A Hemispheric Analysis of Scrubber Washwater Discharge Regulations in Countries of the Americas

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Abstract

The maritime industry produces about 3% of the world's total carbon dioxide (CO2) emissions annually, as well as 15% of sulfur oxide (SO_x) emissions and 13% of nitrogen oxide (NO_x), resulting in significant damages to the environment and human health. In an effort to reduce the maritime industry's adverse environmental health impacts, the International Maritime Organization (IMO) issued a regulation (IMO-2020) in 2008 lowering the limit of allowable sulfur content in ships bunker fuel from 3.5% to 0.5% effective January 1, 2020. While IMO-2020 has reduced airborne ship pollution in coastal seaports since its enactment, the ruling includes regulatory loopholes. Here, the IMO allows ship operators several avenues to comply with this regulation. While some choose to use Low Sulfur Fuel Oil (LSFO) or Liquified Natural Gas (LNG), many vessels, in particular cruise ships, have elected instead to install Exhaust Gas Cleaning Systems, also known as scrubbers. Scrubbers, which most often use seawater to neutralize ship's exhaust gases, produce "washwater" effluents that are released into the ocean, generally untreated, resulting in environmental damages. Recent studies indicate that washwater ship pollution can increase ocean acidification and negatively affect multiple marine species through the increased acidity of the water and released heavy metals. This loophole in IMO 2020 could be fixed by an international ban on scrubber discharges or, at least, a ban in sensitive marine areas—although this would most likely prove a long and fraught process. Because of this, bans, restrictions and special requirements have been imposed at the national, regional, or port level around the world. In this paper, we review several cases of these regulations across sites in the Americas, in an effort to understand the possible solutions to curb marine pollution from scrubbers, as this technology is increasingly adopted worldwide.

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List of Acronyms

Associated Protective Measures: AMP
California Air Resources Board: CARB
Carbon Dioxide: CO_2
Cruise Lines International Association: CLIA
Directorate of Ports and Coasts of Brazil: DPC
Emission Control Area: ECA
Exclusive Economic Zone: EEZ
Exhaust Gas Cleaning System: EGCS
Gigaton: Gt
Greenhouse Gas: GHG
Group of Experts on the Scientific Aspects of Marine Environmental Protection: GESAMP
Heavy Fuel Oil: HFO
International Council on Clean Transportation: ICCT
International Maritime Organization: IMO
Liquified Natural Gas: LNG
Low Sulfur Fuel Oil: LSFO
Marine Environment Protection Committee: MEPC
Marine Gas Oil: MGO
Marine Protected Area: MPA
Nitrogen Oxide: NO_x
Ocean-going Vessels: OGV

Particularly Sensitive Sea Area: PSSA
Particulate Matter: PM
Polycyclic Aromatic Hydrocarbons: PAH
Sulfur Oxide: SO_x
U.S. Environmental Protection Agency: EPA
United Nations Convention on the Law of the Sea: UNCLOS
Vessel General Permit: VGP
Volatile Organic Compound: VOC
Water Quality Standards: WQS

A Hemispheric Analysis of Scrubber Washwater Discharge Regulations in Countries of the Americas

1. Context

1.1 MARPOL and IMO 2020

The maritime industry produces about 3% of the world's total carbon dioxide (CO_2) emissions annually, as well as 15% of sulfur oxide (SO_x) emissions and 13% of nitrogen oxide (NO_x) emissions. According to a World Bank analysis,[1] because of this, along with particulate matter (PM), shipping industry emissions were responsible for about 15% of global premature deaths caused by air pollution (60,000 in absolute terms) in 2015.

The prevailing fuel oil used in the maritime industry, known as Heavy Fuel Oil (HFO), comes from leftover materials from oil refining (i.e. from "the bottom of the barrel") and is highly polluting and dangerous for human health when combusted. As part of an effort to tackle this issue, as well as other contaminants in vessels' air emissions, the International Maritime Organization (IMO) decided in 2008 to lower the limit of allowable sulfur content in ships fuel oil from 3.5% to 0.5%, starting in 2020.

Such regulation (known as IMO 2020) falls under the International Convention for the Prevention of Pollution from Ships—better known as MARPOL,[2] adopted in 1973 and modified by Protocol in 1978—and is expected to improve air quality in coastal regions as well as help tackle the climate crisis. According to the IMO, "*the new limit will mean a 77% drop in overall SO_x emissions from ships, equivalent to an annual reduction of approximately 8.5 million metric tonnes of SO_x. Particulate matter - tiny harmful particles which form when fuel is burnt – will also be reduced*".[3]

The IMO has 174 member countries, and MARPOL is composed by six Annexes. Annex I and II are mandatory for all signatories and regulate oil and oily waters, as well as noxious liquid substances in bulk, respectively. MARPOL also regulates harmful substances in packaged form (Annex III), sewage (Annex IV), garbage (Annex V), and air pollution (Annex VI)—although Annexes III to VI are non-mandatory. It is important to note that IMO's regulations agreed to under MARPOL are legally binding for signatories.

Pertaining air pollution—MARPOL Annex VI—it entered into force years later, in 2005, and seeks to limit the emission of the main air pollutants contained in ships' exhaust gases, including SO_x, NO_x, and PM; prohibits deliberate emissions of ozone-depleting substances; and regulates

[1] https://blogs.worldbank.org/climatechange/expectation-management-lng-bunker-fuel-shipping
[2] MARPOL is recognized as one of the most important international marine environmental conventions.
[3] https://www.imo.org/en/MediaCentre/PressBriefings/Pages/34-IMO-2020-sulphur-limit-.aspx

shipboard incineration as well as the emissions of Volatile Organic Compounds (VOC). Amendments to Annex VI in 2011 also introduced measures to reduce greenhouse gas (GHG) emissions, as well as what are called Emission Control Areas (ECAs), which aim to heavily reduce emissions of air pollutants in designated sea areas through the adoption of special mandatory measures for all vessels. The sulfur limit at all ECAs is 0.1% since 2015.

See *Table 1* below for a detailed timeline of established sulfur limits for shipping fuel under MARPOL, in ECAs and all other sea areas.

Table 1: MARPOL established sulfur limits for shipping fuel.

	Date of regulation	**Sulfur limits for fuel (% m/m)**
Sulfur emission control areas (ECAs)	–before 1 July 2010	1.5%
	1 July 2010-–1 Jan 2015	1.0%
	1 Jan 2015—present	0.1%
Other sea areas	Before January 2012	4.5%
	1 January 2012-–1 Jan 2020	3.5%
	After 1 Jan 2020	0.5%

Source*: A New Perspective at the Ship-Air-Sea-Interface: The Environmental Impacts of Exhaust Gas Scrubber Discharge*.[4]

To date, existing ECAs include:

- Baltic Sea (regulates SO_x and NO_x, enforced since 2006 and 2021 respectively);
- North Sea (regulates SO_x and NO_x, enforced since 2006 and 2021 respectively);
- The North American ECA, including most of the U.S. and Canadian coasts (regulates NO_x and SO_x, enforced both since 2012);
- The U.S. Caribbean ECA, including Puerto Rico and the Virgin Islands (regulates NO_x & SO_x, enforced both since 2014).

Per the IMO, there are different avenues to comply with the new IMO 2020 regulation on sulfur limits, like using Low Sulfur Fuel Oil (LSFO)—such as Marine Fuel Oil—and others: "*Ships may also use different fuels, with low or even zero sulphur - for example, liquefied natural gas, or biofuels. Limiting air pollutants by installing Exhaust Gas Cleaning Systems, also known as scrubbers, is*

[4] https://doi.org/10.3389/fmars.2018.00139

accepted if flag States approve as an alternative means to meet the sulphur limit requirement".[5] Exhaust Gas Cleaning Systems (EGCS), or scrubbers, use an alkaline scrubbing material to neutralize the acidic nature of the exhaust gases of the ships, caused by sulfur and nitrogen oxides, which are generated as a result of combustion of the fuel they use. The avenue to comply with IMO 2020 is up to the owner/operator of the vessel, and leaves the possibility open for vessels to continue to burn cheaper, more polluting high-sulfur fuel as long as they scrub the resulting emissions first with an EGCS. Scrubbers can reduce sulfur emissions by 98%.[6]

