RIVERTRACE

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To scrub or not to scrub?...

and for those who choose to scrub - what is scrubber washwater?

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Introduction

With less than a year to go until the sulphur content of marine fuels is capped at 0.5%, options available for ship operators to achieve this significant reduction from the pre-January 1, 2020 permitted sulphur content level of 3.5% remain limited to three choices:

- Option 1: use a compliant fuel with a sulphur content of <0.5%, which, according to the IMO, will be available in sufficient quantities.
- Option 2: use an engine that can run on an alternative, ultra-low sulphur fuel, such as liquefied natural gas (LNG), methanol, liquefied petroleum gas (LPG), and ethane.
- Option 3: use an exhaust gas cleaning system (commonly known as a 'scrubber') and continue to burn high sulphur heavy fuel oil (HFO).

All of the choices listed above are applicable to both newbuildings and existing ships. Although, the retrofitting of engines that can burn alternative fuel types and scrubber technology has an increased cost compared to the installation incorporated into the building of a ship.

The tricky financial decision between options for compliance have been forced upon ship owners following the culmination of more than 30 years of debate at the IMO around ship emissions. In reality, what should be a simple matter of choice between available compliance options has been made unnecessarily complex by increasingly acrimonious, and sometimes ill-informed arguments, over the validity of the available choices.

Scrubbers have come under repeated attack, sitting at the centre of many arguments. These arguments have stifled the uptake of scrubber technology, hindering their acceptance by the industry. The debate in such arguments predominantly focusses on washwater, the effluent produced by the process of scrubbing sulphur out of HFO using seawater. For open-loop scrubbers, which discharge washwater directly back into the open sea, issues have been raised around the transfer of pollutants to the marine environment. Closed-loop scrubbers avoid this problem as washwater is contained and treated at a shoreside facility.

However, the issues cited by those who hold a standpoint that discourages the use of open-loop scrubbers are countered by the arguments from those in favour of scrubber use who argue that their use has been permitted following careful analysis of scientific literature and extensive testing.

Possibly the biggest barrier to scrubber acceptance that must be overcome is the issue that their technical development has, to a large extent, been completed outside of the IMO's type-approval process. Therefore, a trust issue remains.

Mike Coomber, Managing Director of UK-based wash-water monitoring system manufacturer Rivertrace Limited (Rivertrace) believes this trust issue could be overcome by the provision of evidence for scrubber effectiveness.

He says: "*We have seen recent bans on scrubber operation in some ports because of the washwater discharge issue. However, there is acceptance that the continued use of scrubbers by ships may depend on being able to prove that washwater quality is constantly monitored and shown to meet appropriate standards*".

Possible changes required to current scrubber regulations are an ongoing issue under consideration by the Marine Environment Protection Committee (MEPC) and the specialist sub-committee on Pollution Prevention and Response (PPR) at the IMO.

"While nothing about IMO decisions is ever certain, the fact that scrubber washwater remains to be the only discharge of its type not subject to the same standards as discharges from other shipboard systems will almost inevitably lead the requirement of mandatory monitoring," says Coomber.

Such mandated monitoring requirements should not be feared as they may be the best option to ensure that all scrubber variants remain permitted for use in the future and on the widest possible scale. They will, however, require the use of specialist monitoring equipment.

This monitoring equipment would need to meet exacting performance standards, which has not been a requirement previously. A change in the regulations will mean that scrubber manufacturers will need to make use of multiple monitoring devices or integrate a monitoring device that can conduct monitoring using all required measurement parameters. Furthermore, in order to accurately calculate what the washwater is adding to the environment, measurements must be made at both seawater uptake and at washwater discharge.

Why is fuel sulphur content an issue?

Burning fossil fuels releases a cocktail of chemical pollutants into the atmosphere via gaseous emissions to air.

