Evaluation of the response to emerging environmental threats, focusing on carbon dioxide (CO₂), volatile organic compounds (VOCs), and scrubber wash water (SOₓ)

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Abstract
It has been acknowledged that most international regulations were triggered by a series of tanker disasters that had devastating effects on the marine environment. One way to better protect the aquatic environment is the proactive response of the member states of the various international organisations to expedite the ratification procedures for international conventions, mainly the International Maritime Organization (IMO) legal instruments. Every time this is achieved, ship owners become more responsible for protecting the marine environment, regardless of the economic costs involved. Following this path, ship owners will be obliged to cooperate with competent authorities when a vessel calls at a port for the loading, discharging, bunkering, repairing and other secondary operations, to counter the possible threat of emerging pollution. This paper focuses on issues that are mostly related to the amendments of Annex VI of the MARPOL Convention, which deal explicitly with air pollution. The paper also examines the relationship between technological innovations, the existing regulations and the environmental threats posed by carbon dioxide and volatile organic compounds, and methods to deal with sulphur reduction.

Keywords Volatile compounds · Sulphur emissions · Carbon dioxides · Annex VI of MARPOL · Technical indexes · National policies · International regulations

Introduction
It is widely known that technology and techniques in the shipping industry have changed quite rapidly, particularly in the last decades. As a result, new conventions are required, but existing ones need to be kept up to date; for example, the International Convention for the Safety of Life at Sea (SOLAS) of 1960 was amended six times after it entered into force (in 1965, 1966, 1967, 1968, 1969, 1971 and 1973). In 1974, a completely new convention was adopted, incorporating all previous amendments and other minor changes, and it became the primary convention of the International Maritime Organization (IMO) for maritime safety issues.

The implementation of new legislation or an amendment of an existing one is not part of the work of IMO. The organisation prepares and adopts laws but cannot implement them. This responsibility falls to the governments of the member states. When a state accepts a convention, it becomes part of its national law and it enforces the provisions of the convention as far as its ships are concerned. It also sets penalties for infringements; for example, the International Convention for the Prevention of Pollution from Ships (MARPOL) of 1973 and its protocol of 1978 were ratified by the Greek law 1269/82.

However, before IMO inaugurated the concept of “tacit acceptance”—which allows a convention to enter into force on a particular date rather than requiring explicit approval, to prevent lags of more than 5 years to bring a convention into
force—the adoption and ratification of any important regulations at the international level was time-consuming, especially when dealing with pollution from ships’ operations and when those were involved in an accident (Alexopoulos 1998).

The first convention dealing with oil pollution (and only oil as a pollutant) was the International Convention for the Prevention of Pollution of the Sea by Oil (OILPOL) of 1954, and especially its 1969 amendments, along with the International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties (INTERVENTION) of 1969 and the International Convention on Civil Liability for Oil Pollution Damage (Civil Liability Convention) of 1969. Those were the first three IMO conventions that were the result of the first serious tanker accident, namely the Torrey Canyon1 grounding in the English Channel in 1967. The outcome of this accident was the spillage of almost 120,000 tons of oil into the marine environment, and it became the reason that the international community became aware of accidental pollution from tankers (Alexopoulos 2001).

The MARPOL Convention of 1973 was the first international legal tool that dealt with most types of marine pollution from ships (Szepes 2013). It replaced the last amendments of the OILPOL Convention of 1971, which had never been in force, and it is today considered the primary tool for preventing ship-generated pollution. The MARPOL convention, along with the SOLAS Convention of 1974, was adopted to address severe tanker accidents that have occurred around the globe, with loss of human life and extensive marine pollution (Alexopoulos 2001). Notable examples of tanker accidents in the past in European waters were the Amoco Cadiz (1978)2, the Haven (1991)3, the Erika (1999)4 and the Prestige (2002)5.

