The unanswered questions surrounding scrubber washwater discharge

In an effort to limit sulphur oxides (SOx) from ship's emissions in order to improve air quality, and under the auspices of the International Maritime Organization (IMO) - the International Convention for the Prevention of Pollution from Ships (MARPOL Annex VI, regulation 14.1) was strengthened. As of the 1 January 2020, the sulphur limit of fuel oil used onboard ships is limited to 0.50%m/m (mass by mass) outside Emission Control Areas (ECAs)- whilst remaining at 0.10% within them. The new sulphur limit of 0.50% represents a substantial decrease from the 3.50% prior. This regulation is commonly known throughout the shipping industry as IMO2020.

IMO2020 features three routes by which a ship can comply: a) the use of low sulphur fuel oil, b) the installation of an EGCS (herewith known as a scrubber) or c) the use of inherently low or zero sulphur fuels such as LNG.

This paper will set out the concerns that are frequently raised in connection with the impact of washwater discharges from (open-loop) scrubbers on the marine environment and consider (whether or not/to what extent) they are grounded in science. It will highlight current gaps in our knowledge, explain some of the practical difficulties impeding research, and finally offer some policy recommendations.

There are several types of scrubber. In a wet scrubber, the exhaust gas is mixed with washwater, and the water-soluble components of the exhaust gas are removed by dissolution. In an open-loop design, seawater is used to scrub the exhaust before discharging the washwater back to the sea following treatment.

The discharge of washwater from open-loop scrubbers has proved to be highly contentious. A number of maritime Administrations have banned the discharge of washwater in waters under their jurisdiction, while others have applied criteria that go beyond the requirements of the regulations agreed at the IMO.

Washwater comprises a complex mixture of seawater, soot, trace metals and other chemical compounds, such as polycyclic aromatic hydrocarbons (PAHs) and nitrates,

IMO's criteria for washwater discharge[1] are intended to prevent pollutants found in the exhaust gas from ending up in the sea in damaging levels.

Does discharge comply with current IMO regulations and water quality standards?

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[1] http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Documents/MEPC.259(68).pdf

Studies on chemical fingerprint of open-loop scrubber washwater and its dilution in the marine environment are somewhat conflicting: some point towards low or no effects of scrubber operations on water quality in harbours or coastal waters (Hufnagl et al., 2005[2]; Kjølholt et al., 2012[3]), while others suggest that the metal concentrations or decrease in pH in harbours or along busy sea lanes may exceed the standards (US-EPA, 2011[4]; den Boer and 't Hoen, 2015[5]). There are also concerns that sludge is generally not being collected on ships using scrubbers in open-loop mode, which results in the discharge of non-diluted, non-filtered wash water including all contaminants (Endres et al, 2018)[6]

However, the consensus view is that by ensuring a rapid dilution of effluents, the impact of open-loop scrubber water discharges can be diminished – and by dilution there is compliance with existing standards in ports without local regulations.

Additionally, it should also be noted that the quality of washwater is likely to vary between different scrubber systems. Many scrubber manufacturers claim their latest systems can clean washwater more thoroughly than earlier generations as the technology advances and operational experience is gained from active installations.

So why are we still talking about washwater?

The debate ultimately boils down to the question of whether or not scrubber washwater discharge that meets limits currently stipulated by IMO poses a risk to the marine environment, and if it does, then how significant is that risk. Being unable to answer this question is what triggers precautionary principled regulation adopted by some Administrations.

A Task Team on Exhaust Gas Cleaning Systems was established by the Group of Experts on Scientific Aspects of Marine Environmental Protection (GESAMP) to carry out a review of the relevant scientific literature and also oversee a modelling study of the impacts of discharge washwater from exhaust gas cleaning systems. They presented the results of their study to the IMO Sub-Committee on Pollution Prevention and Response (PPR) at its 7th session in early 2020[7]. The study investigated whether discharge complies with existing standards and what the impact might be on the marine environment.

What, according to GESAMP, are the main issues regarding scrubber discharge washwater?

Issue 1: There is insufficient scientific information to enable evidence-based decision-making

A recurrent theme in literature covering this topic is the lack of peer-reviewed scientific evidence and information to enable an absolute decision to be made on the banning (or not) of open-loop scrubbers. The GESAMP study for example notes:

1. There is sufficient information on trace metals to determine predicted "no effect concentrations" in environmental aquatic systems for an acute and chronic environmental risk assessment but insufficient information on sediments. A new study from CEDeflt does

