Regulating international maritime shipping’s air polluting emissions monitoring, reporting, verifying and enforcing regulatory compliance

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ABSTRACT
Empirical studies have established that ships in international commerce emit air pollutants with damaging effects on human health, climate change and food production. Effective regulation of these emissions depends on technologies, policies and administrative processes that monitor, report, verify and enforce compliance with the regulations (MRV&E systems). The article addresses the following questions: What are the provisions for MRV&E? What are the strengths and weaknesses of the systems? What can be done to make MRV&E systems more effective? The article concludes that current MRV&E policies are defective in some respects, especially concerning enforcement. Nevertheless, there are elements of current MRV&E systems that can provide building blocks for more effective regulatory systems. The conclusions are based on a data set developed from annual reports of Port State Control (PSC) authorities for the three years 2017–2019. The results of more than 80,000 inspections each year in all regions of the world were reported, and the inspections were done on ships of all flag countries. There was also a one-time, Concentrated Inspection Campaign (CIC) in 2018 that focused on compliance with emissions and fuel efficiency regulations. The CIC involved 12,703 inspections in ports of 63 countries, which used a standardized list of inspection questions.

Introduction: context, focus and scope
The multi-level, local-to-global networks of regulatory systems that are intended to reduce ships’ air polluting emissions are under scrutiny by diverse policymakers and stakeholders. The scrutiny occurs in the context of regulatory developments at many levels of governance. At the global level, the International Maritime Organization (IMO) established lower-level limits on the sulfur content of fuel, effective at the beginning of 2020. At the same time, international regional Emission Control Areas (ECAs) implemented parallel but more stringent sulfur limits in the Baltic and North seas, in the North American coasts of the Atlantic and Pacific oceans and Gulf of Mexico, and along the coasts of US territories in the Caribbean Sea. In Europe there are proposals to create a new Mediterranean ECA that could potentially include 22 countries along the sea’s southern, eastern and northern coasts, as well as proposals to include international shipping in the EU Emission Trading System (ETS).

At the national level, China has three domestic emission control zones limiting ships’ fuel and speed in port areas as well as inland waterways. These policies were phased in beginning in January 2016 with additional measures scheduled for January 2022. In September 2020, South Korea began phasing in a programme to improve air quality in port areas with fuel and speed limitations, with more restrictive fuel regulations scheduled for January 2022.

There is diversity in the types and limits of emissions that are covered among existing and potential regulatory systems. However, there is a core set of issues that need to be addressed more thoroughly than they have been to date – namely whether and how emissions and other features of ships’ design, equipment and operation are monitored, reported, and verified for compliance and how the regulations are enforced in cases of non-compliance (i.e., MRV&E issues). In order to understand and evaluate MRV&E policies, processes and technologies, it is necessary to have a basic understanding of emission coverages and standards in existing and prospective regulatory systems. The geographic scope of the paper is thus global. Its governance scope includes all levels: global, international regional, national, sub-national regional, and local.

New evolving information technologies can significantly enhance existing PSC system emission monitoring methods. Because these methods have already been deployed and tested in the Baltic Sea and North Sea/English Channel ECAs, they are good candidates for short-term improvements in the network of MRV&E systems.

Methods
The methodological approach of the analysis is multi-disciplinary and integrative. It combines scientific bodies of knowledge about emissions and their effects,
with technological knowledge about ships’ design features, propulsion systems, and emission control systems. It also includes economic, political and legal analyses of the institutions, policies and procedures of MRV&E systems.

The analysis begins with a brief presentation of the atmospheric chemistry and physics that inform understanding of the kinds of ships’ air polluting emissions. The effects of the emissions on public health, climate change and food production are well understood, based on many studies in the three corresponding fields. In public health studies, the contributions of particulate matter pollutants, including from ships, to public health problems have been under intensive study in many countries even before the covid pandemic (Corbett et al. 2007). The effects of ships’ carbon dioxide emissions on climate change have long been understood and documented (Amann and Klimont, 2012). The contributions of ships’ black carbon emissions to climate change have been less widely recognized, but that has been changing as a result of the cumulative results from numerous studies over the past couple of decades (Brewer 2020a). Studies of the effects of ships’ emissions on food crops have been less numerous, but the central causal processes are well understood; for instance, particulate matter emissions clog the openings of the stomata cells in plants and thus restrict their intake of carbon dioxide (Brewer 2020b).

