 in the scrubber water. All of the added NaOH converts to Na2SO4 and is discharged with the scrubber water. This safe practice has been used for land-based scrubbers since the early 1900's and has passed the scrutiny of all the global environmental agencies. (b) No additives are used in open loop scrubbers. These only use seawater and its natural alkalinity to remove and neutralize the SO2. IONADA None of the additives are transferred to the sea
2.2.15.	**Has any research or cost benefit analysis been done to ascertain whether scrubber wash water can be delivered to PRF whilst at berth?**	ALFA LAVAL None to our knowledge. LANGH TECH No CR OCEAN ENGINEERING I believe that some ports are conducting a program in which they installed a washwater treatment plant at port to treat the washwater from ships at berth. IONADA Membrane scrubbers are designed on the principle of being self-sustaining - there cost benefit analysis includes

	the re-use of NaOH and elimination of transfer of pollutants from the exhaust to the sea.
2.2.16. How easy is it to store wash water onboard whilst entering and leaving a port and whilst the ship is at berth? Would it be logistically possible to deliver this waste to PRF?	ALFA LAVAL As per your first question, ask the shipowners. As per your second question, yes but everything depends on the amount the ship has to contain on board. If it is a reasonable about it would be no problem. The bleed-off water is easily extracted from the ships tank to shore. A comment in connection with this question. As the washwater regardless open or closed mode operation will contain too many salts for ordinary municipal treatment plants to cope with it, the ports might need to invest in some kind of settling treatment. The pollutants will settle as sediment and float on the surface and when removed, the remaining is clean salty water, which can be discharged to harbour/sea. If it is found that, there is too high levels of certain kinds of metals those can most likely be precipitated by the aid of some kind of coagulant. General comment. Please bear in mind that it is not likely that the closed loop scrubbers would avoid treating the washwater onboard as the loss of freshwater would be too big. Freshwater onboard is a limited resource. LANGH TECH At least in Langh Tech system it is easy and possible. CR OCEAN ENGINEERING This can be easily achieved as long as port stays are not very long. It is conceivable that a port could start such program but experience indicates that such steps are not warranted. IONADA The ability to retain all effluents from the scrubbing process and regenerate it for reuse is the heart of Membrane technology - there is no overboard discharge and no need for disposal of any material to PRF.

11. ANNEX-3

ESSF Working Group - Work Package 2

EGCS – Waste handling (contribution from Exhaust Gas Cleaning System Association)

NOTE:

The document contained in this Annex has been the base document for the EGCS sludge sampling and analysis campaign. There have been no recent developments with regards to this exercise.

ESSF Working Group

Work Package 2

<u>EGCS – Waste handling (contribution from Exhaust Gas Cleaning System Association)</u>

1. The Issue and/or Concern

The process fluid (normally wash water) in wet scrubbing systems not only remove SO_2 and SO_3 gases but also removes minor quantities of NOx gases and cools the exhaust gases to allow the condensation of various VOCs. The scrubbing water also traps solids such as incombustibles, ash, and soot.

Upon exiting the scrubbing unit the wash water undergoes several processes before the water is either discharged to sea in open loop operation or is recirculated in the case of closed loop operation.

There are several proprietary process water treatment systems that deal with the removal of exhaust gas compounds from the wash water. These systems include floatation, static centrifuges and filtration processes.

The separated material will often include a substantial portion of process water (sometimes up to 80% of the total sludge collection is water). The water may be acidic unless diluted with additional wash water or by the addition of a neutralising agent.

In accordance with IMO Circular MEPC,184(59) the scrubber sludge must be disposed of ashore. The sludge must not be mixed/ stored in any streams that are disposed of on board using an incinerator.

Ships produce several streams of oily sludge including sludge from fuel tank drains, purifier (fuel and lubricating oil) sludge discharges, bilge sludge and oily water separator sludge.