So far, we may accept that the entire regulatory system lacks a uniform application of international standards; in other words, it is left to be enforced dependent upon the random application of ship operators. In addition, safety measures have been complicated by jurisdictional issues, technological immaturity and maritime states’ passive attitudes. Also, difficulties in ratification have arisen due to the considerable economic cost and technical hindrance in complying with provisions.

The policy of the shipping industry, and especially the independent tanker owners, has not changed considerably over recent years. Several conventional tankers are still in regular operation (Tromiadis and Stanca 2014), even those fitted with dedicated clean ballast tanks (CBT) in some parts, in inland areas (so-called pre-MARPOL tankers). In the 1990s, as the world fleet was ageing, the resulting surplus of ships led to structural overcapacity, especially in bulk transport. As a result, the law of supply and demand resulted in very low freight rates and a low return on venture capital and investment.

On the contrary, in the late 1990s, freight rates experienced an increase, leading undoubtedly to new tanker orders fitted with double hulls. The bottom line is that in a low freight market, ship owners, instead of sending vessels for scrap or selling them, may react by prolonging the life span of ships and by making cuts in maintenance costs. So the fleet ages, and the risk factor increases.

The member states of IMO must proceed with due speed in adopting and ratifying the main existing conventions so that the international regulatory provisions become municipal law, and must notify their national ship owners about any changes that have been made at the international level. In this paper, we will draw our attention to three new and specific issues that will affect, to a greater extent, shipping operations in the near future, especially when ships (tankers) are within port limits (Boviatsis et al. 2019).

### Annex VI of the MARPOL Convention

A revised Annex VI was adopted in 2005. It entered into force in 2010, phasing in a progressive reduction in sulphur oxide (SOx) from ships and further reductions in nitrogen oxide (NOx) emissions from marine engines. From 1 January 2020, the limit for sulphur in fuel oil used onboard ships operating outside designated emission control areas

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1 The master altered course to the east of the Scilly islands because of ample water through there, and he was notified by the ship’s agent not to waste time or otherwise the vessel would miss the evening tide at the discharge port, delaying for 5 days to berth owing to her deeply laden condition. On 18 March 1967, the vessel struck the Pollard Rock on the Seven Stones Reef at a speed of 17 knots. As a result, thousands of tons of oil was soon spilling from the ruptured tanks.

2 Grounding off the French coast, spilling more than 220,000 tons of oil. Because of this accident, the protocol of the SOLAS Convention of 1978 required essential parts of the steering gear of tankers to be duplicated.

3 The most serious tanker accident, in terms of quantity spilled, in the Mediterranean Sea. The vessel exploded in Genoa roads while anchored awaiting orders, after discharging part of her cargo. It would appear that petroleum gas in the tank was ignited, possibly by an electrical spark, causing the explosion shortly after crude residues had been pumped out.

4 Structural failure off the French coast due to extensive metal corrosion. The quantity lost was not significant (19,000 tons), but the consequences were devastating. It challenged the EU to draft, through the European Maritime Safety Agency (EMSA), two packages relating to pollution from ships and the improvement of port state control procedures.

5 Hull failure in strong gale-force winds off the port of La Corunna, spilling 63,000 tons of oil, cut into two pieces and sank in the open waters, while being refused shelter from the Spanish authorities. Problems with maintenance of the vessel.
The primary type of “bunker” oil for ships is heavy fuel oil, derived as a residue from crude oil distillation. Crude oil contains sulphur which, following combustion in the engine, ends up in ship emissions. SO$_x$ is harmful to human health (Seebens et al. 2013). Limiting SO$_x$ emissions from ships will improve air quality and protect the environment. Annex VI limits SO$_x$ and NO$_x$ emissions from ship exhaust and prohibits deliberate emissions of ozone-depleting substances. DECA}s set more stringent standards for SO$_x$, NO$_x$ and particulate matter (PM). 