In the present article, the core of the empirical analysis focuses on two data sets that have been developed by the author for this article. Both sets of data have been compiled on the basis of reports from regional Memorandums of Understanding (MOUs) on Port State Controls (PSCs) that document the MRV&E policies, processes and decisions of local ports and national governments in more than a hundred countries. One set of data has been developed from annual reports of nine international regional MOUs from all parts of the world (International Maritime Organization (IMO) 2021c). These reports are subject to audit by the International Maritime Organization (IMO). Although these MOU annual reports are concerned mostly with compliance with IMO safety and security regulations, there is also a secondary – and even marginal – concern with environmental issues. The MOU reports of the US, for instance, contain major sections on “safety compliance” and “security compliance” but no sections on “environmental compliance” or “MARPOL Annex VI compliance” in the reports for 2017–2019.

Yet, because the first regional MOU system – the Paris MOU – has been functional since 1982 and there are now tens of thousands of annual inspections in more than a hundred countries, the extensive experience with MRV&E processes offers an opportunity to learn about key issues in the design and implementation of international maritime MRV&E systems.

A second data set has been developed from the raw data of the 2018 reports of four diverse regional MOU groups that include: Asia-Pacific ports, European and North Atlantic ports, Indian Ocean ports, and Black Sea ports (Port state control to focus on ship emissions. Gard 2018). The focus of this particular PSC CIC was how effective these countries’ MRV&E systems were for insuring compliance with the air pollution provisions of the IMO’s MARPOL Annex VI regulations (IMO 2021a).

Results

Existing regulatory systems for ships’ emissions

There are multiple international maritime regulatory systems that address ships’ air polluting emissions. They focus on different kinds of emissions, and the institutional participants in them vary across levels of governance. Table 1 summarizes the systems in terms of the kinds of emissions of interest and the levels of governance that regulate them as of early 2021.

IMO regulations

The IMO is clearly the most nearly global in its membership and the geographic range of its policies; it is a central institution in the panoply of interacting institutions. As for compliance with current IMO regulations, the monitoring and reporting activities of the ports and regional secretariats for the Memorandums of Understanding (MOUs) on Port State Control provide an abundance of information about the “M” and “R” in MRV&E processes. There are also verification processes that are inherent in the port inspections, and in addition the reports are subject to audit by a specialized IMO audit process. The MOUs could be incrementally strengthened if the few non-participating countries become signatories to the existing MOUs. Otherwise, the MOUs are institutionally well established. They have trained and experienced professionals that do the actual inspections, and there are institutionalized formats, procedures and precedents for preparing the annual reports. In order to understand the operations of the MOUs, it is necessary to probe more deeply into their structure, operations and reports.

Memorandums of understanding (MOUs) on Port state control and their associated MRV&E processes

The nine existing international regional MOUs on Port State Controls include 145 national governments and territories as participants, and they are an important part of the internationally agreed regulatory systems. Many countries are members of more than one MOU.
Table 1. Types of ships’ air polluting emissions and levels of governance in international maritime regulatory systems (January 2021)\(^a\) (Comer et al. 2015),(Intergovernmental Panel on Climate Change (IPCC) 2013),(Brewer 2017),(Comer et al. 2017).

| Types of Emissions | International Institutional Coverage |
|--------------------|-------------------------------------|
|                    | IMO MARPOL Annex VI Signatories\(^b\) (158 as of 31 December 2019) | 4 ECAs (17 cos.) Baltic Sea North Sea North America US-Caribbean Territories | MOUs (145 countries and territories in 9 regional MOUs & 1 unilateral MOU) |
| Sulphur Oxide (SO\(_x\))\(^a\) | Yes | Yes (4 of 4 ECAs) | Yes |
| Nitrous Oxide (N\(_x\)) | Yes | Yes (2 of 4 ECAs) | Yes |
| Tropospheric Ozone – low level (Secondary Emission)\(^b\) | Yes | Yes | Yes |
| Stratospheric Ozone – high level (Secondary Emission)\(^b\) | Yes | Yes | Yes |
| Volatile Organic Compounds (VOC) | Yes | Yes | Yes |
| Fluorocarbons (CFLS, HCFCS) | Yes | Yes | Yes |
| Black Carbon (BC) | Yes | Yes | Yes |
| Organic Carbon (OC)\(^a\) | Yes | Yes | Yes |
| Methane (CH\(_4\)) | Yes | Yes | Yes |
| Carbon Dioxide (CO\(_2\)) | Preliminary emission targets agreed. Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Plan (SEEMP) are indirect regulations to reduce CO\(_2\) and other GHGs; but direct regulatory measures not yet agreed | | |

\(^a\)Two kinds of emissions — Sulphur Oxide (SO\(_x\)) and Organic Carbon (OC) — are global coolants and thus considered climate change agents. Each co-occurs with the emissions of potent warming agent, black carbon (BC), which is very short-lived in the atmosphere and with a global warming potential (GWP) at 20 years that is approximately 3000 times greater than carbon dioxide (CO\(_2\)) per tonne.