1.2 Exhaust Gas Cleaning Systems, or *Scrubbers*

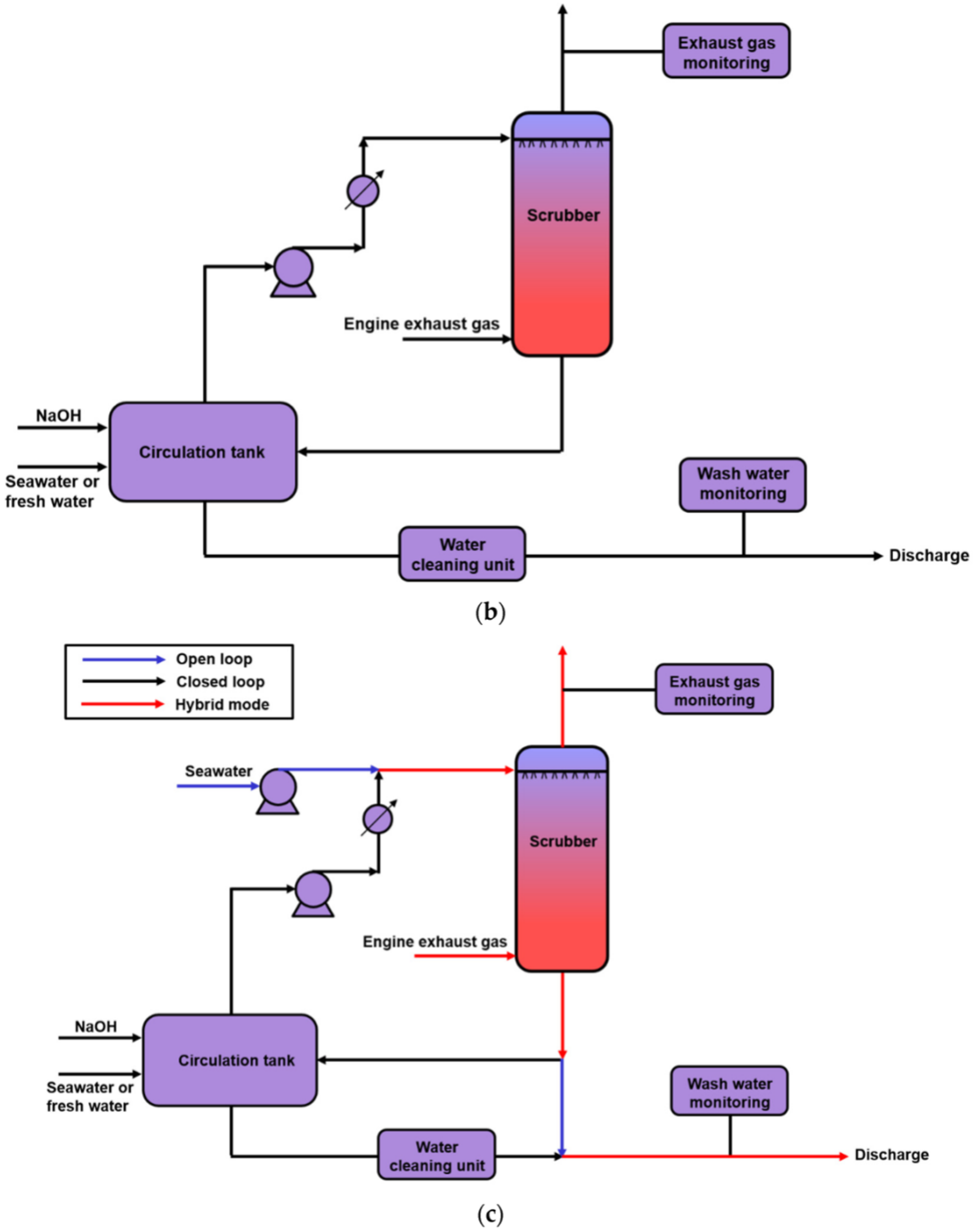
There are different types of EGCS, depending on how they operate. *Open-loop* scrubbers, by and large the most common, use seawater to filter the captured sulfur oxides from the exhaust gases in a chamber before they are released to the atmosphere, and then discharge the used seawater (known as washwater or effluent), back into the ocean. Most open-loop scrubbers discharge this washwater back to the ocean without treating it first.

According to research by the International Council on Clean Transportation (ICCT), as of 2020, open-loop scrubbers accounted for 85% of total EGCS installations, as they are the least expensive technology: "*they are less expensive, dump the sludge they generate overboard, and do not require adding chemical additives to increase alkalinity*".[7] Ships equipped with this type of technology will discharge washwater into the ocean more or less continuously as long as the vessel is consuming power—and this includes while on port and at berth.

In contrast, *closed-loop* scrubbers add caustic soda to filtering water to neutralize the acidity of the exhaust gases (instead of using seawater), and collects the contaminated scrubber sludge on board and stores it for disposal on land. It can operate on zero-discharge mode, and then nothing is discharged back into the ocean waters. Finally, there are also *hybrid* scrubbers that can function on open- or closed-loop mode. According to ICCT research, 14% of scrubber installations to date were hybrid systems and only 1% were closed-loop. See *Figure 1* below for a diagram on how this technology works.

[5] https://www.imo.org/en/MediaCentre/PressBriefings/Pages/34-IMO-2020-sulphur-limit-.aspx
[6] https://www.sciencedirect.com/science/article/abs/pii/S1361920913001491?via%3Dihub
[7] *Global scrubber washwater discharges under IMO's 2020 fuel sulfur limit*, ICCT, 2021.

Figure 1: Open-loop, closed-loop, and hybrid scrubber technology.



Source: Advanced and Intensified Seawater Flue Gas Desulfurization Processes: Recent Developments and Improvements, found at https://www.mdpi.com/1996-1073/13/22/5917/htm.

The IMO established guidelines for EGCS installations, for washwater criterion, as well as for testing and compliance through its Marine Environment Protection Committee (MEPC), [8] long before IMO 2020 came into effect. These Guidelines from 2015, known as RESOLUTION MEPC.259 (68))[9] include the following:

- Washwater discharge criteria.
    - pH: should have a pH no less that 6.5, which is measured at the ship's overboard discharge with a range of 2 pH units between the inlet and outlet.
    - PAHs (polycyclic aromatic hydrocarbons): maximum continuous concentration should not be greater than 50 µg/L PAHphe above the inlet water PAH concentration.
    - Turbidity/suspended particle matter: treatment systems must be designed to minimize suspended PM, the maximum continuous turbidity in washwater should not be greater than 25 formazin nephelometric units or equivalent units of measurement.
    - Nitrates: treatment systems should prevent the discharge of nitrates beyond 12% of removal from exhaust or 60 mg/l of wash water discharge rate of 45 tons/MWh (whichever is greater).
- Residues generated by EGCS should be brought to reception facilities on shore.
    - Each ship should be equipped with proper storage and disposal which is then recorded in EGCS logs.

However, vessels are only expected, but not obligated, to monitor chemical and physical parameters of scrubber's washwater, and the 2015 guidelines do not include limits for any heavy metals. More importantly, the MEPC guidelines are meant to act as an initial guidance for ships, as the IMO intends to amend them in the future as more data becomes available. According to the IMO website, in fact, "*The (MEPC) Sub-Committee on Pollution Prevention and Response is undertaking a review of the 2015 Guidelines on EGCS*". This speaks to a current lack of information and evidence-based data collected to date regarding the effects of this technology on marine ecosystems and the need to better regulate it. These EGCS regulations came into effect years before the IMO 2020—moment when scrubbers become widely adopted to comply with the new sulfur limits—and did not consider many of the consequences seen today by this technology.

As the decision on the *how* to comply with IMO 2020 is left up to the vessel owners, shipping and cruise companies can decide on the avenue that best fits their business model. On the one hand, they can invest in adapting ships to run on liquified natural gas (LNG)—which emits close to zero sulfur emissions or use biofuels. They can also buy the now-readily available, yet still more expensive marine gas oil (MGO) or LSFO, which are also IMO compliant. Lastly, they can also continue to burn regular HFO and retrofit vessels with exhaust gas cleaning systems, in order to ensure emissions are IMO compliant in terms of sulfur limits.

[8] The MEPC is a subsidiary body of the IMO that gets together every nine months to discuss and come to a consensus about the most pressing matters in terms of marine environment protection.
[9] https://www.american-club.com/files/files/bunker_compendium_MEPC_resolution_exhaust_gas_cleaning_systems.pdf

1.3 The Rise of Scrubber Adoption in Vessels

Regarding the potential alternatives to comply with IMO's new fuel sulfur limit regulation, LNG provides an option that emits close to no sulfur, yet LNG infrastructure is still scant and thus supply is too. Thus, at the moment, only around 3% of total bunker fuel demand comes from natural gas,[10] and as the world moves towards a fossil fuel-free future to tackle climate change, LNG might not be a long-term solution but more of a transitional one. An S&P Global analysis points out that, "*Policy support in favor of LNG investment in shipping could easily flip to regulation against LNG as a fossil fuel*."[11] In addition, converting ships to run on LNG also comes at a hefty cost—potentially even more so than installing a scrubber on existing vessels.

On the other hand, according to an assessment published by the University of Southern Denmark,[12] the net present value of MGO falls quickly as the price difference between MGO and the regular heavy fuel oil increases. Supply for MGO is still small compared to HFO, as it is only produced by a few refineries, so price is still much higher—around 30% more expensive, although prices fluctuate. While this remains true, it will be more economical for certain vessels to install scrubbers and use the cheaper, dirtier fuel. This preference towards scrubbers is clearly evidenced in the demand for the technology as the IMO 2020 regulation came into effect. The number of ships fitted with scrubbers increased from 243 in 2015 to more than 4,300 in 2020—the year when IMO 2020 came into force.[13]

Along the same lines, Wärtsilä, one of the leading manufacturers of scrubbers for the international shipping market, stated in an interview that "*We have seen continued healthy interest in orders for scrubbers, especially on the newbuild side, with owners opting for a mixture of open-loop and hybrid types.*" Wärtsilä had its best ever year in 2020 for scrubber deliveries, despite the COVID-19 pandemic, and the interview highlighted that, "*shipowners continued to express an interest in exhaust gas abatement systems as long-term solutions for the global fleet*."[14] This implies that, as long as the price differential between MGO and HFO persists, LNG infrastructure builds up, and regulations do not force the change to low-sulfur fuel oil, certain vessels—such as large cruise ships—will continue to use scrubbers to comply with IMO 2020.