According to Regulations 14.1 and 14.4, SO$_x$ and PM emission controls apply to all fuel oil, as defined in Regulation 2.9, combustion equipment and devices onboard, and therefore include both main and all auxiliary engines together with items such as boilers and inert gas generators. Consequently, these fuel oil sulphur limits are subject to a series of step changes over the years:

Annex VI deals with low-carbon shipping and air pollution control and can be divided into two main pillars:

(a) Combatting air pollution from shipping. IMO regulations to address air pollutants from international shipping, particularly SO$_x$ and NO$_x$, have proved successful for lowering the amount of pollutants emitted from ships. Global caps have more stringent requirements in emission control areas (ECAs). Currently, there are four ECAs designated by IMO: (1) Baltic Sea area (SO$_x$ only), (2) North Sea area (SO$_x$ only), (3) the North American area (SO$_x$, NO$_x$ and PM) covering designated coastal areas of the United States and Canada and (4) the United States Caribbean Sea area (SO$_x$, NO$_x$ and PM) around Puerto Rico and the United States Virgin Islands.

In ECAs, the sulphur cap is 0.10% m/m, but outside these areas the global sulphur cap will be cut to 0.50% from 1 January 2020 (from 3.5% m/m currently). Fuel oil providers already supply fuel oil that meets the 0.10% m/m limit (such as marine distillate and ultra-low sulphur fuel oil blends) to ships that require this fuel to trade in the ECAs. In addition, some ships limit the air pollutants by installing exhaust gas cleaning systems, also known as “scrubbers”.

Flag states accept this as an alternative to meet the sulphur limit requirement. These scrubbers remove sulphur oxides and boiler exhaust gases from the ship’s engine. Therefore, a vessel fitted with a scrubber can use heavy fuel oil since the sulphur oxide emissions will be reduced to a level equivalent to the required fuel oil sulphur limit. Ships can have engines that can use different fuels containing low or zero sulphur, i.e. liquefied natural gas (LNG) or biofuels.

Regarding the SO$_x$ regulations, at the 70th session of the Marine Environment Protection Committee (MEPC 70), the IMO members agreed that the 0.50% global sulphur cap would be implemented from the 1st of January 2020. The decision has provided certainty to the maritime and bunker industries. Still, it has also provoked an intense, ongoing discussion at the MEPC on the practicalities of the implementation and ensuring enforcement. Supportive measures were discussed and clarified at MEPC 74 in 2019. If agreed upon, a possible carriage ban for non-compatible fuels is the only measure likely to have a significant impact (Agrawal et al. 2008).

Ship operators will need to determine their preferred compliance strategy, and this decision will have significant operational and financial implications. There is no one-size-fits-all solution. Scrubbers, LNG and “hybrid” fuels are realistic options, but most vessels are expected to default to marine gas oil (MGO). Local availability issues and price volatility are expected as consequences of a dramatically changed fuel demand situation as of 1 January 2020. A significant number of non-compliance cases will likely occur in the transitional period. Enforcement remains a critical concern, particularly on the high seas where flag states are in charge, as opposed to exclusive economic zones (EEZs) where enforcement is a port state matter. Doubts about the readiness of all flag states to ensure uniform enforcement have been expressed. For reasons of international law, IMO cannot be expected to develop effective enforcement measures.

To assist ship operators and owners in planning for the 0.50% sulphur 2020 limit, the MEPC has approved guidance on ship implementation planning. This guidance is part of a set of guidelines being developed by IMO to consistently implement the MARPOL regulation coming into effect from 1 January 2020. The ship implementation planning guidance includes sections on the following:

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6 See at: [www.imo.org/en/OurWork/environment/pollutionprevention/airpollution/pages/sulphur-oxides-(sox)-%E2%80%93-regulation-14.aspx](http://www.imo.org/en/OurWork/environment/pollutionprevention/airpollution/pages/sulphur-oxides-(sox)-%E2%80%93-regulation-14.aspx) (accessed 02/03/2018) (accessed 14/04/2022).

