# Open-Loop Scrubbers Literature Review

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BRITISH PORTS ASSOCIATION

## Background

On 1 January 2020, the International Maritime Organisation (IMO)'s sulphur cap in marine fuels came into effect. The regulations, known as IMO 2020, mandated a maximum sulphur content of 0.5% in commercial ship fuel outside of emission control areas (IMO, 2019). Shipowners have since installed exhaust gas cleaning systems, colloquially known as 'scrubbers' as an alternative way to comply with the regulations and avoid using more costly, lower sulphur fuel.

As of June 2023, scrubbers have been fitted to 5,050 vessels (Clarksons, 2023), which is around 5% of the global merchant fleet. However, vessels with scrubbers account for 25% of global tonnage, as they are more likely to be installed on large container ships due to their high fuel consumption and potential savings. Many cruise companies have installed scrubbers to their vessels' engines, with Carnival Corporation investing $500 million in scrubber technologies.

Scrubbers remove sulphur dioxide from exhaust gases, allowing ships to continue to use cheaper high sulphur fuel while reducing airborne emissions. There are three types of scrubbers: open loop, closed loop, and hybrid. Open-loop scrubbers use a seawater-based system to clean exhaust gases from sulphur-based fuel. The seawater reacts with sulphur dioxide to form sulfuric acid, which is neutralised by the alkaline properties of the seawater. The resulting effluent is discharged into marine waters. Around 80% installed scrubber systems are open-loop systems (ICCT, 2020). In closed loop scrubbers, an alkaline chemical solution neutralises the sulphur dioxide in exhaust gases. The absorbed sulphur dioxide forms a byproduct that is purified in a closed system and eventually offloaded at dedicated port facilities. Hybrid scrubbers can operate in both open and closed loop mode.

Ports and environmental regulators around the world have expressed concern with ships using open-loop scrubbers discharging in coastal and port areas, with some restricting their use and others banning them altogether. For UK ports, the primary concern regards the steady accumulation of pollutants in sediment. Washwater discharge contains pollutants (e.g. PAHs, lead, mercury, benzene, naphthalene, anthracene) that 'pose a significant risk to the aquatic environment' (as per EU Directive 2013/39/EU) which can, for example, hinder the growth, feeding, and reproductive processes of marine organisms.

The UK has tight regulations on contamination levels in dredged material disposed to sea. If sediment contamination levels increase, dredging campaigns and licenses may be at risk, which threaten a ports obligation to maintain navigable waterways and by extension, threaten their operations altogether.

## Research Summary

As IMO 2020 and scrubber installations are recent developments, there have been few long-term studies into the environmental impact of open-loop scrubber washwater discharges in port areas specifically. Whilst limited in scope, there have been several broader studies into the environmental impact of open-loop scrubbers, with some conflicting results.

A 2020 modelling study in the Flemish Region found that under a high-use scenario, scrubber discharges increased surface water concentrations of naphthalene by 189% and vanadium by 46% (Teuches et al., 2020). It found that substances with the greatest increases in water concentrations were not considered high-risk under EU Water Quality Standards (ibid.). However, several of the other pollutants in washwater are 'priority hazardous substances' list, which the researchers believe justify restricting discharges in estuaries and coastal areas of large ecological value.

Studies into the individual contaminants in washwater discharge can be limited, as not all elements have been adequately studied and rely on readily available lab techniques, detection capabilities, etc. The IMO's Task Team on Exhaust Gas Cleaning Systems identified gaps in the scientific data of many contaminants and believed it to be unlikely that additional data will be collected (GESAMP, 2020).

The German Environment Agency and its Federal Maritime and Hydrographic Agency (BSH) studied the environmental effects of washwater discharge between 2020 and 2023. They tracked both water-soluble and particle- bound contaminants including vanadium, nickel, copper, iron, and zinc, as well as PAHs. Laboratory tests assessing the discharge's total toxicity on marine organisms, including luminescent bacteria, algae, and copepods, revealed varying levels of toxicity. Depending on the specific scrubber system in use, the discharged water's toxicity ranged from "practically non- toxic" to "highly toxic" and even "extremely toxic" with closed-loop samples The paper stated that current regulatory measures were insufficient, and it recommended regional restrictions on washwater discharges.