\(^b\)Ozone is created as a secondary pollutant as a result of combinations of primary emissions of CFCs, halons, and methyl bromides.

\(^c\)Not all IMO members are signatories of the MARPOL Annex IV agreement.

\(^d\)BC emissions are indirectly reduced by fuel efficiency regulations in the Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Plan (SEEMP) regulations, but as of early 2021 there are no explicit BC regulations. The possibility of explicit BC limitations is on the IMO official decision-making agenda for 2021, as a result of the many BC workshops organized by the International Council on Clean Transportation (ICCT) (Comer et al. 2017). As of February 2021, the issue was pending before the Sub-Committee on Pollution Prevention and Response (PPR), specifically in the context of BC’s contribution to Arctic warming and ice melt (both Greenland glaciers and Arctic Sea ice).

\(^e\)CO\(_2\) emissions are indirectly regulated via the Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Plan (SEEMP) regulations.
Table 2. International Regional MOUs (as of 1 January 2021) (IMO, 2021c).

| Name       | Paris | Vina del Mar | Tokyo | Caribbean | Mediterranean | Indian Ocean | Abuja | Black Sea | Riyadh |
|------------|-------|--------------|-------|-----------|---------------|--------------|-------|-----------|--------|
| Year Agreed| 1982  | 1992         | 1993  | 1996      | 2010          | 2011         | 1999  | 1999      | 1999   |
| MemberCos. | 15    | 27           | 21    | 20        | 10            | 20           | 20    | 17        | 6      |
| Region     | Eur. & Can. | South Amer. | West Coast | East & South-east Asia, South Pacific | Car. & NE | South & East Coasts | South & SE Asia & West Coast Africa | West Coast Africa | Black Sea | Persian Gulf |

Table 3. Emission control areas (ECAs) (Special Areas 2021).

| Area Covered | Baltic Sea | North Sea/English Channel | North America | US-Caribbean Territories |
|--------------|------------|---------------------------|---------------|--------------------------|
| Year agreed  | 1997       | 2005                      | 2010          | 2011                     |
| Emissions Covered | SOx | NOx | Particulate | Matter | Members |
|                | Yes        | Yes                       | No            | Denmark                 | Estonia |
|                | Yes        | Yes                       | No            | Finland                 | Finland |
|                | No         | Yes                       | Yes           | Germany                 | Germany |
|                | No         | Yes                       | Yes           | Latvia                  | Latvia  |
|                | No         | Yes                       | Yes           | Lithuania               | Sweden  |
|                | No         | Yes                       | Yes           | Poland                  | Russia  |
|                | No         | Yes                       | Yes           | Sweden                  | Sweden  |
|                |            |                           |               | Canada                  | US      |
|                |            |                           |               | France                  | Puerto Rico & US Virgin Islands |

*These four do not include national Economic Emission Zones established in China and South Korea – which are not registered with the IMO.

*The French self-governing territories of Saint Pierre and Miquelon are off the Atlantic coast of Canada near Newfoundland. They are together known officially as “Collectivité d’outre-mer.”

because they have ports in more than one region in a system where regions are defined by large bodies of water. Canada, for instance, is a member of both the Paris MOU because of its Atlantic ports and the Tokyo MOU because of its Pacific ports; Australia is a member of both the Indian Ocean MOU and the Tokyo MOU for its Pacific ports.

Despite their designation as MOUs instead of treaties or other form of international agreement, the MOUs are recognized as legally binding in international law. Each MOU produces an annual report, which contains much statistical data about standardized metrics. The names and basic information about the MOUs are indicated in Table 2. (The identities of the members of each MOU are listed in Table S1 in the on-line Supplementary Materials.)

(1) Web sites:

a. www.parismou.org
b. https://safety4sea.com/wp-content/uploads/2019/05/Vina-Del-Mar-Annual-Report-on-Port-State-Control-2019_05.pdf
c. www.tokyo-mou.org
d. www.caribbean.org
e. www.medmou.org (Northern Mediterranean ports are included in the Paris MOU.)

f. www.iomou.org
g. www.abujamou.org
h. www.bsmou.org
i. www.riyadhmou.org

The US is a unique case – a country with its own uni-national MOUs in a system where all the other MOUs are international regional agreements. The US is a single member of an MOU – which includes US Atlantic and Gulf of Mexico coast ports that might otherwise be in the Paris MOU with its 27 national members and which includes US Pacific ports that might otherwise be in the Tokyo MOU with its 21 national members. The US, however, is an observer – not a member – of the Tokyo MOU. The world total number of MOUs on Port State Controls is therefore ten – that is, nine regional and one uni-national.