7 See for details at: [http://www.imo.org/en/MediaCentre/hottopics/ghg/pages/default.aspx](http://www.imo.org/en/MediaCentre/hottopics/ghg/pages/default.aspx) (accessed 14/04/2022).
• Risk assessment and mitigation plan (impact of new fuels)
• Fuel oil system modifications and tank cleaning (if needed)
• Fuel oil capacity and segregation capability
• Procurement of compliant fuel
• Fuel oil changeover plan (conventional residual fuel oils to 0.50% sulphur-compliant fuel oil)
• Documentation and reporting.

Only larger ships with gross tonnage (GT) of 400 GT and above engaged in voyages to ports or offshore terminals under the jurisdiction of other parties must have an International Air Pollution Prevention Certificate issued by the ship’s flag state. But all ships will need to use fuel oil that meets the 0.50% limit from 1 January 2020. Some smaller vessels may already be using fuel oil that meets the limit, such as a marine distillate suitable for their engines.

Regarding the NOₓ regulations, NOₓ Tier III requirements have entered into force in the North American ECA for ships constructed on or after 1 January 2016. In essence, anyone constructing a vessel nowadays needs to consider whether the vessel will or might, at some point, operate in the North American ECA. If so, NOₓ control technology will be required for that ship. Additionally, MEPC 71 adopted the MEPC 70 agreement to apply NOₓ Tier III requirements to vessels operating in the North Sea and Baltic Sea ECAs. This will apply to ships constructed on or after 1 January 2021.

(b) Energy efficiency requirements. IMO has established a series of baselines for the amount of fuel each type of ship burns for a specific cargo capacity. Ships built in the future will have to beat that baseline by a set amount, which will become progressively more complex over time. By 2025, all new ships must be 30% more energy-efficient than those built in 2014. Under the energy efficiency regulations, existing vessels must have an energy efficiency management plan concerning improved voyage planning, cleaning the ship’s and the propeller’s underwater parts more often, introducing technical measures such as waste heat recovery systems, or even fitting a new propeller.

The energy efficiency requirements were adopted as amendments to MARPOL Annex VI in 2011, and they entered into force on 1 January 2013. The regulations make mandatory the Energy Efficiency Design Index (EEDI) for new ships, and the Ship Energy Efficiency Management Plan (SEEMP) is a requirement for all ships. In addition, in 2016, IMO adopted mandatory requirements for ships of 5000 GT and above to collect consumption data for each type of fuel oil they use and other additional, specified data, including proxies for transport work. These ships account for approximately 85% of CO₂ emissions from international shipping. The MEPC also approved a roadmap (2017 through to 2023) for developing a “comprehensive IMO strategy on reduction of greenhouse gas (GHG) emissions from ships”, which foresaw the adoption of an initial GHG strategy in 2018.

MEPC 71 agreed to continue its EEDI discussions through a review concluded in 2019. The study considered the reduction levels and the timing of the implementation phases. As a result, phase 3 may be brought forward, and a new phase 4 may be agreed upon, commencing in 2025.

Climate change remains the driving political force behind CO₂ and energy efficiency regulations. In the EU, rules for monitoring, reporting and verification (MRV) of CO₂ emissions have entered into force for all vessels above 5000 GT sailing to or from European ports. Ships must also report cargo data and average energy efficiency. The EU will make the data publicly available on an annual basis. Monitoring plans were due to be submitted to verifiers by 31 August 2017, with 2018 being the first year of reporting. The EU published the first data sets in mid-2019.

The purpose behind the EU MRV regulations was to encourage the IMO to work on a similar mechanism with global rather than regional coverage. Therefore, MEPC 69 agreed on a worldwide mechanism for mandatory MRV of fuel consumption data for all ships of 5000 GT and above. It became known as the IMO Fuel Consumption Data Collection System (IMO DCS) and was adopted at MEPC 70 (2019 being the first year of implementation). Furthermore, MEPC 71 agreed on verification guidelines. The IMO DCS differs from the EU MRV in many aspects, including confidentiality of data, calculation of efficiency metrics and requirements for data verification (Boviatis and Tselentis 2019) (Table 2).