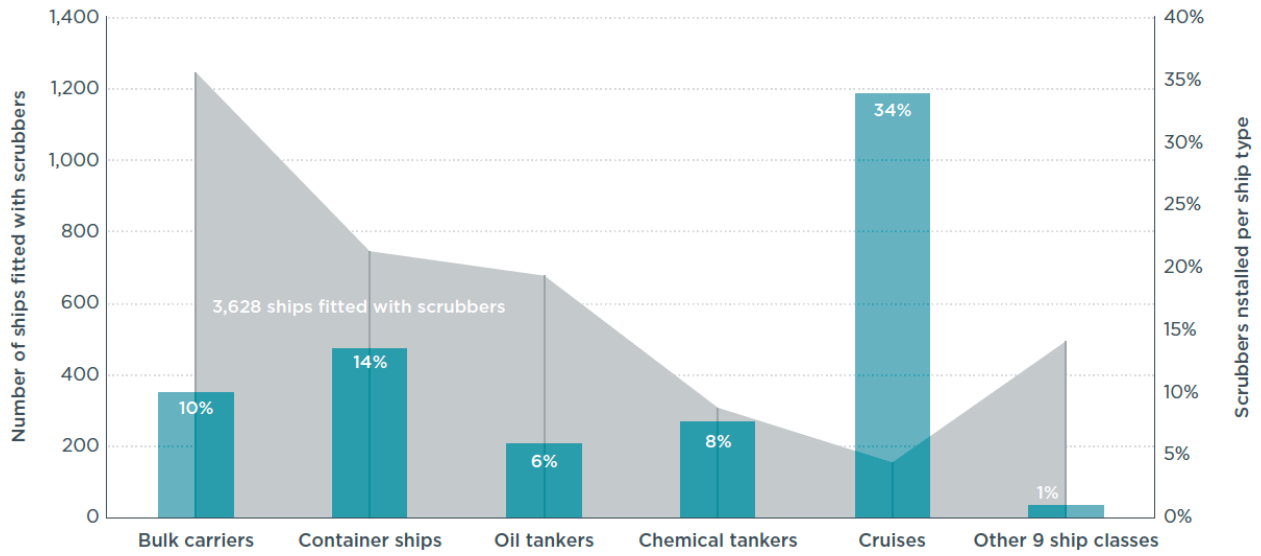
1.3.1 The Rise of Scrubber Adoption in Cruise Ships

The decision on how to comply with IMO 2020 varies among companies and certainly between vessel types. For instance, an ICCT report found that bulk carriers, container ships, and oil tankers make around three quarters of the fleet retrofitted with scrubbers, by number of ships. From

[10] https://www.spglobal.com/platts/en/market-insights/latest-news/oil/060420-analysis-lng-fails-to-answer-shippings-big-energy-transition-question
[11] Ibid.
[12] *The costs and benefits of sulphur reduction measures: Sulphur scrubbers versus marine gas oil*, https://www.sciencedirect.com/science/article/abs/pii/S1361920913001491?via%3Dihub#!
[13] https://www.agcs.allianz.com/content/dam/onemarketing/agcs/agcs/reports/AGCS-Safety-Shipping-Review-2021.pdf
[14] https://www.hellenicshippingnews.com/scrubbers-for-the-future/

those, bulk carriers are the most common ship with scrubbers installed, in absolute terms—1,246 ships, or 34% of all outfitted ships (of all types). Nonetheless, within each ship category, the study also found that cruise ships installed this technology in 34% of their fleet—the largest share within each type—as depicted in *Figure 2*. In fact, a newer report from the Cruise Lines International Association (CLIA)—one of the industry's leading conglomerates—published[15] that by the end of 2021, almost 70% of the cruise ship global fleet was retrofitted with EGCS, and 96% of non-liquified natural gas new build ships will be adapted with scrubbers. This is in line with the fact that the world's four largest cruise companies—Carnival Corporation, Royal Caribbean Cruises, Norwegian Cruise Line Holdings, and MSC Cruises—are installing scrubbers on most of their ships. According to a Miami Herald investigation, as of January 1, 2020, of the 207 cruise ships belonging to these cruise lines collectively, 68% of the vessels were running on HFO and scrubbers, 31% on LSFO, and only 1% on LNG.[16]

Figure 2: Total number of ships with EGCS installed by the end of 2020 (in gray) and share of ships with scrubbers installed, by vessel type (in blue).



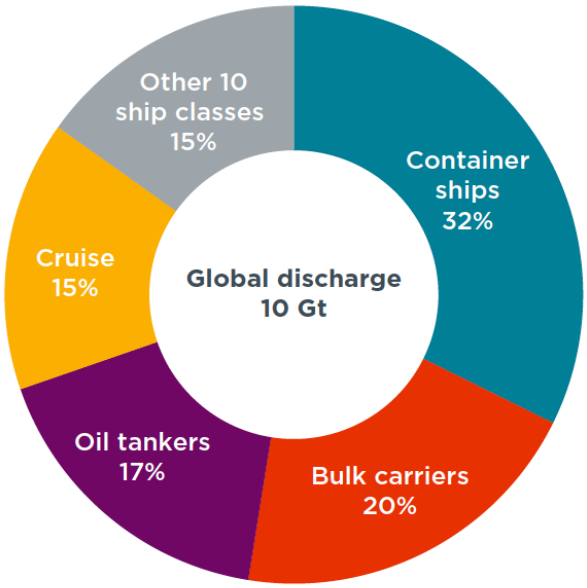
Source: *Global scrubber washwater discharges under IMO's 2020 fuel sulfur limit*, ICCT, 2021[17]

Importantly, although cruises represent only 4% of the scrubber-equipped fleet by number of ships, they are responsible for 15% of total discharged washwater. See *Figure 3* below. They are in fact the main contributor to scrubber discharges in ports, as they spend around 25% of their time at berth and, on average, they consume three times more energy per hour spent at port

[15] https://cruising.org/-/media/research-updates/research/2021-state-of-the-cruise-industry_optimized.ashx
[16] *Cruise lines have a solution for a new clean fuel regulation. But is it the greenest option?* Dolven and Harris, Miami Herald, December 2020.
[17] https://theicct.org/sites/default/files/publications/scrubber-discharges-Apr2021.pdf

than oil tankers and six times more than container ships. As such, cruises account for 96% of discharges in seven of the 10 ports with the highest total washwater discharges globally.[18]

Figure 3: Scrubber washwater discharges per type of vessel, out of a total of 10 Gigatons (Gt) per year.



Source: *Global scrubber washwater discharges under IMO's 2020 fuel sulfur limit*, ICCT, 2021[19]

2. Why is this a problem?

Within the three scrubber types, open-loop systems account for more than 80% of scrubber installations.[20] Open-loop scrubbers use a continuous flow of seawater that gets discharged back into the ocean. Hybrid scrubbers can function in both open- or closed-loop mode and make up for around 17% of total scrubber installations. Closed-loop scrubbers, which make for the smallest percentage of scrubber installations, use freshwater treated with alkaline chemicals and periodically dump smaller volumes of more concentrated waste. In all cases, the treatment of exhaust gases produces a residue *sludge* that is later disposed of on land, at a special reception facility.

For all types of systems, scrubbers' residual waters, after cleaning the exhaust gases, produce effluents that are discharged into the ocean, most often without treatment according to experts—including a ship engineer that worked for years with Carnival Cruises and was interviewed firsthand by the IOA. Royal Caribbean has a policy of not disposing scrubber discharge within three nautical miles off the coast, yet is the only major cruise company with

[18] Ibid.
[19] https://theicct.org/sites/default/files/publications/scrubber-discharges-Apr2021.pdf
[20] https://theicct.org/scrubbers-on-ships-time-to-close-the-open-loophole/

such a rule of the five ones interviewed in a Miami Herald's journalist work.[21] The latest CLIA report[22] from 2021, however, mentioned scrubbers as a technological innovation under its responsible tourism spotlight, underscoring they remove 98% of sulfur content from exhaust gases, yet neglects to point out that they produce effluents that are released into the ocean.

In this regard, Alaska's Ocean Ranger Program,[23] which has recently been dissolved, states in its 2019 annual report[24] for Commercial Passenger Vessel Environmental Compliance Program, that: "*Ocean rangers observed that filtration systems in the EGCS system were not installed on all the EGCS units and that the filtration systems in place were not always utilized*." Furthermore, it states that, "*The EGCS process water discharged overboard is required to be monitored for PAH content by the EPA VGP. Ocean Rangers continued to report oily sooty sheen / surface effects in the waterbody from the EGCS discharges in 2019…and continued to observe "foamy" soot discharges from the EGCS system*." Importantly, the 2019 report also mentions that these areas of interest were repeated ECGS System observations in the previous year's report.

Furthermore, per a recent study published by the International Council for Clean Transportation,[25] shipping produces nearly as many tons of scrubber washwater in a year as the cargo it carries, totaling at least 10 Gigatons (Gt) of effluent per year (in contrast to 11 Gt the shipping sector carries yearly). It is also important to underscore that the study used 2019 ship traffic, when approximately 3,600 vessels had been retrofitted with scrubbers. This amount is now more than 4,000—and counting. Furthermore, from those 10 Gt of effluent, 8 Gt are discharged within countries' Exclusive Economic Zones (EEZ)—within 200 nautical miles from shore—and only 2 Gt at high seas.