2. The Questions to be answered

1. QUANTIFICATION: Does the addition of a scrubber sludge stream significantly increase the volume of sludge to be landed ashore and does this significantly impact the obligations of ports to provide waste handling facilities?
2. HAZARD: Does scrubber sludge pose a different and/or new hazard and a new stream of sludge requiring different handling and segregation?
3. BENEFIT: Does the removal of exhaust gas components other than the target emission (eg SOx gases) provide an additional air quality benefit compared to the use of prescribed fuel in an ECA (e.g. 0.1%S diesel fuel).

3. The Components of Marine Diesel Engine Exhaust Gases

11.1.1. MAN Diesel & Turbo – Emissions Data

MAN Diesel and Turbo (MDT) have published their measurements of the components that make up a diesel engine exhaust gas. The graph below indicates the portion of components in exhaust gas that is either discharged to the atmosphere or captured in scrubber water.

Guiding comparison of emissions from an HFO burning and a gas burning 70ME bore engine

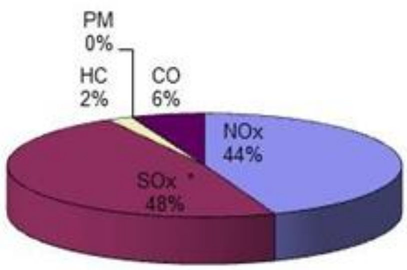
Estimated emissions – 6S70ME-C		Estimated emissions – 6S70ME-GI	
Load 100%	g/kWh	Load 100%	g/kWh
CO_2	577	CO_2	446
O_2 (%)	1359	O_2 (%)	1340
CO	0.64	CO	0.79
NO_x	11.58	NO_x	10.12
HC	0.19	HC	0.39
SO_x	10.96	SO_x	0.88
PM (mg/m_3)	0.54	PM (mg/m_3)	0.34

Table III

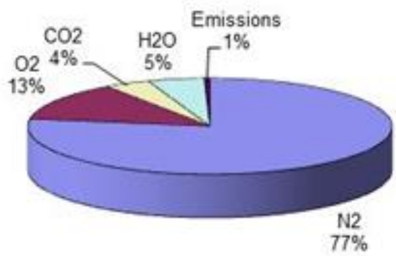
24 Exhaust Gas Emission Control Today and Tomorrow

11.1.2. Lloyds Register of Shipping – Emissions Data

Lloyds undertook a study in 1990 in which they developed emissions factors. The components of exhaust gas align well with MAN's published data (above). The graphs show the exhaust gas composition and then breakdown the component labelled "emissions" which amount to 1% of the total exhaust gases into the "emissions" sub components.



Emission Components



Diesel exhaust gas composition

Lloyds Register of Shipping 1990 – Marine Exhaust Emission Research Project – 3.0%S fuel oil

The following table identifies the breakdown of the 1% of "emissions".

Emission	Exhaust gas
NOx	1.744%
SOx	1.880%
CO_2	96.057%
HC	0.080%
PM	0.003%
CO	0.236%

11.1.3. US EPA Report – Emissions Data

The US EPA published "Proposal to Designate an Emission Control Area for Nitrogen Oxides, Sulphur Oxides and Particulate Matter" in April 2009. The report included detailed information on emission factors taken from an *Entec* report dated 2002.

2.3.2.3.6 Propulsion and Auxiliary Engine Emission Factors

An analysis of emission data was prepared and published in 2002 by Entec.[17] The resulting Entec emission factors include individual factors for three speeds of diesel engines (slow-speed diesel (SSD), medium-speed diesel (MSD), and high-speed diesel (HSD)), steam turbines (ST), gas turbines (GT), and two types of fuel used here (RM and MDO). Table 2-4 lists the propulsion engine emission factors for NOX and HC that were used for the 2002 port inventory development. The CO, PM, SO2 and CO2 emission factors shown in the table come from other data sources as explained below.