The issue of carbon dioxide (CO₂)

Apart from the MARPOL protocol, there is no other supplementary legislation at the international or regional level aimed at further reducing CO₂ emissions. Still, there is no need for another international agreement. The issue is to implement the existing ones, regardless of whether, for the maritime sector, there are both environmental and economic implications, i.e. through the technological advancements in internal combustion engines and the design of the vessel’s hull and propeller system.

It has been suggested that the existing technologies are obsolete and must be replaced to further reduce CO₂ released into the atmosphere and the marine environment. Of course, some will ultimately be consumed for the CO₂ emissions, but it is rather unlikely that trade could be interrupted. Hence, if any, the new technologies have to be cost-effective and designed in such a manner to be appropriately developed, implemented, and established onboard ships (González 2008).
We already know that from the 1st of January 2019, vessels are obliged to carry an approved SEEMP (it would be evaluated beginning 1 January 2020), which probably means that reliable benchmarking may be created to measure results for CO₂ emissions. Carbon capture and storage (CCS) is one technology that may see wider use. It is a method where the CO₂ is extracted from the exhaust gases produced from the combustion of fossil fuels, compressed and liquefied, and finally stored in pressurised containers. The next step is to further store the CO₂ containers underground in depleted oil and gas fields (Kelektsoğlou 2018).

MEPC 76 adopted MARPOL’s Annex VI amendments on GHG emissions. The objective is to improve the vessels’ energy efficiency by providing essential building blocks for future GHG reduction measures. These new measures will require all ships to calculate their EEXI (energy efficiency index for existing ships) and establish their annual operational Carbon Intensity Indicator (CII) and rating.

The carbon intensity links the GHG emissions to the amount of cargo carried over the distance travelled. Ships will acquire their energy efficiency rating (from A to E, A being the best rating). When a vessel is rated D or E for three consecutive years, it must submit a corrective action plan to show improvements in the required index (Al Baroudi et al. 2021). The new amendments are expected to enter into force by 1 November 2022 and include, among other provisions:

- The EEXI applies from the first annual, intermediate or renewal International Air Pollution Prevention (IAPP) survey after the 1st of January 2023.
- The operational CII rating scheme takes effect from the 1st of January 2023.
- A review clause requires the IMO to check the effectiveness of implementing the CII and EEXI requirements by the 1st of January 2026 and, if necessary, develop and adopt further amendments.

Furthermore, an approved SEEMP must be onboard from the 1st of January 2023. The IMO’s SEEMP guidelines suggest various options to improve fuel efficiency, from speed optimisation and weather routing to timely hull maintenance and engine load efficiency (Nguyen et al. 2021).

In practice, the picture is quite different. It is not easy, at least at this time, for the maritime industry to face such a challenge for the IMO’s decarbonisation initiatives before 2030 or 2050. Ship owners and charterers will first need to show that the vessels they invest in and operate are high performers and that less efficient ships from their fleets are subject to performance improvements.

In parallel, shipyards will prioritise higher-efficiency vessels, and under exceptional circumstances, they may have to improve their standard designs to succeed in the minimum CII levels. Although, so far, the impact of the EEXI has been the critical factor, the CII could prove to have a dramatic effect on the marketability of vessels, as it creates a market mechanism for clients (charterers), financiers and regulators to grade the performers.

A substantial fund (US$ 5 billion) is available for accelerating the decarbonisation process to shipping. It is handled by a new International Maritime Research Board (IMRB) with the participation of many nations. As a result, it is expected that the maritime industry will scale up all the necessary steps for the transition to a green future (Awoyomi et al. 2019).

Volatile organic compounds (VOC)

Most charterers and mariners are aware that because vessels carry high sulphur oil cargoes, after or during discharge operation the cargo tanks are filled with inert gas consisting mainly of CO₂, nitrogen and several toxic hydrogen sulphides (H₂S). Therefore, in most ports, before the ship’s berthing for loading, the vessel must purge its tanks with inert gas to displace the H₂S below a certain level.