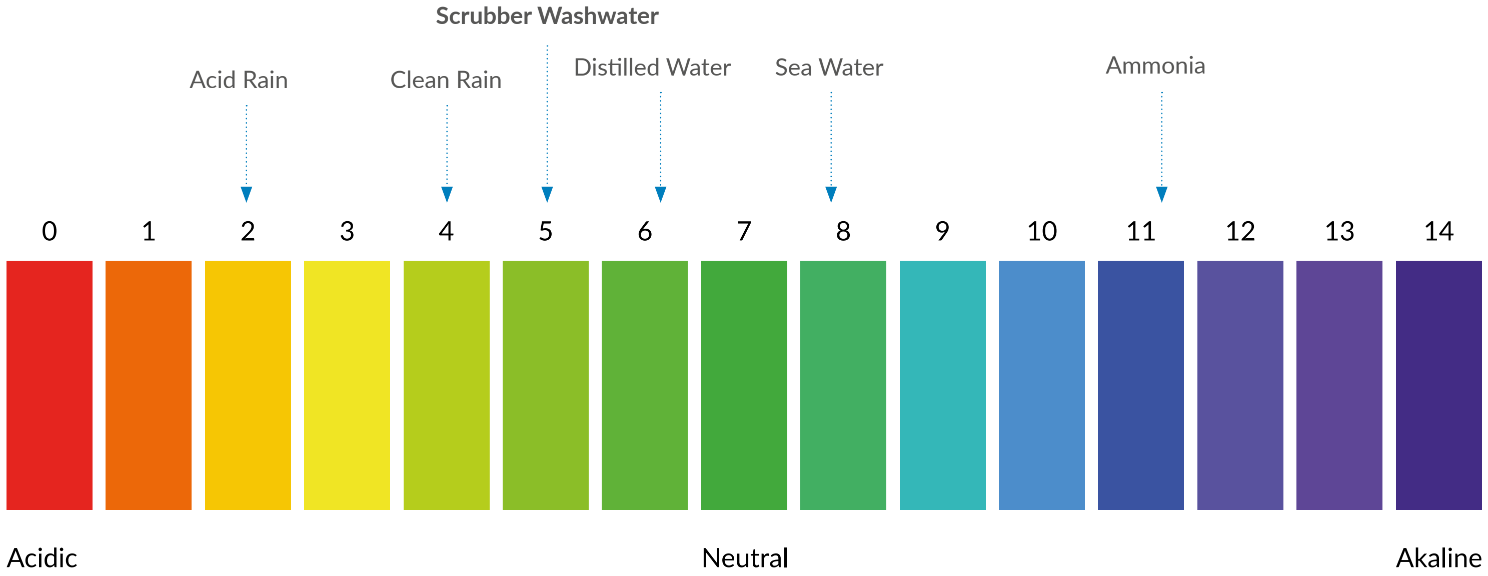
Nitrogen oxides and sulphur oxides (NOx and SOx) are two such pollutants that have been singled out for their damaging effect. NOx and SOx have a significant impact on human health from causing a negative impact to air quality and they have a significant impact on the environment through their role in production of 'acid rain' and its damaging effect on crops and forests.

Acid rain is formed when NOx and SOx rise high into the atmosphere, where they mix and react with water, oxygen, and other chemicals. **Rainwater's acidity also comes from CO_2 in the atmosphere which dissolves in water to form a weak carbonic acid.**

When this acid rain falls into the ocean it lowers the seawater's pH value. This process is called ocean acidification and it can affect ecosystems, particularly the ability of certain marine organisms to harness calcium carbonate to make their hard-outer shells or "exoskeletons". It also affects corals that grow their skeletons upward toward sunlight, thickening them to reinforce them. Ocean acidification impedes the thickening process—decreasing the skeletons' density and leaving them more vulnerable to breaking.

However, the pH value of seawater can also vary considerably due to subsea volcanic activity and river outflows (certain parts of the Amazon river, for example, have a natural pH near to that of acid rain).

Figure 1 *pH level comparisons, illustrating the pH level of scrubber washwater.*



Regulatory milestones at the IMO

The International Convention for the Prevention of Pollution from Ships (MARPOL) is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes.

The Convention was formulated and amended as the IMO's response to environmental concerns expressed at UN summits in Rio (1992) and Kyoto (1997) as well as intermediate developments between the two summits and which have occurred since. As such, MARPOL Annex VI was adopted by the IMO under the 1997 Protocol and entered into force on 19 May 2005 after gaining sufficient ratifying signatures.

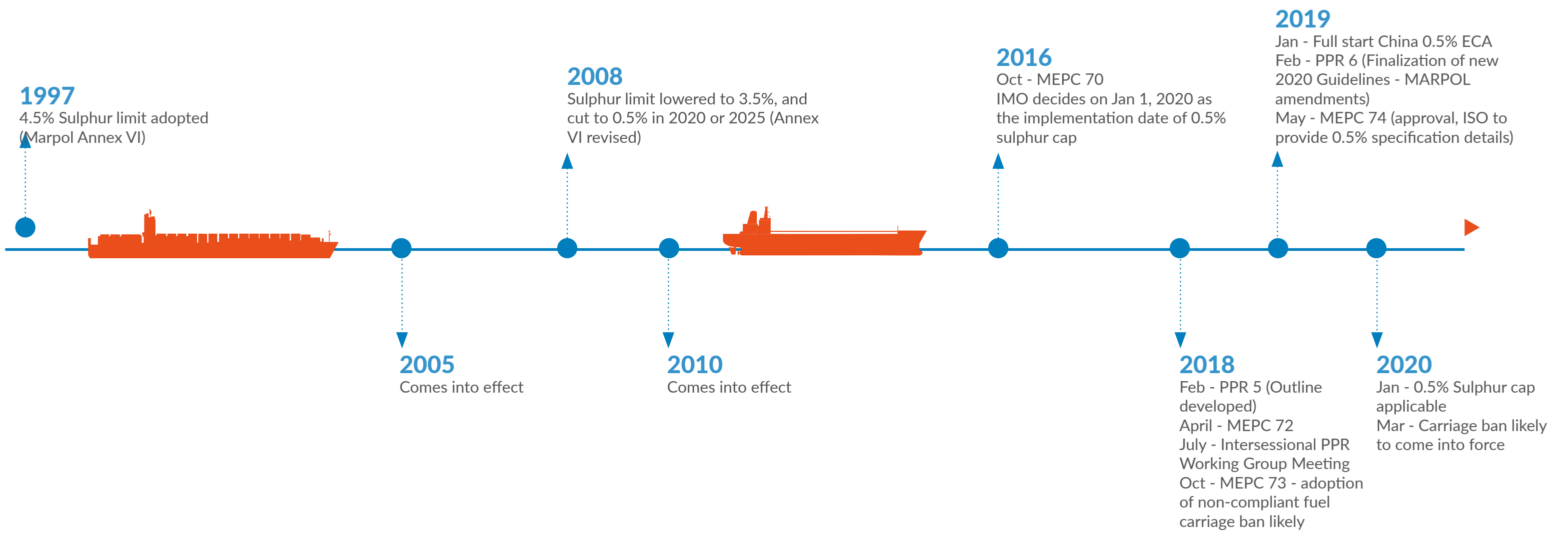
Annex VI was the final Annex to MARPOL to be adopted and covers the emission of ozone depleting substances, NOx, SOx, VOCs and most recently CO_2.