For all of the MOUs, the signatories are national governments, but the operational implementation of the inspections and thus the MRV&E responsibilities include local port authorities as well as national governmental administrative agencies and in many cases military or coastal military-like governmental organizations. In the US, for instance, inspection activities are the operational responsibility of the Coast Guard (USCG). However, the Environmental Protection Agency (USEPA) is also involved, particularly in the
scientific studies and in the standard setting phases. There is an explicit cooperation agreement between the USCG and USEPA (US Coast Guard (USCG) and US Environmental Protection Agency (EPA). 2015).

The MOUs’ annual reports predominantly focus on and report on MRV&E processes concerned with maritime safety. However, there are also occasional references to air pollution regulations, as established in the IMO MARPOL Annex VI. Fortuitously for the present study, there was also a one-time Concentrated Inspection Campaign (CIC) in 2018 that focused specifically on compliance with regulations in MARPOL Annex VI. As has been customary with CICs, not all MOUs participated; in this case, the participating MOUs were Paris, Tokyo, Indian Ocean and Black Sea. The CIC was carried on simultaneously for the three-month period of September-October-November in 2018; it involved 12,413 inspections in ports of 63 member countries, using a standardized list of inspection questions. The results provide a rich source of data about MRV&E processes concerning compliance with IMO and ECA regulations about sulphur, ozone and operational efficiency.

### Emission control areas (ECAs)

Within the institutional context of the IMO regulatory systems, there are four existing ECAs, which have been registered with the IMO and are thus recognized in international law (see Table 3). The four ECAs can be conveniently considered as two pairs in geographic terms. The Baltic Sea and North Sea/English Channel pair connect with one another and thus include all the northern European countries (Denmark, Germany and Sweden are in both). The other pair covers the North American coasts of the Atlantic and Pacific Oceans in one ECA and US-Caribbean Sea territories in a separate unilateral ECA. The US is thus in both. The US-Caribbean Territories ECA is not an international regional ECA in the same sense as the other three.

The North American ECA includes the Atlantic and Pacific coasts of the US and Canada (plus the French self-governing North Atlantic Island territories of Saint Pierre and Miquelon). It was agreed in 2010, entered into force in 2011 and became effective in 2012 for SOx and Particulate Matter (PM). Coverage of NOx was added in 2016. The US-Caribbean ECA is of course much smaller, because it includes only the portion of the Caribbean Sea around the US territories of Puerto Rico and US Virgin Islands. Its coverage of emissions, however, is the same as the North American ECA, with SOx and PM limits becoming effective in 2014 and NOx in 2016 (US Environmental Protection Agency (EPA) 2012).

The focus here is specifically on MRV&E processes concerning the regulation of ships’ emissions of air pollutants, including SOx and NOx, as contained in MARPOL Annex VI. Box 1 provides a summary of the contents and evolution of those regulations.

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**Box 1 MARPOL Annex VI (IMO 2021b)**

MARPOL Annex VI, first adopted in 1997, limits the main air pollutants contained in ships exhaust gas, including sulphur oxides (SOx) and nitrous oxides (NOx), and prohibits deliberate emissions of ozone depleting substances (ODS). MARPOL Annex VI also regulates shipboard incineration, and the emissions of volatile organic compounds (VOC) from tankers.

Following entry into force of MARPOL Annex VI on 19 May 2005, the Marine Environment Protection Committee (MEPC), at its 53rd session (July 2005), agreed to revise MARPOL Annex VI with the aim of significantly strengthening the emission limits in light of technological improvements and implementation experience. As a result of three years examination, MEPC 58 (October 2008) adopted the revised MARPOL Annex VI and the associated NOx Technical Code 2008, which entered into force on 1 July 2010.

Revised MARPOL Annex VI

The main changes to MARPOL Annex VI are a progressive reduction globally in emissions of SOx, NOx, and particulate matter and the introduction of emission control areas (ECAs) to reduce emissions of those air pollutants further in designated sea areas.

Under the revised MARPOL Annex VI, the global sulphur limit will be reduced from current 3.50% to 0.50%, effective from 1 January 2020, subject to a feasibility review to be completed no later than 2018.