According to this analysis, there are three geographic hotspots for shipping's scrubber discharge: the Caribbean; the Baltic Sea, the English Channel, and the Mediterranean Sea in Europe; as well as a route through the Strait of Malacca, along the South and East China Seas. From these, most are shipping traffic bottlenecks that are a consequence of natural geographic characteristics, such as channels and straits, as well as artificial canals and locks, where discharge waters build up. However, the last of the hotspots discovered, at the Caribbean, is not due to a bottleneck but due to a high amount of popular tourism-dependent ports that are home to several cruise ship ports of call—including Miami and Georgetown, in the Cayman Islands. The latter is the port exposed to the largest amount of scrubber discharge per year, where more than 40 Mt of this effluent occurs yearly—within one nautical mile from port—and almost its entirety comes from cruise ships. Furthermore, the report points out that around 665 Mt of the total 10 Gt of yearly

[21] *Cruise lines have a solution for a new clean fuel regulation. But is it the greenest option?* Dolven and Harris, Miami Herald, December 2020.
[22] https://cruising.org/-/media/research-updates/research/2021-state-of-the-cruise-industry_optimized.ashx
[23] Alaska's Ocean Ranger Program allowed U.S. Coast Guard-licensed marine engineers to board vessels to act as independent observers to monitor the state's environmental and marine discharge requirements.
[24] https://dec.alaska.gov/water/cruise-ships/cruise-reports/prior-reports/
[25] https://theicct.org/sites/default/files/publications/scrubber-discharges-Apr2021.pdf

effluents were discharged inside Particularly Sensitive Sea Areas[26] (topic to be developed later in this work).

2.1 Scrubbers and the UN Convention on the Law of the Seas

Scrubber technology also possibly conflicts with the United Nations Convention on the Law of the Sea (UNCLOS),[27] articles 194 and 195. UNCLOS is an international agreement signed first in 1982, establishing a legal framework for all marine and maritime activities, of which 168 countries and the European Union are parties. It must be said, however, that from the Americas, there are multiple nations that are not signatories, such as Colombia, Costa Rica, Honduras, Paraguay, Peru, and the United States.

Article 194 of UNCLOS talks about measures to prevent, reduce and control pollution of marine environments, stating that, "*States shall take, individually or jointly as appropriate, all measures consistent with this Convention that are necessary to prevent, reduce and control pollution of the marine environment from any source, using for this purpose the best practicable means at their disposal and in accordance with their capabilities, and they shall endeavor to harmonize their policies in this connection*." Furthermore, "*the measures taken pursuant to this Part shall deal with all sources of pollution of the marine environment. These measures shall include, inter alia, those designed to minimize to the fullest possible extent: (a) the release of toxic, harmful or noxious substances, especially those which are persistent, from land-based sources, from or through the atmosphere or by dumping*."

As explained before, the best technology available is low-sulfur fuel oil, which entirely complies with international sulfur emissions regulations, and does not involve discharging any type of residual waters to the oceans that could potentially be harmful to the marine ecosystems. Thus, allowing the use of scrubbers seems to be in direct violation of the principles in Article 194.

Similarly, Article 195 says that there is a duty (by States) "*not to transfer damage or hazards or transform one type of pollution into another. In taking measures to prevent, reduce and control pollution of the marine environment, States shall act so as not to transfer, directly or indirectly, damage or hazards from one area to another or transform one type of pollution into another*".

Per the available literature on how Exhaust Gas Cleaning Systems work, they seem to be doing precisely that: transferring SO_x and NO_x air pollution to the marine environment in the form of acidic washwater, potentially harmful to species through heavy metals and polycyclic aromatic hydrocarbons (PAHs), as will be discussed in detail in the following section of this report.

[26] A Particularly Sensitive Sea Area (PSSA) is an area that needs special protection through action by IMO because of its significance for recognized ecological or socio-economic or scientific reasons and which may be vulnerable to damage by international maritime activities.

[27] https://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf

3. Studied Effects of Scrubber Discharge on the Marine Environment

Public information and analysis on washwater contaminant concentrations is scant. While there are many studies regarding ocean pollution and acidification, there are still many questions regarding the direct and indirect impacts of pollution stemming from scrubber discharge on marine ecosystems. Here, ecologically valuable areas (such as estuaries, bays, coral reefs, etc.) are fragile and require special attention to avoid environmental disturbances that can spark a cascade effect of deterioration that could impact a community's wellbeing down the line.

Ocean acidification resulting from the increase in atmospheric GHG emissions is well documented; however, acidification resulting from increased concentrations of sulfur oxides, metals and PAHs from discharged washwater from vessels is a phenomenon not fully understood yet.[28] As explained before, open-loop scrubbers use seawater to "clean" exhaust fume contaminants, but as this seawater (now with higher concentrations of pollutants) is discharged back into the ocean, this technology is essentially transferring pollution from what would have been air emissions, directly into the marine environment.[29] As these substances enter ocean waters, reactions take place—meaning the environment undergoes a series of changes that will, eventually, affect living organisms—especially those unable to move to more stable or favorable areas and ecosystems.[26]

Metal and PAH concentrations will be higher in bodies of water where water circulation is low—such as estuaries or closed bays—and environmental conditions will also affect how fast these substances are degraded or removed from the water column.[30,26] A study found that PAHs require between 3 and 500 days to reduce its initial concentration in half depending on the environmental conditions present at discharge sites. [26]

This means that, to more accurately quantify how much scrubber discharge can impact an ecosystem and the species living in it, we must first understand the original environmental conditions of the area in question. For example, scrubber discharge will add to existing pollution levels, yet some pollutants may already be present at dangerous levels in certain areas.[31,26]

[28] Teuchies, J., T.J.S. Cox, K. Van Itterbeeck, F.J.R. Meysman and R. Blust. (2020). The impact of scrubber discharge on the water quality in estuaries and ports. Environ Sci Eur 32:103. https://doi.org/10.1186/s12302-020-00380-z
[29] Georgeff, E. (2020). A killer whale's tale: Protect critical habitats by addressing scrubber washwater from ships. Available at https://theicct.org/blog/staff/killer-whale-tale-scrubbers-062020
[30] Georgeff, E., X. Mao and B. Comer. (2019). A whale of a problem? Heavy fuel oil, exhaust gas cleaning systems, and British Columbia's resident killer whales. International Council on Clean Transportation. Washington D.C. 33 pp.
[31] Magnusson, K., P. Thor and M. Granberg. (2018). Scrubbers: Closing the loop Activity 3: Task 2 Risk Assessment of marine exhaust gas scrubber water. Report number B 2319. IVL Swedish Environmental Research Institute Ltd. 45 pp.

3.1 Effects from Acidification of the Marine Environments (pH)

Compared to preindustrial times, the world's ocean's pH has decreased on average by 0.1 pH units, from 8.2 prior to the Industrial Revolution, to 8.1 at present. This represents a 25% increase in acidity.[32,33] As seawater becomes more acidic (i.e. lower values on the pH scale), carbonate becomes less available for animals and can cause shells and skeletons to become brittle or dissolve. Dissolved CO_2, carbonic acid, bicarbonate, and carbonate exist in balanced proportions in seawater. This balance is altered as CO_2 in seawater increases, thus causing the carbonate ion concentration to decrease as it is transformed to bicarbonate.[30,31]

The acidification effect of metals and PAHs from wastewater discharges from scrubbers can be greater than that caused by anthropogenic CO_2 atmospheric emissions. Open-loop scrubber systems depend on the alkalinity of the sea to neutralize the acid ions which, even in coastal areas, can be high enough to remove excess SO_x from the water.[34,26]. In close-loop systems however, sulfur compounds with a large acidifying capacity from the fuel are discharged straight into the water. [26] In an environment that may be already suffering from the effects of ocean acidification, washwater discharges add to this environmental stress.

Furthermore, the seawater's pH is extremely important because organisms depend on it for different biological processes. Whether it be maintaining for an adequate physiological pH balance or being able to assimilate calcium carbonate to form skeletons and shells, marine species depend on a stable environment for their survival.[32,30] Echinoderms, mollusks and corals create calcium carbonate structures, a process which requires energy and, as pH decreases (or acidity increases), this mineral becomes less available. Additionally, over the past years, researchers have documented how ocean acidification—increasing due to climate change—causes shells and skeletons to dissolve as water pH decreases.[30]

Lastly, lower seawater pH also compromises larvae development and the overall fitness of marine species. Particularly for marine mammals and sea birds, the impact of ocean acidification might not be as direct, but it will become apparent as the entire marine food chain shifts.[32]

3.2 Temperature

Water temperature in specific areas may also increase as washwater is discharged back into the marine environment. Changes in water temperature can affect an organism's metabolic rate, and once pH is factored in, there could be a combined effect. Species that are fixed to the sea floor,

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[32] United States Environmental Protection Agency. (September 30, 2021). Understanding the Science of Ocean and Coastal Acidification. EPA, USA. https://www.epa.gov/ocean-acidification.

[33] National Oceanic and Atmospheric Administration. (April 1, 2021). Ocean Acidification. NOAA, USA. https://www.noaa.gov/education/resource-collections/ocean-coasts/ocean-acidification.

[34] Lange, B., T. Markus, and L.P. Helfst. (2015). Impacts of scrubbers on the environmental situation in ports and coastal waters. Umweltbundesamt. Germany. 88 pp. http://www.umweltbundesamt.de/publikationen/impacts-of-scrubbers-on-the-environmental-situation

or have limited movement, are impacted the most by changes in water temperature. Oxygen solubility is temperature dependent; as temperature increases, oxygen decreases (Lange et al., 2015). Thus, areas with limited water circulation and where vessel traffic is constant should receive special attention and constant monitoring, as these are areas where impacts will be more evident, and temperature could play a role in those too.