Table 2-4 Emission Factors for OGV Main Engines using RM, g/kWh

	All Ports		West Coast Ports			Other Ports				
Engine	**NOX**	**CO**	**HC**	**CO2**	**PM 10**	**PM 2.5**	**SO2**	**PM 10**	**PM2. 5**	**SO2**
SSD	18.1	1.40	0.60	620.62	1.4	1.3	9.53	1.4	1.3	10.29
MSD	14.0	1.10	0.50	668.36	1.4	1.3	10.26	1.4	1.3	11.09
ST	2.1	0.20	0.10	970.71	1.4	1.3	14.91	1.5	1.4	16.10
GT	6.1	0.20	0.10	970.71	1.4	1.3	14.91	1.5	1.4	16.10

11.1.4. Summary of emissions reports

(No information. Work in progress)

11.1.5.

11.1.6. A Quantification of Sludge Production

(No information. Work in progress)

12. 4. The Exhaust Gas Components Identified in Wash Water

The components/compounds that can be expected to be found in the scrubber wash water will be sourced from;

1. Incoming sea-water
2. Material picked up from the wash water pipelines and other systems (if connected)
3. Compounds and gases from the exhaust gases

This report will deal with the compounds and substances that may be removed from the exhaust gases. The principle source of compounds and substances is from the fuel and to a minor extent from the engine lubricating oils.

Typical materials found in marine fuel include;

- Ash Forming Compounds
  - Nickel (contained in HFO)
  - Vanadium (contained in HFO)
  - Zinc (anti-wear additive in lube oil) Not normally in marine fuel
  - Magnesium (detergent additive in lube oil) Not normally in marine fuel
  - Calcium (detergent additive in lube oil) Not normally in marine fuel
- Oil compounds
  - Carbon, soot (dry compounds)
  - Partially oxidised fuel (oily compounds)
  - Volatile organic compounds (normally gaseous compounds prior to exit to atmosphere)
  - PAHs (contained in fuel and formed during combustion, some of which some are classified as carcinogens)

Typical materials in engine lubricating oil include;

- Ash Forming Compounds
  - Calcium
  - Zinc
  - Phosphorous
- Oil Compounds
  - Similar compounds as found in marine fuel noted above

The above compounds and substances would under normal circumstances be emitted to the atmosphere. It is noted that for diesel fuels the quantities of nickel and vanadium will be near zero.

The various ash and gaseous compounds will be discharged to atmosphere as fine particulate (micron size particles) and ultra-fine particulate (nano metre size particles) and as gases. This applies to all marine fuels and not just heavy fuel oil.

The process of cooling the exhaust gas in a wet scrubber is understood to cause the condensation of many organic hydrocarbon compounds that would otherwise be discharged to atmosphere. The ash and soot particulates become the surfaces for VOC condensation and thus the particles in the wash water are a combination of oxidised metals or soot which are coated in a variety of species of hydrocarbons.

The wash water treatment systems are designed to remove the high density material (VOC & oil coated ash) by centrifugal force whilst the compounds that have a density less than that of the wash water are separated by flotation methods.

13. 5. Analysis of PAH Content of Shipboard Sludge sources

The following analysis was undertaken at BP from sludge sampling programme on the Pride of Kent.

"PAH- I selected 4 of the sludges for analysis and comparison to the crank case oil and settling tanks oil. The PAH analysis (by GCMS) indicated that the dried sludges contain, in all instances bar one compound, lower concentrations of PAH than the settling tank sludge and dirty crankcase oils. Please note these results are a quick turn around and preliminary. I intend to arrange for further tests by an additional lab on the other sludges to confirm these results. The concentration of the compound that appears in red text- the benzofluorathene- is being checked as this appears to be somewhat anomalous. The First four compounds on the list are either present in levels below the detection limit (the accuracy of this result is currently being examined). Jim and I expect that we may well see them in the water from the cyclone or sludge tank, as the lower mass PAHs tend to be more soluble in water than the higher molecular weight compounds."