Current regulatory matters covered by Annex VI are in the majority focussed on SOx and CO_2, whereas other concerns have been progressed to the point where final control under Annex VI has already been reached. However, bleed water from Exhaust Gas Recirculation systems used to reduce NOx are still being discussed. Future changes to MARPOL Annex VI may seek to regulate particulate matter (PM) and metals.

For ship SOx emissions, alternative methods to a reduction in sulphur levels in fuels were robustly debated at the IMO and, after much deliberation, were permitted and written into the MARPOL Annex VI. The regulation at this point specifically referred to exhaust gas cleaning systems being permitted for use if approved by the flag state.

Over the past few years, the permitted level of sulphur content in marine fuels has, as a result of tightening restrictions mandated by MARPOL Annex VI, gradually been reduced and will reach a final global limit of 0.5% in 2020. In designated Emissions Control Areas (ECAs), the current cap for fuel sulphur content is 0.1%.

Figure 2 *Timeline of IMO Events*



Comparing the Global Sulphur Cap 2020 compliance options

Low-sulphur fuels

Fuels that have a low sulphur content (option 1) are considered to be the easiest route to ensuring compliance with the MARPOL Annex VI global sulphur cap rules, but it does rely on the availability of complaint fuels.

Since almost all ship engines are capable of running on a wide variety of fuel oils, including HFO and clean distillates such as MDO or MGO, little or no modifications are needed to adapt the engines. Using such fuel different to HFO could also bring some benefit as the ships' fuel treatment systems could be simplified, reducing the issue of damaging cat-fines present in the fuel.

From the negative perspective, distillate fuels command a considerable premium over residual fuels such as HFO. Distillates currently account for approximately 25% of all marine fuel use, with the majority of ship operators using HFO. LNG and other niche fuel use currently accounts for approximately 1% of the existing world fleet in terms of number of ships.

Quadrupling the amount of distillate fuel that is available for use by the global shipping fleet cannot be done by further refining of residual fuels alone. In fact, only a small percentage of the required fuel demand could be produced in this way. The remaining demand would need to be achieved in competition with other distillate users onshore or through the increased refining of crude oil. A small amount of distillate fuel could be produced using bio-fuels however, this is a controversial application if the crops grown for bio-fuel production and subsequent distillate production displace crops for human and animal consumption.

An alternative to distillates might be the desulphurisation of residual fuels. This is already being undertaken but not on a large enough scale to replace all the residual fuel currently consumed. Also, the establishment and operation of a desulphurisation plant is expensive and would likely increase the price of the fuel produced.

Gas-fuelled engines

Using LNG fuel or a similar alternative is an option (option 2) that has been pushed hard for several years. Using LNG has the added advantage of also reducing Nitrogen Oxides (NOx) emissions. However, pure gas or dual-fuel engines involve higher capital investment, a relatively simple but expensive fuel storage and delivery system, and a lack of bunkering infrastructure currently exists.

The bunkering infrastructure issue is being addressed however, not on a scale whereby be universal availability of LNG will be achieved by 2020.

Retrofitting a high percentage of the existing world fleet with pure gas or dual-fuel engines would appear to be economically unviable due to the length of time needed for implementation on individual ships and the required cost. However, some retrofits are already taking place. LNG is considered to be a better choice for newbuildings, especially those intended to operate on fixed schedules or always in areas where a fuel supply is available.

Exhaust gas cleaning systems

The removal of sulphur from exhaust gas streams by 'scrubbing' has been an accepted practice in shore-based power plants for decades. Land-based systems in the majority use dry scrubbing techniques however, scrubbing with seawater has been practised in oil refineries dating back to 1989. Research into the effect of wet scrubbing using seawater at coastal refineries dates back many years, with the first one put into operation at Mongstad in Norway. Almost certainly, when discussing the issue of SOx emissions at the IMO in the 1990s, the experience of refinery scrubbing would have been part of the conversation.