MEPC 70 (October 2016) considered an assessment of fuel oil availability to inform the decision to be taken by the Parties to MARPOL Annex VI, and decided that the fuel oil standard (0.50% sulphur limit) shall become effective on 1 January 2020.

The limits applicable in ECAs for SOx and particulate matter were reduced to 0.10%, from 1 January 2015.

Progressive reductions in NOx emissions from marine diesel engines installed on ships are also included, with a “Tier II” emission limit for engines installed on a ship constructed on or after 1 January 2011; and a more stringent “Tier III” emission limit for engines installed on a ship constructed on or after 1 January 2016 operating in ECAs (North American Emission Control Area and the U.S. Caribbean Sea Emission Control Area). Marine diesel engines installed on a ship constructed on or after 1 January 1990 but prior to 1 January 2000 are required to comply with “Tier I” emission limits, if an approved method for that engine has been certified by an Administration.

The revised NOx Technical Code 2008 includes a new chapter based on the agreed approach for regulation of existing (pre-2000) engines established
Table 4. References to MARPOL VI Deficiencies and Detentions in Annual MOU PST Reports (2017, 2018, 2019) [12]

| MARPOL VI Deficiencies and Detentions | Paris | Vina del Mar | Tokyo | Carib-bean | Mediterranean | Indian Ocean | Abuja | Black Sea | Riyadh |
|--------------------------------------|-------|--------------|-------|------------|---------------|-------------|-------|-----------|--------|
| 2017                                  |       |              |       |            |               |             |       |           |        |
| Total no. of Inspections              | 17,925| 31,315       | 769   | 5,200      |               | 5674        | 2074  | 5,112     | 304    |
| Ships                                | 17,000|              | 1,000 |            |               |             |       |           |        |
| Inspected                            |       |              |       |            |               |             |       |           |        |
| MARPOL VI Deficiencies               | 408   | 886          | 42    | 2          | 8296          | 52,000      | 214   | 3214      |        |
| MARPOL VI Deficiencies per ship Inspected | 0.03  | 0.05         |       |            |               |             |       |           |        |
| Total no. of Inspections              | 17,955| 31,589       | 635   | 5,343      |               | 5697        | 2409  | 5,214     | 3214   |
| Ships                                | 17,304| 17,301       | 51    |            |               |             |       |           |        |
| Inspected                            |       |              |       |            |               |             |       |           |        |
| MARPOL VI Deficiencies               | 494   | 212          | 2     | 83         | 2010          | 5,214      |       |           |        |
| MARPOL VI Deficiencies per ship Inspected | 0.05  | 0.09         |       |            |               |             |       |           |        |
| 2019                                  |       |              |       |            |               |             |       |           |        |
| Total no. of Inspections              | 17,908| 31,372       | 782   | 5,380      |               | 5934        | 2695  | 6,036     | 3207   |
| Ships                                | 15,440| 17,647       |       |            |               |             |       |           |        |
| Inspected                            |       |              |       |            |               |             |       |           |        |
| MARPOL VI Deficiencies               | 528   | 954          | 1     | 43         | 487           | 6,036      | 13    |           |        |
| MARPOL VI Deficiencies per ship Inspected | 0.03  | 0.05         |       |            |               |             |       |           |        |

a Approximate estimate derived by author from 2018 and 2019 data.
b Some MOU reports do not include the number of ships but do report the number of inspections.
c Indian Ocean MOUs are unusual in their listing of individual ships with their unique MOU vessel number in a list of deficiencies. It also has a searchable database with much information including data on 18 specific types of MARPOL Annex VI inspection data.
d Mediterranean MOU data is stored in the EU’s EMSA system at https://portalemca.europa.eu/web/thetis-med
in MARPOL Annex VI, provisions for a direct measurement and monitoring method, a certification procedure for existing engines and test cycles to be applied to Tier II and Tier III engines.

MEPC 66 (April 2014) adopted amendments to regulation 13 of MARPOL Annex VI regarding the effective date of NOx Tier III standards.

The amendments provide for the Tier III NOx standards to be applied to a marine diesel engine that is installed on a ship constructed on or after 1 January 2016 and which operates in the North American Emission Control Area or the U.S. Caribbean Sea Emission Control Area that are designated for the control of NOx emissions.

In addition, the Tier III requirements would apply to installed marine diesel engines when operated in other emission control areas which might be designated in the future for Tier III NOx control. Tier III would apply to ships constructed on or after the date of adoption by the Marine Environment Protection Committee of such an emission control area, or a later date as may be specified in the amendment designating the NOx Tier III emission control area.