This process releases significant amounts of toxic gases and combustion derivatives containing CO₂ into the atmosphere, which contributes to the greenhouse effect. Some ports around the world, i.e. Rotterdam, Ceyhan and the majority of US ports (this number is gradually increasing), have made it mandatory for visiting vessels to use the vapour line to displace to shore facilities all gases contained in the cargo tanks while loading cargoes. The next step is for the land installations to remove the H₂S and release the CO₂ into the atmosphere. The technique has been present for some time, but IMO has not proceeded to make it mandatory (Endresen et al. 2008).

Regulation 15 (chapter 3) of Annex VI of MARPOL stipulates the requirements for preventing air pollution from ships and volatile organic compounds. In addition, the EU defines a VOC as “any organic compound having an initial boiling point less than or equal to 250 °C (482 °F) measured at a standard atmospheric pressure of 1013 kPa”.

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8 According to the US Environmental Protection Agency (EPA), Total Exposure Assessment Methodology (TEAM) studies found levels of about a dozen common organic pollutants to be two to five times as high inside closed areas as outside those areas. Additionally, they indicated that when people are using products containing organic chemicals, they can expose themselves and others to very high pollutant levels, and elevated concentrations can persist in the air long after the activity is completed.

9 Kilopascal is a unit of pressure. KPa is approximately the pressure exerted by a 10-g mass resting on a 1-cm² area (1013.3 kPa = 1 atm).
VOC Solvents Emissions Directive is the main policy instrument for reducing industrial emissions of VOCs in the EU. It covers a wide range of solvent-using activities, such as printing, surface cleaning and vehicle coating. The directive requires installations in which such activities are applied to comply either with the emission limit values set out in the directive or with the requirements of the so-called reduction scheme. However, it does not apply at all to ships and shipping operations.

With respect to shipping, it is evident that this regulation affects only the tanker industry. However, some cases apply to gas carriers, mainly when the loading and containment system allows safe retention of non-methane VOCs or their safe return ashore. According to IMO10, this regulation has two aspects of VOC control.

Regarding regulations 15.1–15.5 and 15.7, control of VOCs emitted into the atmosphere regarding specific ports or terminals is achieved by a requirement to utilise a vapour emission control system (VECS). Where so required, the shipboard and shore arrangements are to be by MSC/Circ.585 “Standards for vapour emission control systems”. A party may choose to apply such controls only to particular ports or terminals under its jurisdiction and only to specific sizes of tankers or cargo types. Where such rules are required at certain ports or airports, tankers not so fitted may be accepted for up to 3 years from the implementation date.

The second aspect of this regulation, 15.6, requires that all tankers carrying crude oil have an approved and effectively implemented ship-specific VOC Management Plan covering at least the points given in the regulation. Guidelines regarding the development of these plans are offered by resolution MEPC.185(59), and related technical information on systems and operation of such arrangements is given by circular MEPC.1/Circ.680.

**Scrubber wash water (SOₓ)**

The desulphurisation process for marine fuels can also be a matter of cost. The prevailing method to reduce such effects is to use SOₓ scrubbers. They are a type of machine that washes the exhaust gases using seawater, and with alkalinity, they neutralise the acidity of the sulphur oxides. However, this use is not without the risk of environmental pollution, which is not yet regulated (Russo et al. 2018).11

Pollution issues stem from the wash water from scrubbers, which has a high concentration of substances and soot deposits that are discharged during the process and have proved harmful to marine life. MARPOL has not yet included a proviso about this issue, just a general reference. Still, this scrubber technology is evolving at a fast pace owing to the high demand from the ship owner side (by the end of 2021, most manufacturers had reached their total production capacity) (Ostad-Ali-Askari 2022).

It was suggested by Herkenrath (2019) that in the years to come, strict regulations will be imposed regarding the wash water discharge from SOₓ scrubbers. It is possible that there will be a complete ban on discharge by implementing so-called closed-loop scrubber systems (Henriksson 2007).