Scrubbers: the options

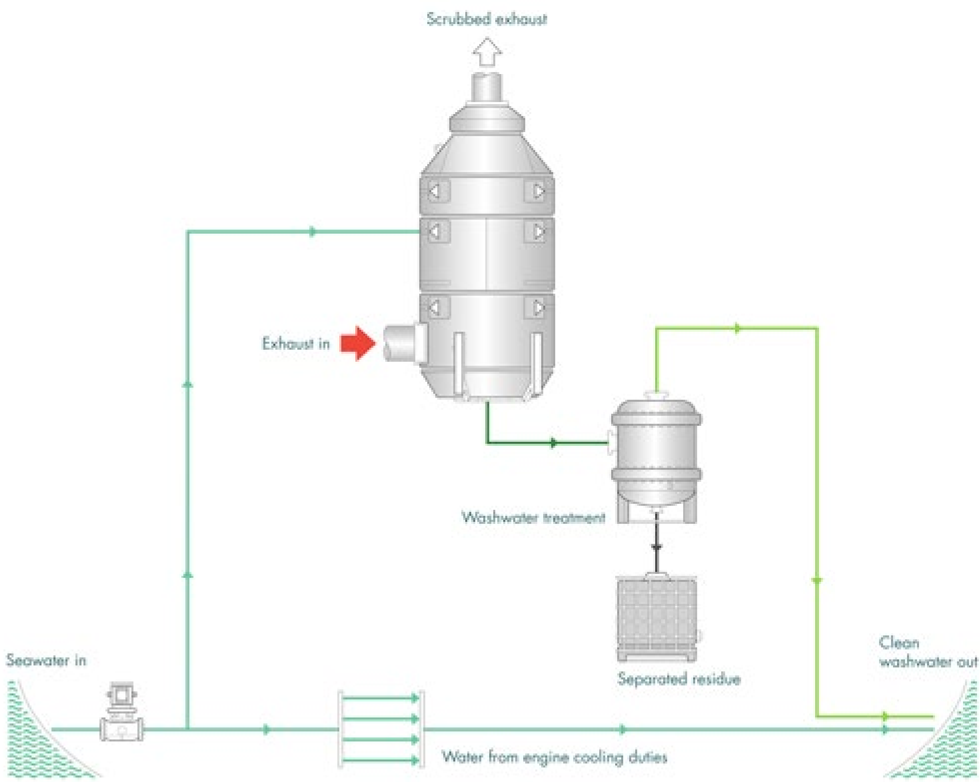
There are considered two main types of scrubber systems: dry and wet.

Dry scrubbing systems removes SOx by passing the exhaust stream over calcium hydroxide to form gypsum. Although dry systems are simpler in their design and installation requirements, they carry a significant weight and space penalty, and marine references are very few. No washwater is produced by dry scrubber systems.

Wet scrubbing systems operate by passing the exhaust gases from oil-fired engines and boilers through alkaline water. For ships, in most instances the sources of the water will be seawater. If operating in a fresh or brackish environment some additional buffering capacity will be needed and this is done either by increasing the quantity of seawater used for scrubbing or by addition of chemicals such as sodium hydroxide. If neither option is possible, then the ship would need to switch to operate using compliant fuels.

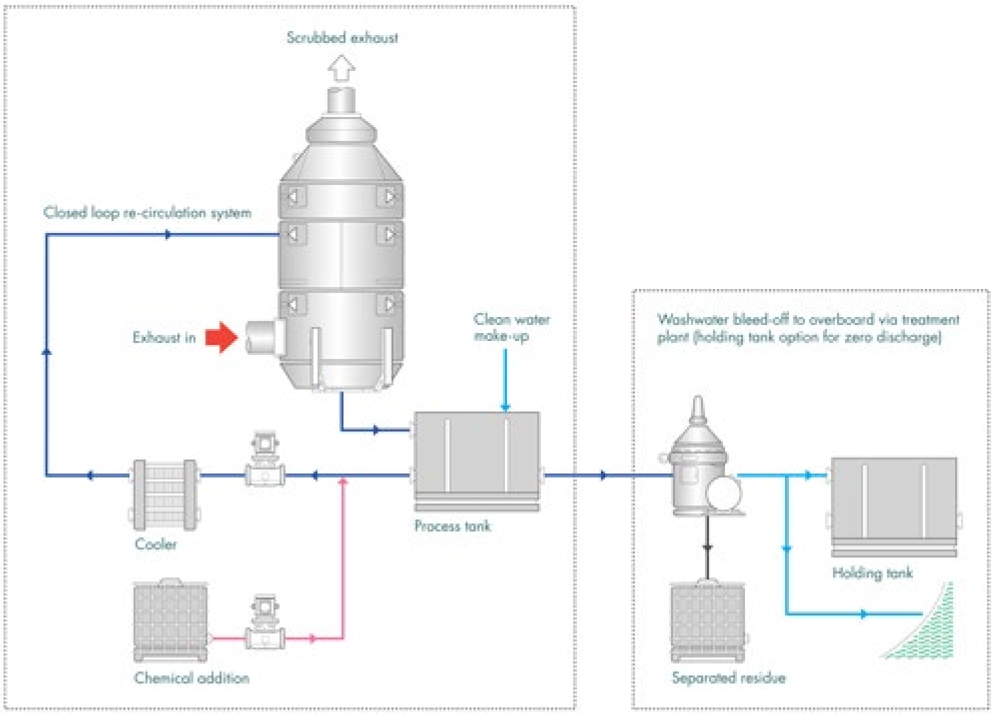
Wet scrubbers come in three design variations: open-loop, closed-loop and hybrids. An open-loop scrubber system makes use of sea water without the use of additional chemicals and produces large amounts of washwater, all of which is discharged to the sea after sludge and contaminants are removed. Washwater from the open-loop scrubber is treated and monitored at the inlet and outlet to ensure that it conforms with the MEPC 259(68) discharge criteria.