In addition, exhaust gas cleaning systems discharge water may affect phytoplankton, as it is mostly found in the upper layers of the water column where light is abundant and where this water is discharged. Changes in water temperature may catalyze a change in species composition, and an abundance in phytoplankton species, which in turn can spark a cascade of changes throughout the food web.[32]

3.3 Toxicity

Heavy metals and PAHs persist in the marine environment and are of major concern since they are ingested and absorbed by living organisms. Pollutants can be found throughout the entire food chain, from zooplankton (the base of food chain) to top predators, such as whales and sharks.[32] This phenomenon is known as bioaccumulation, and it refers to the accumulation of substances in an organism at a faster rate than the rate at which the substance is eliminated.

Heavy metals occur naturally in the environment; some are essential nutrients (zinc, iron, copper), while others are toxic (lead, mercury, cadmium). Heavy metals are not biodegradable, which means their concentration in an organism's tissues will increase as an organism continues to feed on contaminated preys. PAHs are organic pollutants that are not easily biodegraded and can damage DNA.[32,27]. Marine mammals and fish are known to store (bioaccumulate) these pollutants in their blubber, liver, muscles, and kidneys. When these pollutants are metabolized, they can cause damage to the animals' immune, reproductive, nervous, and digestive systems.[27] There are numerous studies on the effect of PAHs on marine mammals worldwide, several of which report high incidences of cancers.[28]

Magnusson et al. found that water from an open loop scrubber system was more toxic than that of a closed loop system.[29] However, even at low contaminant concentrations, zooplankton was affected, which can lead us to believe that the dilution of effluent water alone will not address the threat of toxicity. To fully understand the extent of scrubber discharge toxicity, other sources of pollutants need to be identified—including power plants and all types of ships.

3.4 Eutrophication

Eutrophication is characterized by excessive plant and algal growth due to the increased availability of one or more limiting growth factors needed for photosynthesis, such as sunlight,

carbon dioxide, and certain nutrients.[35] Although this occurs naturally, human activities have accelerated the rate and extent of eutrophication in some places, especially in coastal areas.

Scrubber washwater contains nitrate, which is a nutrient that can act as a fertilizer when in high concentrations. As more "food" becomes available for plants and algae, their biomass will increase, causing water turbidity to increase too.[32] Eutrophication can lead to oxygen depletion and the creation of "dead zones", where water conditions are so poor that it becomes difficult for other organisms to thrive and, in extreme cases, can become a hazard for human health.[30,31]

3.5 Turbidity

Turbidity refers to the relative clarity of a liquid and is measured by the amount of light that is scattered by suspended material when light is shined through it.[36] The more particles are suspended in the water sample, the higher the turbidity. In the context of this report, scrubber discharge can increase turbidity, and this means less light will penetrate the water column. A decrease in light can then affect natural processes from living organisms such as photosynthesis, which in turn can impact the amount of food available for species higher up on the food web. Additionally, the suspended solids may contain pollutants, including heavy metals and PAHs, which can be ingested and bioaccumulated by fish and other species (Lange et al., 2015) and thus worsening other effects of scrubber washwater.

Overall, washwater discharged by ships' exhaust gas cleaning systems has been found to be toxic for marine organisms by multiple studies, and in multiple ways. With a greater number of vessels opting for scrubber technology instead of using low sulfur fuels available and considering that marine ecosystems are already under pressure from pollution and ocean acidification from climate change, these studies have concluded that the discharge of scrubber washwater should be restricted or, at the very least, regulated (particularly within sensitive marine ecosystems and in areas where water circulation is low). Furthermore, as scientific evidence is still scant, having a baseline of current ecosystems' health is crucial, as this will allow for a better understanding of the magnitude of harmful impacts resulting from scrubber discharge.

[35] Chislock, M. F., Doster, E., Zitomer, R. A. & Wilson, A. E. (2013) Eutrophication: Causes, Consequences, and Controls in Aquatic Ecosystems. Nature Education Knowledge 4(4):10 https://www.nature.com/scitable/knowledge/library/eutrophication-causes-consequences-and-controls-in-aquatic-102364466/

[36] USGS

4. Proposed Solutions to Mitigate EGCS's Pollution and its Impact on the Marine Environment

4.1 International Level

As EGCSs are meant to provide an alternative compliance method for IMO 2020's regulation on sulfur limits for vessels bunker fuel oil—an alternative that the IMO itself authorizes—it would then be possible for the IMO to stop allowing such an alternative. This would de facto make scrubbers useless, as ships would be forced to use low-sulfur fuels to comply with IMO 2020. IMO would then have to establish a timeline for phasing out existing scrubbers. However, as has happened with previous regulations, IMO's processes are long and experts think such a ban could take up to a decade to come into effect. Member countries negotiations would take several years to conclude, plus two additional years for the changes to become enforceable once an IMO regulation is agreed upon. Furthermore, ship owners will likely lobby hard against such a ban, as they have spent millions of dollars in retrofitting old vessels with scrubbers—and manufacturing new ones.

Nonetheless, in response to growing concerns regarding the adverse effect of scrubbers' washwater on marine ecosystems, the IMO has ordered an independent review, led by a task force of their Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP),[37] to "*assess the available evidence relating to the environmental impact of discharges of exhaust gas cleaning system effluent*". This seems to hint that, at the very least, the issue is being discussed at the IMO-level.

4.2 Particularly Sensitive Sea Areas (PSSAs)

Another perhaps incomplete, or temporal, solution proposed by the International Council on Clean Transportation is that the MEPC passes a resolution calling on vessels to immediately stop discharging scrubber washwater in Particularly Sensitive Sea Areas (PSSA), Marine Protected Areas (MPAs), and other vulnerable marine ecosystems. This just while other more comprehensive solutions or measures are taken.

A PSSAs is an area "*of the marine environment that needs special protection through action by the International Maritime Organization because of its significance for recognised ecological, socioeconomic, cultural heritage or scientific attributes that may be at risk of damage from international shipping activities*".[38] These sites, once designated by the IMO, are protected through Associated Protective Measures (AMP), which are aimed at preventing, reducing or eliminating the threat or identified vulnerability of the area, and have to be approved and

[37] https://www.lexology.com/library/detail.aspx?g=9fd86518-3794-4ddb-9ced-3744084bd8d0
[38] Australian Maritime Safety Authority Fact Sheet

adopted by the IMO as well.[39] In this way, all vessels, navigating with any flag through a PSSA, must comply with the Area's APMs. It is relevant to note however, that from all PSSAs associated protective measures, none is meant to target scrubber effluents in particular.

The ICCT analysis from April 2021 shows[40] that vessels are expected to discharge at least 665 Mt of washwater per year in PSSAs, out of the total of 10 Gt of effluents. *Table 2* below shows the discharges that happened in PSSAs in the Americas, as well as the reason for the PSSA designation, the extension of the PSSA, and the discharged water amount, in Mt. The PSSA that received the highest amount of effluents was, by and large, the Florida Keys, in the United States—a locale that is highly dependent on tourism. On the other hand, the only PSSA in the Americas that was spared from scrubber effluents was Colombia's Malpelo Island, a UNESCO Biodiversity World Heritage Site, and the smallest of the PSSAs with an extension of only 600 km_2.

Table 2: Washwater discharges in PSSAs in the Americas, based on 2019 vessel traffic patterns.

Name	Region	Reason for designation	Area (km2)	Discharge water (Mt)
Florida Keys	South Florida, U.S.	Threatened reef system	13,000	2
Papahanaumokuakea Marine	Western Hawaii, U.S.	Threatened reef system	440,000	0.16
Galapagos Archipelago	Ecuador	Protecting endangered marine life	144,000	0.13
Archipielago Sabana Camaguey	Cuba	Threatened reef system	38,000	0.08
Saba Bank	Caribbean (owned by Netherlands)	Threatened reef system	2,700	0.009
Paracas National Reserve	Coast of Peru	Protecting endangered marine life	2,900	0.003
Malpelo Island	Columbian waters	Protecting endangered marine life	637	n/a

Own table. Source: *Global scrubber washwater discharges under IMO's 2020 fuel sulfur limit*, ICCT, 2021

PSSAs are not designed with the objective of protecting marine sites from scrubber pollution and, as explained before, EGCS washwater is discharged too inside these internationally protected waters. In that regard, it could prove beneficial to designate a PSSA around a marine ecosystem that is vulnerable, and this designation could help protect it from scrubber pollution—if it were to be accompanied by other national/site-specific regulations and APMs. This could also become an avenue to protect these sites from scrubber discharge if the IMO were to eventually ban the use of this technology, or at least open-loop systems, from all designated PSSAs as suggested by the ICCT.

[39] APMs require a separate approval process in the relevant sub-committee of the IMO.
[40] *Global scrubber washwater discharges under IMO's 2020 fuel sulfur limit*, ICCT, 2021

4.3 Regional and National Levels

On the other hand, some jurisdictions have already taken measures to mitigate scrubbers' washwater pollution through regulations of their own. If a ship is installed with a hybrid- or closed-loop system and enters a port where discharging is banned, it must operate on a zero-discharge mode. Similarly, if the vessel it is retrofitted with an open-loop scrubber, it must then make a fuel change to use a compliant-fuel oil and make no use of its EGCS.