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2 http://www.dieselduck.info/machine/01%20prime%20movers/2005%20Effects%20of%20scrubbers.pdf
3 https://www2.mst.dk/Udgiv/publications/2012/06/978-87-92903-30-3.pdf
4 https://www3.epa.gov/npdes/pubs/vgp_exhaust_gas_scrubber.pdf
5 https://www.nabu.de/downloads/150312-Scrubbers.pdf
6 https://www.frontiersin.org/articles/10.3389/fmars.2019.00110/full
7 http://www.gesamp.org/work/task-teams/task-team-on-exhaust-gas-cleaning-systems

provide some insight on this and suggests there may be negligible effects of trace metals[8]. Assuming a zero concentration baseline, the modelling shows that for the Standard OECD-EU Commercial Harbour the increase in sediment concentrations of metals and PAHs after five years is less than 0.3% of the referenced standards for dredged materials. However, in ports with low hydrodynamic exchange, the increase can be higher.
2. With respect to polycyclic aromatic hydrocarbons (PAHs) there is missing (eco-)toxicity data for sediments AND a lack of data on the acute and chronic ecotoxicity for aquatic organisms. Toxicity experiments are understandably difficult to undertake.
3. Our understanding of how scrubber washwater discharges affect the ecological functioning of coastal marine ecosystems is incomplete. The biological effects of increased scrubber operation in shipping transport has barely been addressed

However, a number of studies conclude that the scrubber washwater MAY impact biogeochemical processes (such as acidification, eutrophication) and marine life through accumulation of pollutants in the marine environment, especially in the coastal regions. This is because coastal regions often already have higher concentrations of contaminants and less dilution and dispersal potential compared to the open sea.

The GESAMP report goes as far as saying "in terms of total amounts of contaminant discharges through EGCS, it appeared that large scale use may lead the deterioration of environmental status, especially in the ecologically vulnerable and sensitive areas such as coastal waters, semi-enclosed seas and also in ports and harbours."

This is backed by Endres et al (2018) which states similar: "Despite the existing guidelines for levels of monitoring and compliance of scrubber washwater, there is still the risk for acidification, eutrophication, and accumulation of PAHs, PM, and heavy metals in the marine environment, especially in the ecologically sensitive coastal regions, with often already higher background concentrations of contaminants and less dilution compared to the open sea"[9]

Issue 2: Omission of cumulative and interactive effects

There is a risk of cumulative and interactive effects of different pollutants. For example:

1. Large scale discharge of scrubber washwater containing high concentrations of metals may pose a significant risk to the marine environment, since the low pH has a strong effect on metal speciation and induces a shift towards the ionic, more bioavailable, fraction of metals (Millero et al., 2009)[10]. This is of particular concern in semi-enclosed environment such as harbours, which generally also receive a high load of metals from ships coated with copper-based antifouling paints
2. Metals and PAHs can interact and bio-concentrate in the first trophic levels of plankton and can then be transferred to higher trophic levels through food webs, especially to filter feeding marine molluscs. There is a lack of scientific knowledge on the synergistic effects of the scrubber discharge washwater, the efficiency of transfer of metals and PAHs from lower trophic levels to organisms higher up the food chain (which may be consumed by humans) and the contribution of discharge washwater to the overall contaminant loading in coastal waters. At present only few studies have considered combined effects of two metals or other contaminants on plankton organisms while no

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[8] https://www.cedelft.eu/en/publications/2399/the-impacts-of-egcs-washwater-discharges-on-port-water-and-sediment
[9] https://www.nabu.de/downloads/150312-Scrubbers.pdf
[10] https://doi.org/10.5670/oceanog.2009.98

study has investigated combined effects of more than two metals, or the combined effects of metals, PAH compounds and pH.

3. “Unforeseen” consequences. This includes the addition of inorganic nitrogen (from uptake of NOx). Whilst unlikely to reach high concentrations an additional load of nitrate from shipping may have considerable effects on the growth of pelagic microplankton, especially in eutrophicated environments such as the Baltic Sea.

What are PAHs?
Polycyclic aromatic hydrocarbons (PAHs) are hydrocarbons—organic compounds containing only carbon and hydrogen—that are composed of multiple aromatic rings. The simplest such chemicals are naphthalene, having two aromatic rings, and the three-ring compounds anthracene and phenanthrene. PAH properties will vary considerably depending on the number of rings. Low molecular weight PAHs can cause tainting of fish and shellfish, rendering them unfit for sale and second, metabolites of some of the high molecular PAHs are potent animal and human carcinogens. There are marked differences in the behaviour of PAHs in the aquatic environment between the low molecular weight compounds and the high molecular weight compounds as a consequence of their differing physical-chemical properties. The low molecular weight compounds are appreciably water soluble and can be bioaccumulated from the dissolved phase by transfer across the gill surfaces of aquatic organisms; whereas the high molecular weight compounds are relatively insoluble and hydrophobic, and can attach to both organic and inorganic particulates within the water column. PAHs derived from combustion sources may be deposited directly to the marine environment already adsorbed to atmospheric particulates, such as soot. PAHs can enter the marine environment through atmospheric deposition, run-off, industrial discharges and as a result of oil spills and other pollution events. Sediment will act as a sink for PAHs in the marine environment. PAHs are readily taken up by marine animals both across gill surfaces (lower molecular weight PAHs) and from their diet. Filter-feeding organisms such as bivalve molluscs can accumulate high concentrations of PAHs. Fish do not generally accumulate high concentrations of PAHs and other marine vertebrate and marine mammals also metabolise PAHs efficiently. OSPAR, 2017[11] A list of 16 PAHs, issued by the U.S. Environmental Protection Agency (EPA) in 1976 and intended for a chemical analysis of drinking water to assess risks to human health, has essentially become a standardized set of compounds to be analysed, particularly in environmental studies. These 16 “priority PAHs” are routinely investigated in environmental situations but also in other contexts, such as in food safety.