***Figure 3** Schematic showing an open loop scrubber system [Source: EGSCA]*



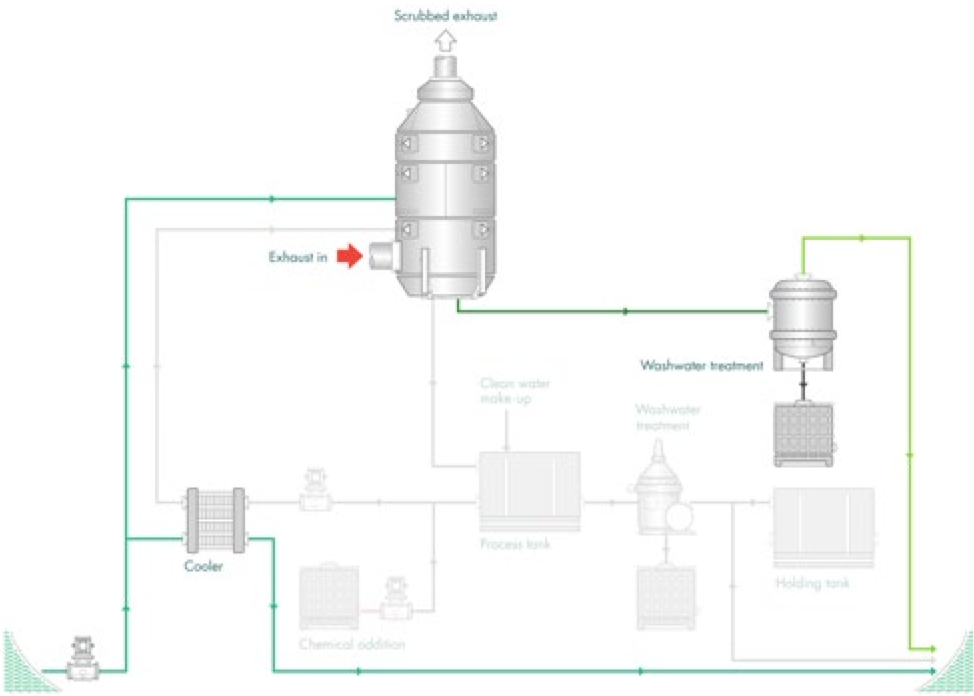
A closed-loop scrubber system continuously circulates the same seawater or freshwater in the system but with the addition of an alkaline additive. This additive is usually sodium hydroxide (NaOH) although magnesium hydroxide is also becoming available which is much safer to handle. A small bleed off is extracted and treated before discharge. The main treatment method for a close-loop scrubber is very similar to that of an open-loop scrubber. In open-loop systems there is also a dosing unit and a holding tank which washwater can be stored in when discharge is not permitted.

***Figure 4** Schematic showing a closed loop scrubber system [Source: EGSCA]*



A hybrid scrubber system combines the features of both an open-loop and a close-loop system and can operate in either mode, as required. If considered necessary, as a means of meeting future regulations, it is usually possible to convert any open-loop scrubber system into a hybrid scrubber system by means of retrofitting the additional components. Many scrubber manufacturers are now designing their systems to make this conversion as simple as possible.

__Figure 5__ Schematic showing a hybrid loop scrubber system [Source: EGSCA]



The chemistry of scrubbing sulphur from exhaust gases

The SOx emissions produced by marine engines typically consist of around 95% sulphur dioxide (SO2), the remainder being sulphur trioxide (SO3). These SOx gasses are water soluble therefore, once they have dissolved in the seawater, a reaction occurs whereby the SO2 is ionised into sulphuric acid.

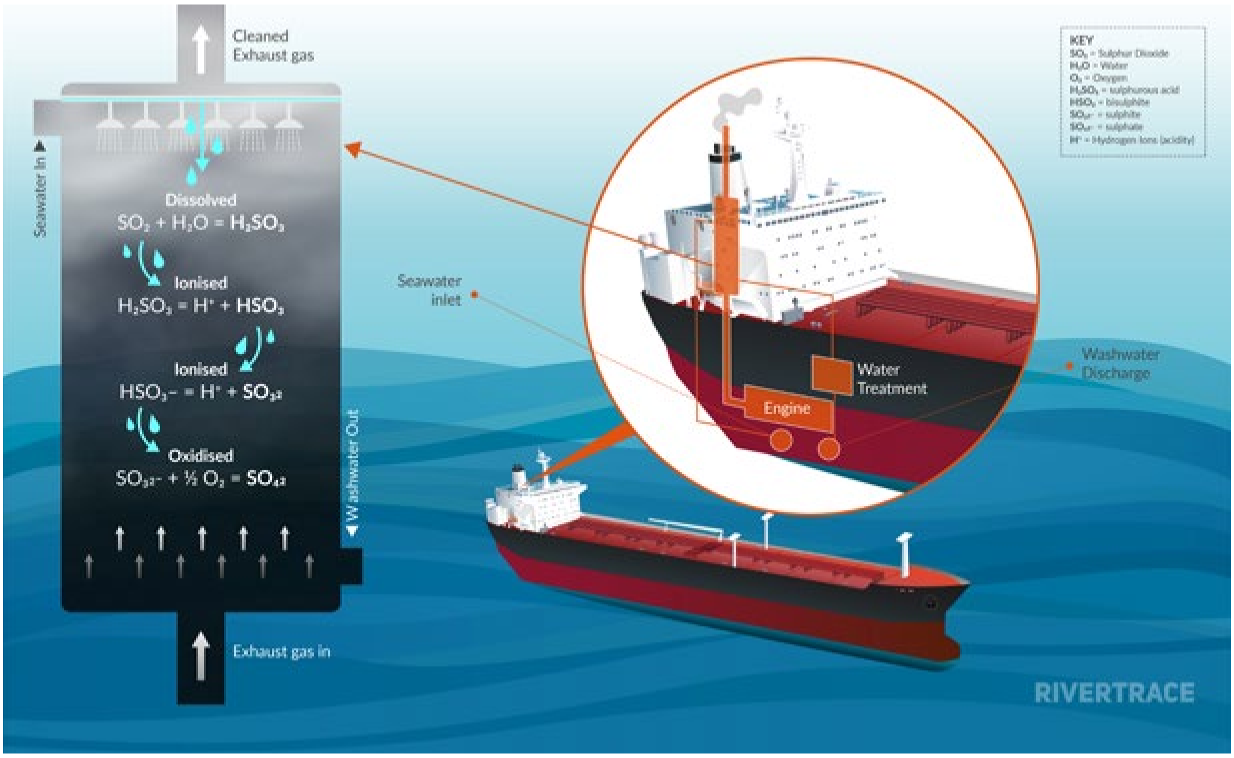
The sulphuric acid in the water then reacts with carbonates and other salts present in the seawater to form sulphates which are natural salts found in seawater. Sulphuric acid formed from sulphur trioxide (SO3) also produces acidity. This acidity is neutralised initially by the alkalinity of the seawater, due to its natural bicarbonate content.