At the national level, there are now several countries across the Americas that ban scrubber washwater from being discharged throughout their national waters—such as Belize, which established since 2018 that, "*Discharge of Exhaust Gas Cleaning Wash Water is prohibited in territorial waters and port areas*".[41] According to this report, the nation-wide approach to scrubber effluents could further benefit from a regional implementation, in which multiple countries harmonize EGCSs bans, thus covering entire marine ecosystems and animal migration routes that cross political borders.

When the pollution issue is heavily localized in certain areas or ports, or when there is no political support to pursue a nation-wide ban, there are a few options on the table too. On the one hand, ports can actively ban washwater discharges under their jurisdiction (i.e. at ports waters). Such is the case in Port Canaveral, in Florida, or at Sept-Iles, in Canada. On the other hand, this could be pursued at the state-level, as in the case of California or Connecticut. When this is the case, it is desirable for ports to install infrastructure for vessels to plug in to onshore power; otherwise, ships will be forced to use low-sulfur fuel oil. Lastly, nations can choose to ban scrubber discharge from certain zones, called "Special Areas". This is the case of the Panama Canal in the Western Hemisphere, as well as other sites such as Gibraltar, and certain domestic control areas delimited in China.

According to evidence found by the ICCT, results from territorial water-bans in contrast to port-wide bans or state-wide regulations depend on multiple factors—aside from enforcement—such as the size of the overall national waters compared to the size of the ban, as well as port busyness. For instance, countries whose national waters are not vast can achieve good results in avoiding washwater discharges by simply implementing bans in their busiest ports. The ICCT analysis mentions places like Singapore and Bahrain, which, by banning discharges at their ports only, managed to reduce EGCS effluents by 67% and 100%, respectively. However, these are both small nations (with 283 and 300 square miles each, respectively).

However, in most other cases, evidence suggests bans to be more effective in reducing marine pollution from scrubbers when establishing a nation-wide ban. Per the ICCT report, for instance, national waters from the United States are expected to receive over 300 Mt per year of scrubber washwater—as bans are only localized in certain states. According to the ICCT, "*Countries that*

[41] Per Belize's Marine Circular 01/2018 – BPA/MS/23-1/2018(98), dated 12/12/2018.

adopted bans on scrubbers only for selected ports ended up with the lowest effectiveness—less than 14% in all cases".[42] This will be addressed in further detail in section (5) of this report.

5. Current Scrubber Discharge Bans in Sites across the Americas

Currently, eight sites in the Western Hemisphere ban EGCS discharges in some shape or form (ten if we count Argentina and Brazil, whose bans are not currently active). See *Table 3* for details. From the total of ten bans, four cover the country's entire territorial waters; two are state-wide bans; one is at a Special Area (the Panama Canal); and three cover discharges at port terminals only.

Table 3: Sites in the Americas that ban scrubber discharges.

Ban Site	Country	Type of Ban	Status
Argentina	Argentina	Territorial Seas	Inactive due to COVID-19 protocols. Scrubber washwater discharge prohibited.
Belize	Belize	Territorial waters and port areas	Active. Scrubber washwater discharge prohibited.
Bermuda	Bermuda	Territorial Seas	Scrubber washwater discharge prohibited.
Brazil	Brazil	Territorial Waters	Inactive. Scrubber washwater discharge prohibited. Active at *Vale* company's terminals only.
California	United States	State territorial waters and ports	Active. All scrubbers banned, including closed-loop. Mandatory to change to compliant fuel.
Connecticut	United States	State territorial waters and ports	Active. Ban on all discharge of exhaust gas scrubber washwater.
Panama Canal	Panama	Special Area	Active. Ban on open-loop and hybrid scrubbers at the Canal.
Port Canaveral, Florida	United States	Port Terminals	Active. Scrubber washwater discharge prohibited.
Port of Seattle, Washington	United States	Port Terminals	Active. Prohibits all scrubber discharges from cruise ships at berth.
Port of Sept-Îles, Quebec	Canada	Port Terminals	Active. Ban on open-loop scrubbers in port boundaries.

Own table. Multiple sources.

[42] https://theicct.org/sites/default/files/publications/scrubber-discharges-Apr2021.pdf

Argentina

Argentina passed in early 2020 Regulation No. 15/2020,[43] which came into force in August 2020, prohibiting discharge of washwater from exhaust gas cleaning systems of national- or foreign-flagged vessels traveling into Argentinean jurisdictional sea or river waters. Such law is regulated by the Environment Protection Bureau and enforced by the *Prefectura Naval Argentina*. It was passed under an environmental precautionary principle, under the premise that "*EGCS washwaters may be toxic*" and requires further investigation to avoid polluting the marine environment.[44] However, the *Prefectura* suspended this regulation's enforcement starting October 3rd of the same year, and until further notice, citing the COVID-19 sanitary emergency (as the pandemic complicated the transportation of specialized personnel to help enforce it). [45]

Belize

In 2018, the government of Belize banned exhaust gas cleaning system washwater in all territorial waters and port areas. Such regulation is enforced by the Belize Port Authority.

Bermuda

Bermuda, in the Caribbean, has an "Environmental Policy for Ships" since December 2019 under which, "*Wash-water and residue from the with Exhaust Gas Cleaning Systems (EGCS) shall be not disposed of in Bermuda or discharged into Bermuda's waters but shall be stored on board the ship until outside of Bermuda's waters*".[46] Authorities thus ask that all vessels equipped with an EGCS entering Bermuda waters notify port authorities in advance. Such policy is regulated by the Department of Environment and Natural Resources—which has a broad mandate to *"protect Bermuda's environment and responsibly manage its natural resources"*.

Brazil

Brazil banned the discharge of effluents generated by scrubbers while on Brazilian territorial waters prior to July 2020. However, on that date, the Directorate of Ports and Coasts (DPC) of Brazil—the regulating authority within jurisdictional waters—made a clarification to such regulation and changed its previous guidance, indicating that, "*the discharge of wash water from open loop and/or hybrid Exhaust Gas Cleaning Systems is allowed within Brazilian Jurisdictional Waters until the competent environmental authority has the opportunity to better assess the scenario*". This, under the assumption that the vessel's scrubbers are so approved by IMO's Marine Environment Protection Committee's 2015 Guidelines for Exhaust Gas Cleaning Systems (MEPC.259 (68)) previously mentioned in this report.

Within Brazilian waters, mining multinational firm *Vale S.A.*, and one of the largest logistics operators in the country, does not allow EGCS effluent discharges of vessels operating in its

[43] https://www.argentina.gob.ar/normativa/nacional/disposici%C3%B3n-15-2020-340875/texto
[44] Ibid.
[45] https://www.argentina.gob.ar/normativa/nacional/disposici%C3%B3n-22-2020-342837/texto
[46] https://www.gov.bm/environmental-policy-ships

Brazilian ports and terminals. The company requires ships to change to IMO-compliant fuel before entering contiguous zones or coastal waters (24 nautical miles from the coastline).

It is interesting, however, that a scrubber effluent ban existed in Brazil up until July 2020 and was later scrapped, only a few months after IMO 2020 entered into force, citing the need to further assess the impact of such technology by environmental authorities. This reversal of an existing, preventive environmental regulation comes in opposite direction as the one seen in other countries or ports of the hemisphere which have, on the contrary, established a ban while authorities and experts further investigate the potential negative effects of EGCS effluents on the marine environment.

California, United States

The California Air Resources Board (CARB) issued *Marine Notice 2020-1*[47] in January 2020 with an "Advisory to Owners or Operators of Ocean-Going Vessels Visiting California Ports" establishing that "*Ocean-Going Vessels (OGV) Fuel Regulation requires the use of marine distillate grade fuel with a maximum sulphur level of 0.1%...within Regulated California Waters (all waters within 24 nautical miles of the California baseline)."* It also mentions specifically that alternative emissions control technologies such as scrubbers are not allowed. This means all ships going into California waters must change fuels to LSFO to comply.

This is in contrast to coastal waters in the rest of the United States—covered by the North American Emissions Control Area with sulfur limits of 0.1 percent—which does allow for "alternate compliance methods" such as EGCS. Furthermore, the North American ECA regulation only requires vessel fuels to meet sulfur content requirements, in contrast to California waters, which also require fuels to meet specifications for distillate grades (only permitting marine gas oil or marine diesel oil). As such, California's emissions and effluents regulations are one of the strictest in the country.

Connecticut, United States

The state of Connecticut does not allow EGCS washwater discharges in its ports or territorial waters from any vessel, per the state's Water Quality Standards (WQS) set by Connecticut's Department of Energy and Environmental Protection, and Connecticut General Statutes' Water Pollution Control, Section 22a-427. This regulation requires ships to either use low-sulfur fuels, or instead, closed-loop scrubbers in zero-discharge mode, and is included in the "VESSEL GENERAL PERMIT FOR DISCHARGES INCIDENTAL TO THE NORMAL OPERATION OF VESSELS (VGP)" published by the U.S. Environmental Protection Agency (EPA) in 2013, under Section 6.5.9 pertinent to the state of Connecticut.[48]

[47] https://ww2.arb.ca.gov/sites/default/files/2020-01/Marine%20Notice%202020-1_final_rev_ADA.pdf
[48] https://www3.epa.gov/npdes/pubs/vgp_permit2013.pdf

EPA's 2013 VGP sets the applicable regulations for vessel discharges and ballast waters, and any applicable state and local government requirements, incidental to the normal operation of commercial, non-fishing vessels greater than 79 feet in length, and is in effect until "new regulations are final and enforceable."[49]

Panama Canal, Panama

In the case of the Panama Canal, the government of Panama issued *NOTICE TO SHIPPING No. N-1-2020*[50] in January 2020 to establish vessel requirements, under which, "*The use of open loop scrubbers or hybrid scrubbers in open loop mode is prohibited in Panama Canal waters. Vessels opting to use closed loop scrubbers or hybrid scrubbers in closed/zero discharge mode shall submit documents to the panama-canal authority*." As such, this regulation forces vessels to either change to low-sulfur fuels or to operate in zero-discharge mode and retain and collect scrubber residues on board. For the latter option, the authorities require all vessels to submit certain documents related to scrubber certification and volume of effluent-holding tanks, at least 96 hours in advance to entering Panama Canal Waters.