Further, the Tier III requirements do not apply to a marine diesel engine installed on a ship constructed prior to 1 January 2021 of less than 500 gross tonnage, of 24 m or over in length, which has been specifically designed and is used solely, for recreational purposes.

Revisions to the regulations for ozone-depleting substances, volatile organic compounds, shipboard incineration, reception facilities and fuel oil quality were also made with regulations on fuel oil availability added.

The revised measures are expected to have a significant beneficial impact on the atmospheric environment and on human health, particularly for those people living in port cities and coastal communities.

Data reflecting the results for MARPOL VI issues from regular annual MOU reports are presented in Table 4, and the results from the special CIC inspections are presented in Table 5.

The relative paucity of deficiencies explicitly related to MARPOL Annex VI is self-evident in Table 4 with data from the regular annual reports. Where there were reports of MARPOL VI deficiencies, the number were generally quite low, except for the Paris and Tokyo MOUs. Within the Paris MOU, there were relatively high levels of inspections by ports in countries bordering the Baltic Sea and North Sea ECAs, where sulphur limitations have of course been low compared with the global IMO limitations for many years and where there has been much activity in testing and deploying MRV systems. The 12 countries with Baltic and/or North Sea ports accounted for between a third and half of the total Paris MOU inspections in each of the years 2018 and 2019. (These do not include the UK, whose Channel ports are in the North Sea ECA but which has many other ports as well.) Even in the Paris MOU, however, there were only 3 in a hundred inspected ships with MARPOL VI deficiencies in 2017 and 2019 and 5 in a hundred in 2018. In the Tokyo MOU, there was a somewhat higher rate of deficiencies between 0.05 and 0.10. In the other MOUs, the rate was typically less than 1 in a hundred. No detentions were reported, but this could be partly the consequence of a lack of detail in the printed reports, which have generally been more focused on safety issues.

Given the paucity of data on MARPOL VI issues in the annual PSC reports, it is important to utilize in more detail the results of the inspections devoted to those issues in the 2018 CIC.

Table 5. Ship inspections for MARPOL annex VI CIC (September-November 2018) [19-22]

| Countries participating | MOUs Participating in the Campaign |
|-------------------------|-----------------------------------|
| Inspections with CIC Questionnaire | Tokyo (Asia-Pacific) | Paris (Europe-North America) | Indian Ocean | Black Sea |
| Flag states of ships inspected | 21 | 27 | 7* | 8 |
| Numbers of countries/ships/inspections/flag states/ship classes | 6,604 | 4,021 | 1,007 | 781 |
| *Only 7 of the 20 Members of the Indian Ocean MOU participated in the CIC: Australia, Bangladesh, France, India, Iran, Kenya, South Africa. |

Table 6. Targeted sampling strata for CIC inspections [19-22]

| Risk Category | Tokyo | Paris | Indian Ocean | Black Sea |
|---------------|-------|------|-------------|-----------|
| High          | 2047  | 330  | NA          | 119       |
| Regular       | 2414  | 3345 | NA          | 543       |
| Low           | 2143  | 168  | NA          | 117       |

*Based on previous inspection record of each ship.
Specialized inspections for compliance with MARPOL VI

The questions in the standardized questionnaire for the special MARPOL VI CIC inspections in 2018 are presented in Box 2. Questions 1–5 concern the sulphur emissions and hence the sulphur content of fuel, which of course has been the dominant emission regulation topic in recent years.

Box 2 standardized MARPOL annex VI Questionnaire for CIC (paris MOU on port state control, report of the 2021; tokyo MOU on port state control, report of the 2021)

1. Are bunker delivery notes, with details of fuel oil for combustion purposes, kept available on board for the required period of 3 years? Annex VI, regulation 18.5 and 18.6
2. Do bunker delivery notes indicate that fuel oils delivered and used on board is not exceeding the maximum allowed sulphur content, as appropriate? Annex VI, regulation 14.1.2 and 14.4.3
3. Do ships which are using separate fuel oils to comply with the maximum sulphur content of 0.1% m/m in fuel oil while operating in SOx emission control areas, have a written procedure showing how fuel oil change-over is to be done for achieving compliance with the above requirements when entering SOx emission control areas? Annex VI, regulation 14.6
4. Are alternative arrangements, (e.g., scrubbers) installed on board according to regulation 4.1 approved by the flag State? Annex VI, regulation 4.1
5. Do ships which are using separate fuel oils to comply with the maximum sulphur content of 0.10% m/m in fuel oil and entering or leaving SOx emission control areas, record detailed