When mixed with water that is alkaline, such as seawater or fresh water treated with sodium hydroxide (NaOH), SOx in exhaust gases is converted to form natural sulphate salts. Sulphate is an abundant component of seawater with the world's oceans containing more than one trillion tonnes.

It has been said in some scientific papers that if all the sulphur in the sea were spread out as a layer, the total ocean area of the world would be covered by layer more than 1.52m thick. If all of the sulphur in the world's known fossil fuel reserves were added. The increase would be less than 0.05mm.

The discharge of scrubber washwater may contain what is thought to be high levels of sulphate however, when the huge volume of natural sulphates present in seawater is taken into consideration – it should not represent a limiting factor for use of scrubbers by ships.

Figure 6 Infographic showing the chemistry of washwater



Beyond sulphur, other benefits of scrubber use

Beyond the benefits associated with the removal of sulphur from exhaust gases by scrubbers, there are other environmental impacts that are reduced through the use of the technology.

The cost advantage of scrubbers

The principal advantage of scrubbers is that they allow the user to yield cost benefits associated with the continued use of lower-priced HFO.

The exact advantage yielded in overall fuel costs depends on the price differential between HFO and 2020 compliant fuels. The price of HFO has varied massively over the last sixteen years since the first prototype scrubbers were installed on the P&O ferry Pride of Kent.

When initially considered as a means of meeting Sulphur Emission Control Areas (SECA) requirements, the benefits of scrubber technology use was limited to ships operating in such areas. Ships which operated continuously in SECAs – such as ferries in the Baltic and North Seas –could expect a payback on the capital outlay for the scrubber in a matter of months and ensure continued compliant operations. It is these ferries that were the early adopters of scrubbers, followed by the cruise sector when the North America ECA came into effect at a later date. Ships which spent most of their time in the open oceans or otherwise outside of controlled areas using scrubbers, could also yield benefit but payback periods would be much longer – perhaps as much as ten years or more.

With the Global Sulphur Cap 2020 fast approaching, the return on investment calculation for scrubbers will change and greater benefits will be on offer for most ships, the exception being those ships calling at the relatively few ports which have placed restrictions on open loop scrubbing operations. These are currently few, and in most cases, the need to switch fuels will be for just a very short distance and has generally been dismissed by shipowners as having little significance.

The Exhaust Gas Cleaning Systems Association (EGCSA) has suggested that the switching to low sulphur fuel be undertaken for the port stay where open loop operation is not possible for lower cost impact, as over 90% of fuel consumption happens at sea.

EGCSA says While closed loop and hybrid systems are available for enclosed bodies of water with little water exchange or where discharges are restricted by local regulation, ECGSA suggests the alternative of switching to low sulphur fuel for the port stay where open loop operation is not possible. The cost impact is likely to be limited as over 90% of fuel consumption is during full away at sea, which is where the financial benefits really accrue.

Particulate Matter (PM)

Firstly, the removal of particulate matter (PM). The exhaust of a typical two-stroke engine will contain approximately 120mg/Nm3 of particulates including PM10 and PM2.5 sized particles. Both of these particulate matter sizes are considered damaging to human health. It should also be considered that PM emissions are not restricted to ships burning HFO, even engines running on sulphur-cap compliant fuel will produce them. However, measurements taken on ships operating with scrubbers have indicated that around 80% of PM emissions are removed from the exhaust by the scrubbing process.

Metals

Another positive yielded from the use of scrubber technology is the removal of metals found in exhaust gases. The source of the metals can be from the fuel oil being burned or from the engine itself. Those metals from the fuel oil may be naturally occurring or have been introduced at any stage from well to bunker tank. Some metals that have been found in exhaust gas are known to be toxic but are typically at low levels that would not ordinarily be considered harmful to the environment. IMO guidelines do not, as yet, enforce any limits for metal content or monitoring.