A new limit on the sulphur content in bunker (fuel oil) used onboard, known as “IMO 2020”, came into force as a measure to improve air quality and protect the marine environment and human health. This limit is enforced outside DECAS to 0.5% m/m, which is, by all means, a significant reduction from the previous limit of 3.5%. In specific DECAS, the boundaries were already stricter (0.1%). The new limit is made compulsory according to Annex VI of MARPOL (Javadinejad et al. 2019).

Before this new limit, ships were using heavy fuel oil (residue derived from crude oil distillation), which had a much higher sulphur content that, following combustion in the engine, ended up in the ship’s emissions. Nowadays, ships use very-low-sulphur fuel oil (VLSFO) to comply with the new limit. In other words, the response of the international maritime community was rapid and effective in implementing the newly introduced regulations (Kim and Seo 2019).

For lowering fuel consumption and thus limiting emissions in recent years, the shipping industry has seen the introduction of shaft generators (MAN Diesel & Turbo), the so-called ECO ships, with more sophisticated aerodynamic and hydrodynamic design (BIMCO 2016), LNG-powered vessels (DNV GL 2016) and many other solutions that are still in an experimental stage. However, with fuel prices fluctuating widely, ship owners are very reluctant to make any long-term investments.

In recent years we have also noticed a significant increase in the fuel additives market that has begun to focus more and more on making the existing fleet more efficient, economical and environmentally friendly (Merkouris-Stylopoulos and Alexopoulos 2017). For vessels to meet these requirements, they must use low-sulphur fuel oil such as MGO.

Under the provisions adopted in 2008, ships may meet the SOₓ requirements by using approved methods, such as exhaust gas cleaning systems or scrubbers which clean the emissions before releasing them into the atmosphere (Bureau Veritas 2012). However, the equivalent arrangement must be

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10 See at: https://www.imo.org/en/OurWork/Environment/Pages/Volatile-organic-compounds-(VOC)-%E2%80%93-Regulation-15.aspx.

11 Ostad-Ali-Askari (2022). Javadinejad et al. (2019).
approved by the vessel’s flag state, that is, a state party to MARPOL Annex VI (IMO 2015).

Such additives increase the efficiency of combustion, thus lowering consumption, reducing damage to the engine by increasing lubricity in the fuel and reducing the catalytic fines by preventing incompatibility of the fuels as well as significantly lowering the production of sludges, something that is becoming a significant issue and cost for ship owners and charterers (Boviatsis et al. 2022).

Conclusions

So far, we have shown that the existing international regulatory system is more efficient today than in past years. In particular, regarding CO₂ emissions, there are new rules and plans based on MEPC 76 and the SEEMP in conjunction with the CCS method, which have contributed to a significant decrease in most emissions. For the VOCs, regulation 15 of the MARPOL Annex VI introduced the mandatory use of vapour lines in ports at the international level. Furthermore, in the SO₂ scrubber wash water sector, IMO 2020 encouraged the implementation of scrubber systems and qualitative fuels as an alternative solution for mitigating possible environmental damage.

Another point of discussion is that technology measures on their own have proved inadequate to solve the issue of releasing emissions into the atmosphere, despite the presence of protective environmental tools. In other words, the use of technological tools and a proactive regulatory system may both be required for the shipping industry to be environmentally efficient, friendly and cost-free.

The latter, equally essential for the ship owners, is based on the actual benefits of fuel additives and shows the difference in consumption, the rate of machinery deterioration, the percentage of sludge production and the emissions produced. As a result, there are improvements in the condition of the engine. For the charterer’s position (especially in time chartering), such modifications make the vessel more appealing, as it consumes fewer bunkers. When there is an argument regarding whose account sludge removals are charged to, the ship owner can be less reluctant to undertake such costs, asking for a small additional premium.

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Declarations

Conflicts of interest Not applicable.

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