	Sample ID: Dover 1	Sample ID: Calais 1	Sample ID: Crossing 2	Sample ID: Overnight 2	Sample ID: Lubricating Oil	Sample ID: Separating Tank Sludge
Name	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg	mg/Kg
Naphthalene	-	-	-	-	-	3246
Acenaphthene	-	-	-	-	-	1201
Acenaphthylene	-	-	-	-	-	973
Fluorene	-	-	-	-	-	2460
Dibenzthiophene	0.3	0.3	1.8	0.1	114	1404
Phenanthrene	2.2	1.4	8.8	0.5	569	5924
Anthracene	<0.1	0.1	0.1	<0.1	77	848
Fluoranthene	0.7	0.3	2.4	0.1	50	339
Pyrene	0.2	0.4	1.8	<0.1	264	1600
Benzo(a)anthracene	0.1	0.1	1.3	<0.1	100	583
Chrysene	0.6	0.2	3.6	<0.1	141	731
Benzo(b)fluoranthene	73.6	0.3	191.6	88.5	42	144
Benzo(k)fluoranthene	9.7	0.3	33.3	8.3	27	37
Benzo(a)pyrene	1.0	0.3	5.1	1.7	60	246
Indeno(1,2,3-cd)pyrene	2.4	0.2	15.2	6.3	27	37
Dibenz(a,h)anthracene	4.3	0.2	19.7	6.0	29	58
Benzo(g,h,i)perylene	2.5	0.3	12.8	3.2	39	125

14. 6. Hazard Evaluation of Scrubber Sludge

The lubricating oil of any diesel engine (NB crosshead engines theoretically separate the crankcase oil from the combustion space by means of a diaphragm) is continually exposed to exhaust gases. Thus it is not surprising to find that hazard assessments of used engine oils note that the oils may contain known carcinogens and maybe toxic. Normal precautions are recommended such as avoidance of prolonged dermal exposure and ingestion.

The wash-water sludge unsurprisingly accumulates similar compounds to those found in used lubricating oils, albeit possibly in differing concentrations. In addition scrubber sludge often contains significant quantities of sea water debris such as sand, organic materials etc.

For the purposes of sludge disposal ashore there are several oily streams generated on board ship, including fuel oil & lube oil centrifuge sludge, bilge oily water separator sludge, sludge form draining fuel tanks, used lubricating oils, and in addition the new stream of scrubber sludge.

With similar constituents and hazard factors there is no reason for logistical purposes not to store these sludge streams together. In fact this is common practise. Scrubber sludge introduces two additional factors that need to be considered.

1. Scrubber sludge may have a low pH and therefore must be neutralised by addition of an alkali (Caustic soda) prior to transfer to a common sludge holding tank to avoid damage to the surfaces and pipelines.
2. Scrubber sludge often has a high percentage of water content (perhaps 80%) and very little hydrocarbon. This may impact the commercial value of the sludge to a sludge disposing company where often the business model involves processing and on-selling the energy value of the sludge.

15. 7. Benefits of Scrubber vs Diesel Fuel – Air Quality

There appears to be three potential benefits of wet scrubbing exhaust gases, noting that neither benefit is currently regulated.

It has been mentioned in this report that the cooling of exhaust gases causes the condensation and removal of volatile organic compounds. These compounds are still present in the air in the case where a prescribed fuel is used to meet sulphur emissions regulations.

The particulate matter produced by diesel engines is known to be present in both micron (fine PM) and nano-metre (ultra-fine PM) size ranges. There appears to be conflicting reports as to the quantification of ultra-fine PM resulting from the combustion of different fuels. A recent presentation by AVL on the production of ultra-fine PM in direct injection gasoline engines appears to imply that so called cleaner fuels may have a greater propensity to produce ultra-fine PM. Wet scrubbing is known to remove a percentage of ultra-fine PM. A study undertaken by Ricardo UK Ltd measured an 80% reduction in ultra-fine PM when using a condensation stage in a wet scrubber operating on 1.5%S EN590 diesel fuel (NB the EN 590 was doped with a organic sulphur compound to increase sulphur content from 10ppm to 1.5%S).

The consumption of lubricating oil in marine diesel engines will inevitably lead to emissions of ash compounds (eg detergents are typically compounds of calcium carbonates, salicylates, carboxylates, or other soap compounds). Wet scrubbing will remove the majority of these ash compounds.

Annex 1

Work Package Table EGCS subgroup – updated January 2017

Annex 2

Report on the consolidated replies to the PRF Sub-group questionnaire