Polycyclic Aromatic Hydrocarbons (PAHs)

Also considered as contentious are Polycyclic Aromatic Hydrocarbons (PAHs). These are naturally occurring substances in fuel oils and are also produced as a result of combustion. PAHs are known to be carcinogenic and accumulate in ecosystems. Current IMO guidelines on washwater contain recommendations but there is some debate over the way that the levels have been arrived at.

A paper (MEPC 73/INF.5) presented by Committee of EU Shipbuilders' Association (CESA) to the 73rd MEPC session in 2018 detailed the results of a study that analysed water samples from exhaust gas cleaning systems. The study examined water samples from 22 vessels operating in European waters using IF380 HFO and scrubbing systems. The average PAH concentration was less than 12µg/l. PAH composition and comprised an average of 47% naphthalene, the lightest PAH, which readily volatilises from surface waters and has a half-life of less than one day in the atmosphere.

In the study, the concentration of benzo(a)pyrene (BaP) (a marker for PAH used by the World Health Organization), all but one sample was found to be below the WHO (World Health Organization) drinking water guideline limit when normalised at a washwater flow rate of 45m3/MWh; (0.74µg/l compared with 0.7µg/l). The average normalised BaP concentration was 0.06µg/l and unnormalised concentrations were all below the WHO limit. Therefore, the research proved that the scrubber technology on board the ships reduced the volume of PAHs.

The Regulation of Scrubbers

The Guidelines for scrubber systems that cover both washwater and air emissions were contained in the original MARPOL Annex VI text and have been updated on numerous occasions. IMO Resolutions MEPC.130 (53), MEPC.170 (57), MEPC.184 (59) 2009 and MEPC.259 (68) 2015 represent the various stages in the evolution of the guidelines.

Similar to all IMO guidelines, those relating to scrubbers are not mandatory regulations, although it is unlikely that any flag state would permit systems that do not meet the relevant guidelines.

The Guidelines also recommend that flag states collect data on washwater discharges in accordance with Appendix 3 of the Guidelines. This information is intended to be used in any subsequent reviews by the IMO, taking into account any advice from the Joint Group of Experts on the Scientific Aspects of Marine Environmental Pollution (GESAMP).

The washwater standards are quite comprehensive and in order for compliance to be proved, monitoring performance criteria have been established. Full details of the requirements are set out in section 10 of MEPC.259(68).

MEPC.259(68) allows two methods of determining if a scrubbing system meets the air emission targets and has a single section devoted to washwater.

The Guidelines state that monitoring should take place for pH, PAH and turbidity. When a scrubbing system is operated in ports, harbours, or estuaries, the Guidelines recommend that washwater monitoring and recording should be continuous and that values monitored and recorded should include pH, PAH and turbidity.

In other areas the continuous monitoring and recording equipment should also be in operation, whenever the system is in operation, except for short periods of maintenance and cleaning of the equipment.

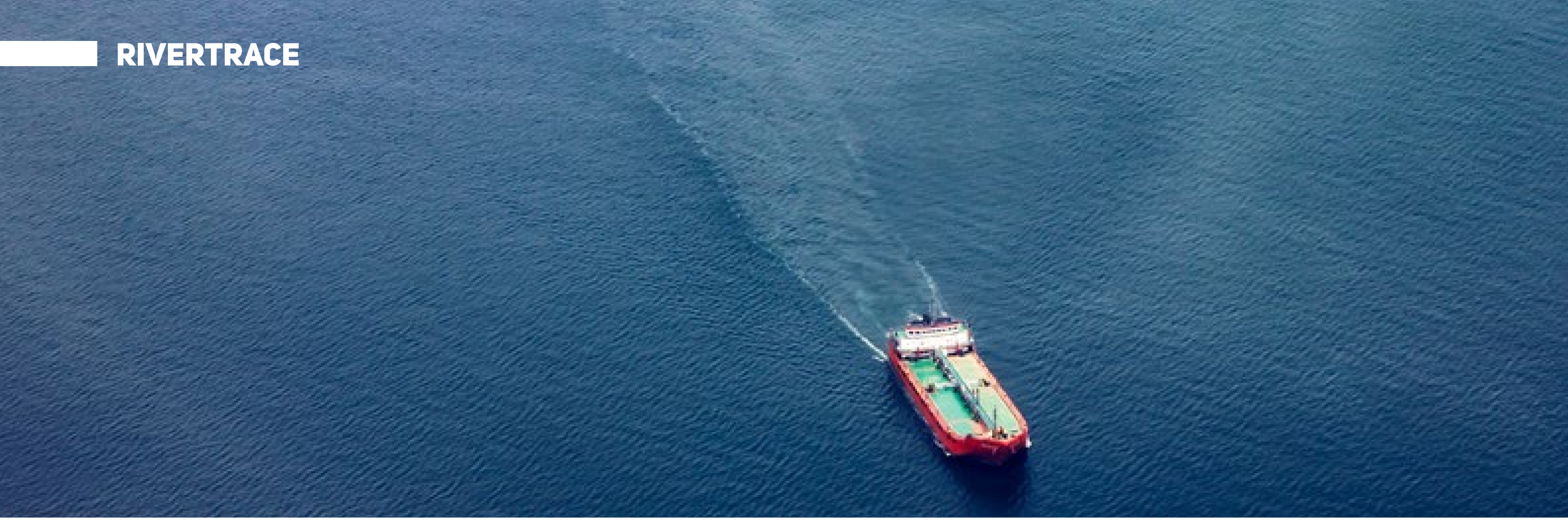
This particular monitoring approach requirement reflects the current Guidelines being put in place before the Global Sulphur Cap was set to come into operation and the use of scrubbing technology outside of ECAs was not be obligatory. In the future, it can be expected that scrubbing will take place unless a ship is running on compliant fuels.