Table 7. Number of Deficiencies for Each CIC Question and Aggregated Number of Detentions [19-22]

| Questions | Participating MOUs | Number of CIC Inspections | Number of CIC Deficiencies | Number of CIC Detentions | Ratio of Detentions to Deficiencies |
|-----------|-------------------|---------------------------|----------------------------|--------------------------|-----------------------------------|
|           | Tokyo (6,604)     | 118                       | 94                         | 7                        | 0.06                              |
|           | Paris (4,021)     | 29                        | 63                        | 4                       | 0.26                              |
|           | Indian Ocean (1,007) | 1                        | 179                       | 33                       | 0.26                              |
|           | Black Sea (781)   | 68                        | 45                        | 6                       | 0.26                              |

*Current MOU response, there is no indication that these three questions were not answered with this possibility.

**There were multiple deficiencies in some cases.

The length of the detentions is not reported.

Table 8. Summary of deficiencies and detentions in MARPOL VI CIC reports [19-22]

| MOU         | Number of countries participating in CIC | Number of CIC Inspections | Number of CIC Deficiencies | Number of CIC Detentions | Ratio of Detentions to Deficiencies |
|-------------|-----------------------------------------|----------------------------|-----------------------------|--------------------------|-----------------------------------|
| Tokyo       | 21                                      | 6604                       | 889                         | 5                        | 0.06                              |
| Paris       | 27                                      | 4021                       | 350                         | 9                        | 0.026                             |
| Indian Ocean| 7                                       | 1007                       | 101                         | 1                        | 0.01                              |
| Black Sea   | 6                                       | 781                        | 139                         | 0                        | 0.00                              |
| Totals      | 62                                      | 12,413                     | 1,479                       | 15                       | 0.01                              |

*Corresponds to the number of ships inspected or detained.

**There were multiple deficiencies in some cases.

*Ratio of total deficiencies (including multiple deficiencies per ship in some cases) to number of detentions.
information showing that the ship has completed/initiated the change-over in the log-
book prescribed by the Administration? Annex VI, regulation 14.6

(6) Do ships which have rechargeable systems containing ozone depleting substances (refer
to the supplement to the IAPP Certificate, item 2.1), have the ozone-depleting substances record book maintained? Annex VI, regulation 12.6

(7) Where an Approved Method in accordance with Annex VI, regulations 13.7.1–13.7.5 (refer
to the supplement to the IAPP Certificate, item 2.2.1) is installed, has such an installation been
confirmed by a survey using the verification procedure specified in the Approved Method File,
including appropriate notation on the ship’s International Air Pollution Prevention Certificate of the presence of the Approved Method? Annex VI, regulation 13.7.1.1

(8) For ships equipped with a shipboard incinerator or thermal waste treatment device installed
as an alternative arrangement, is the ship’s crew responsible for the operation of the
equipment familiar with, properly trained in, and capable of implementing the guidance
provided in the manufacturer’s operating manual? Annex VI, regulation 16.8

(9) Are the master and crew familiar with essential shipboard procedures in the approved VOC
Management Plan relating to the prevention of air pollution from ships? Annex VI, regulation 15.6

(10) Does the ship keep on board a Ship Energy Efficiency Management Plan (SEEMP)?

(11) Was the ship detained as a result of the Inspection Campaign?

Data about the results of the sampling process are presented in Table 5. These four MOUs participated in the 2018 CIC.

Bangladesh, France, India, Iran, Kenya, South Africa.

The sampling process uses targeted groups of vessels based on their history that indicates “high
risk” of deficiencies, “regular risk” or “low risk” (see Table 6). Such a targeting approach is appropriate,
given the purpose of the CIC. Although the sample results cannot be the basis for making probabilistic
inferences to the entire populations of inspections based on standard statistical procedures, the results
are nevertheless useful for gaining information about the kinds of questions that can be empirically
answered and how to ask them. The exercise can thus facilitate standardization among MOUs in the
implementation of PSC authorities. Because the sample sizes are large, the results can also be sub-
stantively useful for assessing the incidence and patterns of compliance/non-compliance behavior
among segments of the industry. Since the present article is focused on MRV&E issues in the regulatory
systems, it is not intended to be a comprehensive report or assessment of the results; rather, it is
a preliminary empirical effort to address key MRV&E issues, with the hope that future rounds of
inspections will provide more evidence based on both targeted samples and random samples –
each type with its advantages and disadvantages.