This regulation is enforced by the Panama Canal Authority. As a major logistical hub and international route for maritime trade, this site reported more than 250 million long tons of cargo in the 2019 fiscal year and registered a total of 13,785 transits, reason why the port authority heavily regulates all vessel effluents and water residues.

Port Canaveral, Florida, United States

Port Canaveral allows scrubbers as an alternative method of compliance for IMO 2020's fuel sulfur limits, yet bans EGCS effluent discharges in port waters. Per the Port Authority Tariff No.16, Rule 500, "*It shall be unlawful for any person, company or corporation to deposit, place or discharge into the waterways of Port Canaveral…ship engine exhaust scrubber washwater effluent discharge, or any other matter, which is capable of producing floating matter or scum on the surface of the water, sediment on the bottom of the waterways, turbid water within the water column, or the odors and gases of putrefaction."* [51] This means vessels can either change to sulfur-compliant fuel, or else use closed-loop scrubbers in zero-discharge mode.

Similar to the Panama Canal, Port Canaveral in Florida is one of the busiest ports globally, both for cargo and for cruise ships and tourism, as it is the gateway to Disney World in Orlando. About 4.5 million cruise passengers went through Port Canaveral during 2016 alone, and it moves over 6 million short tons of bulk cargo yearly.

[49] https://www.epa.gov/vessels-marinas-and-ports/vessels-vgp
[50] https://www.egcsa.com/wp-content/uploads/N01-2020.pdf
[51] https://www.egcsa.com/florida/

Seattle, Washington, United States

Vessels at berth in the port of Seattle are not permitted to discharge scrubber washwater (whether treated or not) since January 1st, 2020—when IMO 2020 came into effect. As such, the port provides access and infrastructure to shore power. The regulation was put in place citing environmental concerns of potential negative effects from scrubber effluents on the marine environment, particularly at Puget Sound, including water quality: "*As of January 1, 2020, out of an abundance of caution and to aid in preservation of Puget Sound's sensitive marine environments, Port of Seattle prohibits all wash water discharges from cruise ships at berth. This prohibition also will apply to all cruise ships calling on the proposed berth at the new cruise terminal*."[52]

According to authorities, Puget Sound is a sensitive ecosystem prone to poor water quality conditions, and a "*no discharge zone addresses this source of preventable pollution from impacting shellfish beds, beaches, and water quality*."[53] Furthermore, more than half of the state's population lives in the Puget Sound region and is highly dependent on its resources.

It is noteworthy that the Port of Seattle is an important economic driver in the region and one of the largest cruise markets in the west coast of the United States—an industry worth about $900 million/year. To achieve the sustainable growth of the industry, and thus the economy, without jeopardizing the marine ecosystem's health, the port has a voluntary clean water agreement with cruise lines and regulators. The port claims it is the only agreement of this nature in all North America.

Sept-Îles, Quebec, Canada

The industrial port of Sept-Îles in Quebec, Canada, banned open-loop scrubber discharges inside port boundaries. The authority in charge is Transport Canada, a federal institution in charge of promoting safe, secure, efficient, and environmentally responsible transportation. This means that only closed-loop scrubbers are allowed, in zero-discharge mode, or else vessels must change to compliant fuels. The ICCT estimated that the Sept-Îles ban alone has prevented 250,000 tons of scrubber's effluent from being discharged at the Gulf of St. Lawrence, from both bulk carriers and cruise ships.[54]

As we can see in *Table 4* below, from those sites in the Americas included in the ICCT[55] 2021 analysis—namely Brazil, Panama and the U.S.—the most effective ban was Brazil's, which covered the country's full territorial waters, with 100% effectivity (before the ban was reversed). The discharge bans in Panama and the United States fare much less effectively, with 27% and 14% effectivity, respectively. These two countries, however, are regulating discharge washwater

[52] https://www.portseattle.org/sites/default/files/2021-04/PORT_2102_Sustainble-crusing_FIN.pdf
[53] Ibid.
[54] https://gsgp.org/media/mchnfs21/green-marine-9-21.pdf
[55] *Global scrubber washwater discharges under IMO's 2020 fuel sulfur limit*, ICCT, 2021

in small areas relative to their own territorial waters—Panama at the Panama Canal only, and the U.S. in certain ports and certain states only—reason the ICCT finds guilty of such a low efficacy of the ban in mitigating scrubber pollution.

In fact, Brazil's ban was one of only three bans globally that was 100% efficient in avoiding scrubber discharge (i.e, that managed to prevent 100% of the effluents it would have occurred without such a regulation in place). The other two nations that achieved such a result were Malaysia and Bahrain, from which Malaysia issued a ban that prohibits discharges in all territorial waters, and Bahrain's covers all ports only. In the case of Bahrein, however, being such a small nation likely plays an important role in this result, with only 303 sq. miles of extension.

Table 4: Avoided discharges in territorial seas and internal waters due to scrubber discharge bans in countries across the Americas, from those studied in ICCT's 2021 analysis.

Country	Washwater in territorial seas, internal waters, ports & combined		Where ban is implemented	Banned discharge water by current regulation
	No-ban scenario (discharged)	Ban scenerio (not discharged)		
Brazil	34	34	Territorial seas	100%
Panama	11	3	Special zones	27%
United States	170	23	Special zones	14%
Total/Average	**215**	**60**		**47%**

Own table. Source: *Global scrubber washwater discharges under IMO's 2020 fuel sulfur limit*, ICCT, 2021

In addition, a few other sites in the hemisphere have special requirements/standards for scrubber effluents (beyond those established by the own IMO's MEPC 2015 guidelines), with the goal of limiting its polluting effects. See *Table 5* below.

Table 5: Sites in the Americas with EGCS effluents special requirements

Site	Country	Type of Ban	Status
Hawaii	United States	State territorial waters	Active. Imposes special water quality criteria.
Port Everglades, Florida	United States	Port Terminals	Active. License to discharge needed, plus special water quality criteria.
Port of Vancouver, Vancouver	Canada	Port Terminals	Optional to plug in to shore power at port, while at berth. Currently, an amendment proposed to ban all discharges at port (as of November 2021).

Own table. Multiple sources.

To this effect, the state of Hawaii sets special parameters for EGCS effluents in EPA's 2013 Vessels General Permit (VGP), section 6.7 for the state of Hawaii.[56] Under these rules, scrubber effluents are allowed, yet are subject to strict additional quality requirements by Hawaii's Clean Water Branch *Blanket Section 401*, on Water Quality Criteria, which covers 27 categories of effluent discharges—including EGCS. Relative to EGCS, the state established special limits for both pH and turbidity. Such requirements are set by the state's Department of Health Clean Water Branch.

This regulation states that all EGCS discharges must "*have received the best control or treatment into waters of the State of Hawaii incidental to the normal operation of the applicable vessels*". Furthermore, EGCS discharges may not be allowed if:

- The system has no wash water treatment, so the discharge has not received 'best control or treatment'; and,
- The discharge cannot meet limits in Hawaii's Administration Rules Title 11, Chapter 54 and VGP table 6.7.1 (shown below as *Table 6*).

Table 6: Parameters and limitations contained in Table 6.7.1 from EPA's 2013 VGP, applicable to all discharges from a vessel in Hawaii state waters:

Parameter	Limitation in Fresh waters	Limitation in Salt waters	Units
Chlorine, Total Residual Chlorine (TRC)	19.0	13.0	µg/l
pH	Shall not deviate more than 0.5 units from ambient conditions and shall not be lower than 5.5 nor higher than 8.0	Shall not deviate more than 0.5 units from a value of 8.1, except at coastal locations where and when freshwater form stream, storm drain or groundwater discharge may depress the pH to a minimum level of 7.0	pH Unit
Turbidity	25.0	5.0	NTU
Temperature	Shall not vary more than one degree Celsius from ambient conditions.	Shall not vary more than one degree Celsius from ambient conditions.	°C
Enterococcus	Enterococcus content shall not exceed a geometric mean of 33 per one hundred milliliters in not less than five samples which shall be spaced to cover a period between 25 and 30 days. No single sample shall exceed the single sample maximum of 89 CFU per 100 milliliters or the site-specific one-sided 82 per cent confidence limit.	Within 300 meters (one thousand feet) of the shoreline, including natural public bathing or wading areas, enterococcus content shall not exceed a geometric mean of 35 CFU per 100 milliliters in not less than five samples which shall be spaced to cover a period between twenty-five and thirty days. No single sample shall exceed the single sample maximum of 104 CFU per 100 milliliters or the site-specific one-sided 75 per cent confidence limit. Marine recreational waters along sections of coastline where enterococcus content does not exceed the standard, as shown by the geometric mean test described above, shall not be lowered in quality.	CFU

Source: EPA (https://www3.epa.gov/npdes/pubs/vgp_permit2013.pdf)

[56] https://www3.epa.gov/npdes/pubs/vgp_permit2013.pdf

Similarly, Port Everglades in Florida has established since October 2019 water quality and effluent standards that include specific limits on PAH, pH, turbidity, and metals that any vessel discharge, including that from scrubbers, must comply with. Such limits must comply with the Broward County Code of Ordinances, and it requires vessels to obtain a license to discharge. Such rules are enforced by the Broward County Environmental Protection and Growth Management Department.[57]

In a different approach, the Port of Vancouver gives cruise ships the option—but is not mandatory—to "plug-in" to the electrical grid to use shore power instead of burning fuel while at berth. In this case, this brings benefits in terms of air emissions too, since power at this site comes primarily from hydroelectric power, according to port authorities. However, this only avoids EGCS discharges from ships that connect to the grid, and only at the time when at berth. In addition, it is important to mention that not all ships are retrofitted to run their complete systems on shore power only.