The Science of Washwater Monitoring

The 2015 IMO Guidelines identified a method of determining the pH value from discharge washwater, either by direct measurement or by using a calculation-based methodology (computational fluid dynamics or other equally scientifically established empirical formulae). This is to be left to the approval by the flag state.

For turbidity, a standard measurement as outlined in ISO 7027:1999 is used to measure the Suspended Particle Matter. It is stipulated that the maximum continuous turbidity in washwater should not be greater than 25 FNU (formazine nephelometric units) or 25 NTU (nephelometric turbidity units) or equivalent units, above the inlet water turbidity.

For PAH detection, as PAH are a group of compounds found in oil that can be measured in water at parts per billion concentrations, the monitoring of extremely low levels of oil in scrubber washwater, can be applied. These levels are well beyond the measurement capability of traditional instruments associated with 15ppm or even 5ppm bilge water separators.



PAH fluorescence can be used to monitor PAH levels. When exposed to ultra violet light energy monitors tuned to emit UV light around a wavelength where it is absorbed by one PAH compound in particular – phenanthrene can be used for monitoring purposes. Phenanthrene is the second most common of the PAH in petroleum. Water monitoring of the fluorescence from other PAHs overlaps with that from phenanthrene and the overall response can be used to report the concentration of PAH as phenanthrene equivalents or PAHphe.

Getting it Right

The combination of performance criteria required for the monitoring washwater is unique to scrubbing systems and requires equipment specifically designed for the task. To this end, shipowners may prefer to request scrubber manufacturers incorporate a monitoring system from a proven independent supplier rather than one from a lesser known source.

"It will be enormously important for shipowners to be able to rely on the monitoring equipment as any failure in monitoring would mean that the scrubber operation may need to be stopped and a much more expensive compliant fuel used instead," says Coomber.

It is important for the resultant washwater to be monitored for its pH value and the flow rate to ensure that its neutralisation capacity is maintained. The scrubber washwater flow rate should be increased or decreased according to the ability of the scrubber to scrub the sulphur, particularly if scrubbing becomes reduced as buffering capacity in the washwater is consumed.

One monitoring system is the Smart ESM developed by UK-based Rivertrace Limited. The company has almost 40 years' experience in developing and producing monitoring systems for marine application including bilge alarms, oil in water monitors, boiler condensate monitoring and scrubber systems, and more.

Rivertrace Limited launched the Smart ESM monitoring system last year as one of a very small number of scrubber washwater monitoring systems on the market. The monitoring system is suitable for use at both the seawater inlet and washwater discharge outlet of a wet open-loop, closed-loop and hybrid scrubber system, measuring and recording PAH, Turbidity, Temperature and pH. The Smart ESM system is fully compliant with MEPC 259(68) and provides reliable information to ensure compliance with the worldwide fuel sulphur content limits.

The Smart ESM system displays real time data which can be sent to other systems as required. Historical data graphs can be displayed on the system's inbuilt touch screen display, if required. The data can be used to prove compliance with washwater regulations to Port State Control authorities.

Rivertrace's experience of marine monitoring systems and the environments onboard a ship ensure that ease of maintenance was a high priority on the system specification during development.

The unique Plug and Play maintenance design of the Smart ESM system allows separate calibrated PaH and Turbidity cartridges to be fitted inside the measuring cell. This permits the calibrated parts to be swapped without the need of isolating the sample. Rivertrace also provides its users with calibration check kits for in-situ testing.

The Smart ESM has been developed to support all scrubber systems and include a broad selection of inbuilt analogue and digital outputs, making Rivertrace the 'Partner for Compliance' for all OEMs.

Rivertrace has adopted a truly flexible and accommodating approach to how they work with, and service, each partnership with the OEMs, taking into consideration the differing designs, sizes and target markets of each supplier.

Looking to the future

"It is almost certain that at some future point, the IMO's washwater guidelines will be converted into a mandatory requirement and the accurate monitoring of washwater will become essential. Because of IMO procedures it is too late for that to happen before the 1 January introduction of the sulphur cap, but it may come within 2020 or 2021.

Before any regulatory developments can come into effect, it is expected that some more accusations will be levelled at scrubber use. Much of this will come from outside of shipping and may affect the way in which scrubbers are viewed at national and local levels. Some of the opposition will also come from within the industry from shipowners and organisations that see scrubber use as unfairly permitting the use of less expensive fuels. Organisation such as EGCSA which represents scrubber manufacturers and CSA2020 a consortium of shipowners that support scrubber use are undertaking an education and information campaign."

Mike Coomber concluded.

Please contact Rivertrace for further information:

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