Issue 3: What about metals?

Metals are also considered of concern by the scientific community mainly due to their omission from the washwater criteria. The IMO washwater discharge criteria includes acidity (pH), PAHs, nitrate content, as well as turbidity - with turbidity used as a proxy for suspended solids such as

[11] https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/pressures-human-activities/contaminants/status-and-trends-concentrations-polycyclic-aromatic-hydrocarbon/

metals. Endres et al describe this as "unfortunate" and highlight several studies reporting elevated copper and zinc concentrations in scrubber washwater.

The origin of these metals in the scrubber washwater is still unknown and needs more study. Potential sources include combustion of fuel and lubricants, impressed current cathodic protection (ICCP) systems in the sea chest, and metals released from the piping of the seawater cooling system. In a study by Koski et al. (2017)[12] high concentrations of copper were found both in the open loop configuration scrubber inlet and in the effluent water, indicating that copper may originate from antifouling paints or due to pipe constructions rather than the scrubbing process itself.

Issue 4: The difficulty in measuring contaminants

The GESAMP study highlights difficulties related to the determination of PAH concentrations in the scrubber washwater effluents. The chain of processes, from sampling at sea through to conservation, transport and preparation for final analysis, is considerably demanding and requires trained personnel at every step. The GESAMP state that standardized controlled protocols for routine sampling and PAH analysis is not practicable in real-world ship activities. It concluded that the difficulties of PAH determination in EGCS washwater, together with the lack of compulsory recording of test conditions, EGCS specification, sampling protocols etc., and the quality of obtained data means considerable uncertainty is likely in measurements.

Endres et al (2018) go so far as saying that some of the commonly applied monitoring methods are scientifically questionable in terms of their statistical significance. Typically PAHs are measured using a fluorescence signal characteristic for one single compound, phenanthrene, which is then used as an indicator of all PAHs emitted from combustion. It is argued that since PAHs are typically found as complex mixtures in the environment, phenanthrene concentrations may differ from total PAH concentrations (US EPA, 2011).

The GESAMP study also looks at onboard installations of scrubber systems fitted with optical sensors for continuously monitoring PAHs. Certain manufacturers claim that a conversion factor of 6 should be applied to convert from optical phenanthrene determination to the 16 EPA priority PAHs. However, this does not agree with conversion factor derived from data cited in the scientific literature looking at the development and application of optical sensors, like MiniFluo-UV, which are installed on the ocean monitoring autonomous systems (such as underwater gliders) for continuous detection of selected PAH (Cyr, et al., 2019)[13]. Inconsistent results for the conversion of optical phenanthrene concentrations to the 16 EPA PAHs requires further investigation, because the online measurement of PAH phenanthrene equivalents could lead to over or underestimates of PAH discharges from EGCS leading to incorrect treatment from a regulatory perspective.

Another example is the use of turbidity to determine particulate matter (i.e. metals) concentrations. This method is problematic, as its measurements depend on the scattering of light, which is influenced both by the quantity of organic materials in the seawater and the type of light source used. Moreover, smaller particles have a very low influence on the turbidity (U.S. EPA, 2011). With Koski et al (2017) noting that sub-lethal effects to plankton observed at concentrations only marginally higher than the environmental water quality standards, it raises

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[12] doi: 10.1016/j.marenvres.2017.06.006
[13] https://doi.org/10.3389/fmars.2019.0011

the question as to whether "marginally" falls within the bounds of the error in measurement and how big a risk may actually be posed.

What were the conclusions?