Using data from the Vancouver Fraser Port Authority, the ICCT calculated that, if all cruise ships that plugged in to shore power at this port, in a given year, were scrubber-equipped too, this option provided to vessels would avoid around 280,000 tons of scrubber washwater.

Taking a step further, the Port Authority proposed[58] in November 2021 an amendment to the city's scrubber regulation to ban vessels' discharges while at port, effectively forcing ships to use either closed-loop scrubbers at no-discharge mode, or to change to sulfur-compliant fuel: *"The discharge of wash water from exhaust gas cleaning systems (EGCS) from all fuel combustion machinery (excluding main engines) into the environment is not permitted while a vessel is at anchorage or at berth within the Port of Vancouver. This applies to the wash water from open-loop and closed-loop EGCS."* Such reform already received public comments, which are under review before a final decision and publication is made by the authorities. Here, the ICCT notes an important loophole in the proposed amendment, in that it would not ban effluents from fuel combustion of the ships' main engines—which could heavily undermine the desired results of the new regulation.

As a last step, a second phase of the amendment would be eventually proposed to prohibit discharges in all waters within the Port Authority's jurisdiction (and not only while at anchorage or at berth), and a third and last phase would outright prohibit the use of scrubbers within the same area—effectively forcing vessels to switch to low-sulfur fuel oils.[59]

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[57] https://assets.simpleviewinc.com/simpleview/image/upload/v1/clients/porteverglades/1015_10012019rv2_fd9b0230-d200-4476-bc88-181c1d7637f5.pdf

[58] https://www.portvancouver.com/wp-content/uploads/2021/11/2021-11-24-Notice-of-Amendment-Port-Information-Guide.pdf

[59] https://theicct.org/vancouver-can-marine-scrubber-reg-jan22/

6. Conclusions

The International Maritime Organization (IMO) imposed a new limit on sulfur content for bunker fuel of 0.5% (down from 3.5%), starting in January 2020. This regulation, known as IMO 2020, is meant to tackle air contaminants from the maritime sector—particularly SO_2 emissions—and to help mitigate climate change. Amongst the different avenues to comply with IMO 2020, however, there is a technology that allows for ships to continue to burn heavy fuel oil (with higher sulfur content), using an Exhaust Gas Cleaning System (EGCS), or scrubber.

Scrubbers effectively decrease the sulfur content from ships' exhaust gases, enough to comply with the new IMO-imposed limit. However, this technology uses seawater to decrease SO_x in those gases, and it is then released to the ocean as washwater. This washwater is more acidic than seawater and has been found to contain polluting heavy metals and other contaminants. Heavy metals present in EGCS effluents include vanadium, nickel, copper, cadmium, mercury and lead—a major concern since these are toxic substances that are ingested and absorbed by living organisms and accumulated through the food chain.

Furthermore, the acidic nature of these effluents lowers the pH of the seawater in areas where vessels discharge. This can threaten multiple marine species since it may affect their ability to maintain an adequate physiological pH balance or assimilate calcium carbonate to form skeletons and shells. In addition, scientists also suspect the acidification of the oceans resulting from increased concentrations of sulfur oxides, metals and PAHs from discharged effluents from vessels can be an important issue moving forward, as it would contribute even further to human-induced climate change. As such, it is something that requires further investigation. Yet, overall, there is ample evidence that these effluents have negative impacts on the marine environment, because they alter the delicate balance of these ecosystems (through changes in temperature, turbidity, pH and other factors), and by directly affecting multiple marine species through its polluting nature.

Out of all types of vessels, cruise ships were found by the International Council on Clean Transportation to be the one type that is most inclined to be retrofitted with an EGCS, as opposed to switching to low-sulfur fuel oil. All major cruise companies are retrofitting most of their fleets with this technology. And even though cruise ships represent only 4% of the totality of the scrubber-equipped fleet by number of ships, they are responsible for 15% of total EGCS yearly effluents. Importantly, these effluents occur even when cruises are at berth or anchored at ports; not only when in movement or when passenger-related operations are active. Cruises are in fact the main contributor to scrubber discharges in ports, as they spend around 25% of their time at berth and, on average, consume three times as more energy per hour spent at port than oil tankers, and six times more than container ships.

As the long-term impacts of EGCSs washwater on marine ecosystems are still unknown and under current investigation, several countries and ports around the world are banning ships from discharging scrubber effluents into their waters. This is forcing vessels to either use this

technology in zero-discharge mode (thus having to dispose of the residual waters on land or into international waters), or else to switch to low-sulfur fuel oil. Some sites, such as all ports in California, ban the use of scrubbers entirely, forcing vessels to use IMO 2020-compliant fuels.

Action by the IMO to ban scrubbers is, at the moment, unlikely, although this UN agency has already ordered further investigation and review of its impacts on the marine ecosystem through the Marine Environment Protection Committee (MEPC). In the meantime, it is up to each nation or port to impose regulations to mitigate this potential contamination of their coastal waters and ecosystems.

In the Western Hemisphere, eight sites currently ban EGCSs discharges in some shape or form, and ten if Argentina and Brazil are considered, whose bans are not currently active. From those, four are bans that cover the country's entire territorial waters; two are state-wide; one covers a Special Area (the Panama Canal); and three ban discharges at ports terminals only.

In addition, a few other sites in the Americas have special criterion for scrubber effluents (beyond those established by the IMO EGCS 2015 guidelines), with the goal of ensuring effluents are given the best possible treatment before being discharged at sea. To this effect, the state of Hawaii and Port Everglades, in Florida, have both set specific parameters for EGCS effluents that include limits on PAH, pH, turbidity, and metals that all vessels must comply with. In a different approach, the Port of Vancouver provides cruise ships the option—although not mandatory—to "plug-in" to the electrical grid to use shore-power instead of burning fuel while on its terminals. Vancouver's Port Authority also proposed in November 2021 an amendment to its regulation to ban vessel discharges while at port, which would force ships to either use closed-loop scrubbers at no-discharge mode, or to change to sulfur-compliant fuel. A second phase of the proposed amendment, according to the ICCT, would prohibit discharges in all waters within the Port Authority's jurisdiction—not only at its terminals.

In any case, regulations to mitigate the pollution of marine ecosystems by ship scrubbers need to be not only drafted by the authority based on the site's needs and circumstances, but they have to be implemented and enforced by port authorities, which should then conduct regular monitoring of waters to check for levels of pH, heavy metals, PAHs and nitrates. The IMO has no jurisdiction or obligation to enforce such regulations.

According to evidence found by the ICCT, the effectivity of territorial water-bans, in contrast to less extensive bans, such as port-level bans, depends on multiple factors—aside from enforcement—such as the extension of national waters compared to the size of the ban, as well as port busyness. For instance, nations whose national waters are not vast can achieve good results in avoiding scrubber discharge pollution by simply implementing bans in their busiest ports. However, evidence suggests the latter are, in general, less effective: "*Countries that adopted bans on scrubbers only for selected ports ended up with the lowest effectiveness—less than 14% in all cases*".[60]

[60] https://theicct.org/sites/default/files/publications/scrubber-discharges-Apr2021.pdf

Scrubbers are bound to become more popular in the maritime sector, and particularly within the cruise fleets, as it is a more economical solution to comply with IMO 2020—at least at the moment. The number of ships retrofitted with scrubbers went up from 243 in 2015 to more than 4,300 in 2020, when IMO 2020 came into effect. In that sense, it is also safe to assume that at least a percentage of all new vessels will be adapted with this technology. This will remain the case so long low-sulfur fuel options are more expensive than regular heavy fuel oils. Countries, then, have at their disposal different regulations that have already been implemented and tested throughout the Western Hemisphere, which can be implemented according to their needs and resources.

These regulations are active in a variety of locales across the Americas, from ports in California such as Long Beach and Los Angeles, with high fluxes of traffic from cargo ships, to ports that are almost entirely dependent upon tourism from cruise ships, such as Bermuda and Belize, to ports that are sited within sensitive marine ecosystems or prone to poor water quality, such as the Port of Seattle, Washington, in the Puget Sound region in the U.S. Northwest. Until more in-depth research and evidence comes to light specific to the long-term consequences of exhaust gas cleaning system's effluents on the marine environment (and indirectly, humans), and if or while the IMO acts at the international level, it will remain in the hands of individual jurisdictions to protect their marine environments by implementing local, regional or even nation-wide regulations.