Additionally, research into discharges in Baltic Sea ports found that scrubbers account for 9% of certain cancer-causing PAHs found in marine environments, >98% of which derived from scrubbers operating in open-loop mode (Ytreberg et al., 2022). Though it also noted that the environmental impact of discharged washwater was far lower than that of air emissions (when measuring the total pollutant impact per vessel per trip).

Discharged washwater can intensify the acidification process in water bodies, causing pH levels to decrease at a faster rate than that already occurring from climate change. A 2020 study from Royal Belgian Institute of Natural Sciences (RBINS) found that sulphur dioxide (SOx) pollution from open-loop scrubbers in the English Channel may cause a yearly pH drop equivalent to 2 to 4 times the annual rate of climate change acidification, and 10-50 times the rate in coastal areas (RBINS, 2020). Though due to the "flushing effect" in the English Channel, the researchers did not anticipate a significant yearly accumulation of SOx pollution from shipping in the area.

The rate of acidification depends on water circulation, baseline alkalinity, and the concentration of washwater discharge. For example, a 2017 study focused on the Baltic Sea found that open loop scrubbers could increase shipping lane acidification to 1970s – 1990s levels (Claremar, Haglund, and Rutgerson, 2017). Though other research into acidification in the Port of Barcelona's South basin found that it had a strong capacity to recover to normal pH levels following washwater discharge (Delgado and De Osés, 2022). It also noted that seawater's buffering capacity (alkalinity) is not unlimited, and that open loop scrubbers can accelerate the process by which this buffering capacity is met.

Whilst some research has found that scrubber discharges can negatively affect marine environments, other studies suggest they have a very low environmental impact. A CE Delft modelling study found that when assuming zero original sediment concentration, a standard port will see a very small increase in metals and PAHs levels, though pollutants are still lower than those stipulated in UK Action Level Guidance (CE Delft, 2019). Though, this depends on the level of hydrodynamic exchange (tidal flow) within a port, and pre-existing pollution levels.

The BPA and UKMPG commissioned CEFAS to review the CE Delft Study. It concluded that its model used for assessing pollutants in port areas was useful but had limitations as it overlooked variations beneath ships and failed to identify certain contaminants in the washwater (e.g. lubricants and corrosion inhibitors). CEFAS also stated that CE Delft's simple accumulation model takes no account of the reactions at the water sediment interface that exist as a result of temperature and pH change. They also highlighted the importance of water exchange - when there is limited water exchange, sediment pollution concentrations can be greater as sediment remains in the water column in the vicinity of birth. Such 'contamination hotspots' may create an issue for dredge disposal options (ibid.).

A Carnival-backed DNV GL study checked washwater samples against a range of stringent environmental benchmarks from the across the EU and IMO and found that cruise ship washwater was significantly below pollutant limits (DNV GL, 2019). It did not, however, assess the cumulative effects of washwater discharges, or make conclusions on its relation it tidal flow conditions. Additionally, separate ecotoxicological studies on marine species by EGCSA/DHI and the Japanese Government found that risks to marine organisms were in an acceptable range and were only slightly above detection limits (EGCSA, 2021; Ministry of Land, Infrastructure, Transport and Tourism, 2019).

## Conclusion

It is the BPA's view that more research is required on the impact of contaminants in washwater discharge on port marine areas, particularly those with different tidal flow conditions and washwater dilution levels. Some studies indicate that scrubber discharge has a limited impact on marine environments and aquatic life. However, whilst pollutant levels may be in an acceptable range at the point of discharge, concerns still exist about their cumulative effects on sediment pollution over time in low flow environments and sensitive marine areas.

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