The GESAMP Task Team were not tasked with making a judgment as to whether open loop scrubbers should be banned or restricted – merely to present the existing science base and to identify where gaps exist. Nevertheless, they made recommendations that would support a potential reduction of chemicals discharged into the marine environment in order to reduce potential risks to aquatic organisms and subsequently humans. They recommended:

1. For HFO-fuelled ships, sulphur emissions should be controlled to a relevant minimum and other contaminants removed to environmentally acceptable levels;

2. Application of Exhaust Gas Recirculation and Selective Catalytic Reduction was preferable to minimize the emission of NOx;

3. Closed loop EGCS are preferable because a greater proportion of contaminants are prevented from polluting air and water. However, it is recognised that highly concentrated washwater will be discharged in small mass amounts;

4. Sufficient reception and processing facilities for residual sludge from closed loop EGCS should be made available at major harbours around the globe. Smaller harbours may collect but not process the waste and have to transport the waste to the nearest facility.

What are the options for policymakers in coastal and port States and for ship operators?

Regardless of the science or cognizant of the lack of science the list of ports banning the discharge of washwater may continue to grow whilst others may move to regulating it more strictly. In an alternative scenario washwater discharge may become more acceptable as countries prioritise dealing with human health issues associated with air pollution. Clearly the direction taken will influence the choices made by ship owners.

A number of organisations such as The Britannia P&I Club[14] and GARD[15] have compiled lists of countries and ports where such restrictions are currently understood to be in place and these are often updated. However, local legislation can change at short notice. Interestingly some of these restrictions depend on proof of compliance with the discharge standard PLUS an ability to demonstrate that no harm to ecosystems will occur- which is inherently difficult given the uncertainties alluded to in this paper.

Four potential options:

1. A shipowner can buy and install an open-loop scrubber "confident" that they are in compliance with the existing IMO regulations provided they have the means to treat and discharge the washwater and have checked local regulations. However, often the vessel's size and layout, its engine configuration and its trading profile will shrink the available options and may effectively make the decision for the shipowner.
2. Policymakers apply the regulations in their current form – allowing discharge of washwater that complies with the IMO discharge criteria.

[14] See https://britanniapandi.com/blog/2020/01/27/list-of-jurisdictions-restricting-or-banning-scrubber-wash-water-discharges/ for the full list.
[15] http://www.gard.no/web/updates/content/26939066/beware-of-local-restrictions-before-discharging-washwater-from-exhaust-gas-scrubbing

3. Policymakers can apply the precautionary principal in its purest form based on the lack of scientific evidence. This may be attractive to states with stringent water quality regulations or vulnerable habitats, marine protected areas.
4. Policymakers can apply a risk-based approach with rules based on an assessment of our current scientific understanding of washwater discharges, gaps in our knowledge, and practical/commercial considerations. This may lead to different rules in different sea areas for example within EEZ waters and /or across regions and create practical challenges for operators of vessels trading between areas with differing frameworks.

As intimated in the four options described above, some degree of consensus or harmonisation of regulatory approach towards washwater discharges is paramount to instilling confidence among and engendering support from vessel operators. The current trend for varying local regulations risks creating confusion, adding to the cost burden on vessel operators, and may provoke resistance or non-compliance. A graduated approach – baseline, strict and very strict – between States may serve as an interim solution but ultimately an international consensus is the best way forward.

Conclusion

The impact of open-loop scrubber water discharges can be diminished by ensuring a rapid dilution of effluents. Many scrubber manufacturers claim their latest systems clean washwater more thoroughly than was previously possible thanks to advances in technology and experience gained from active installations. This is definitely a step in the right direction.

However, many uncertainties remain and efforts need to be ramped up to address these. The quantities of individual substances contained in scrubber washwater are relatively small, but the number of different substances is huge. We still know relatively little about their effects on human health (toxicological) and aquatic life (ecotoxicological) or how they behave in the environment – either individually or when they interact.

Studying these effects and making predictions about the accumulative environmental impact of washwater discharge – particularly as the use of open-loop scrubbers becomes more widespread – is further complicated by the fact that the techniques available for measuring them are inconsistent and have intrinsic underlying uncertainties.

Furthermore, any non-uniform addition of a mixture – no matter how weak and diluted – of acidifying, toxic, polluting and nutrifying chemicals must be considered in relation to other environmental considerations such as other pollution pressures exerted by shipping and other maritime activities, the level of existing contaminants, the dilution and dispersal potential and the ecological sensitivity of the area..

Increasing the measurements of pollutants along shipping lanes and in ports would allow the temporal and spatial variations in washwater discharge to be better evaluated and provide an enhanced baseline body of data to inform discussions on how these are treated in conjunction with environmental pressures.

Endres et al (2018) summarise this well stating that "in order to estimate the ecological consequences of increasing operation of open loop scrubbers in shipping transport, we need a sound database of the composition of washwater to increase our understanding of the ecological and biogeochemical effects of washwater discharge from shipping considering seasonally- and spatially-variable phytoplankton communities, cumulative effects as well as interactive effects with other environmental parameters".