In any case, the small number of detentions relative to the large number of deficiencies is particularly puzzling since “high risk” ships with previous records of high rates of deficiencies and detentions were intentionally over-sampled in the targeted sampling process. The apparently small rate of detentions compared with large number of deficiencies is evident in Tables 7 and 8.

There are several notable findings in Table 7. The responses to questions about sulphur emissions are problematic. The Paris MOU report noted that there were 26 instances where ships did not have bunker delivery notes that indicated that the sulphur content of the fuel was in compliance with the IMO’s regulatory limits. This was one of the three questions where there was guidance that a deficiency on this question “may be considered for detention.” A substantial majority were not detained. Why not? Responses to this question were particularly significant since there were 94 Paris MOU inspections that found that there were not the required bunker delivery notes on board. Of the nearly 4000 inspections, only 70 for question 1 and 32 for question 2 were reported as not applicable. (See Tables S6 and S7 in the on-line Supplementary Materials for further details.)

Another sulfur-related deficiency report about compliance with a regulation is concerning. Question 4 asked “Are alternative arrangements, (e.g., scrubbers) installed on board according to regulation 4.1 approved by the flag State?” For many of the ships in all four MOU reports, the question was not relevant because they did not have scrubbers. However, of the answers that were either “yes” or “no,” 63% in the Paris MOU report indicated “no,” 33% in the Indian Ocean MOU reported “no,” and 46% in the Black Sea MOU report indicated “no.” This was also a question for which a “no” answer “may be considered for detention.”

There is also a notable difference between the Black Sea’s reported 48 deficiencies among its 781 reports (6.1%), for whether the “master and crew [were] familiar with essential shipboard procedures in approved VOC [volatile organic compounds] Management Plan relating to the prevention of air
pollution from ships." This was the third of the three questions where a ship with a "no" answer may be considered for detention.

There are other significant patterns in the data, especially about detentions. In Table 8, the ratio of detentions to deficiencies was about 0.01.

Two additional kinds of data would be useful. One is the occurrence of multiple deficiencies found in the same ships when inspected in more than one port or even more than one MOU system. Another kind of missing information, which is especially pertinent to this article’s focus on enforcement (the "E" in MRV&E), is the absence of information about the length of the detentions and any possible additional sanctions for non-compliance. The question of the nature and magnitude of any sanctions for non-compliance with emission regulations, of course, has been a central concern about the efficacy of shipping’s regulatory systems.

Discussion

In terms of the number of inspections and the numbers of ports and countries covered by the MOU reports, this is an impressive network of MRV&E systems. More than 80,000 inspections each year for the three recent years’ reports analyzed here provide a credible empirical basis for numerous and diverse observations about the functioning of the systems. The existing systems have established training programs for thousands of inspectors in more than a hundred countries. The level of cooperation among MOUs establishes much uniformity in the details of implementation processes. The existing PSC systems of annual MOU reports are therefore valuable building blocks for more elaborate and effective systems.

The specialized CIC exercise in 2018 that focused on MARPOL Annex VI air pollution regulations has provided opportunities for practical experience for conducting and reporting the results of thousands of inspections involving wide varieties of ship types, flag countries and recognized organizations. The inspections have also provided preliminary performance evaluation data for individual ports. In sum, the regular annual inspections, as well as those in the particular CIC on compliance with MARPOL Annex VI, are valuable for their experiential data.

It is important to recall that the explicit official purpose of these MRV&E systems is to assure compliance with regulations. For this article, the focus is on the emission and fuel efficiency regulations identified in the article on the basis of official IMO, national governmental and MOU documents. This focus on MARPOL Annex VI issues may yield different results from a focus on safety or other kinds of regulations. In addition to assurance of compliance, there are two other uses of the different patterns in the results of the inspection systems. They can be used for administrative evaluation purposes to assess and improve ports’ PSC processes. In the case of specialized CIC inspections, they can also be used as pilot exercises for gaining more experience for subsequent PSC regulator annual inspections.

A specific practical implication of the existence of multiple purposes and thus evaluative perspectives concerns inspection sampling procedures. In particular, for the practical purpose of using CIC inspections as pilots to gain substantive knowledge about specific kinds of emissions, it is reasonable to use the stratified target sampling used in the 2018 CIC focused on compliance with MARPOL Annex VI environmental regulations. With the smaller samples of a CIC exercise, compared with regular annual inspections, it made sense to increase the sampling of “high risk” vessels based on their past performance in regular annual inspections in order to increase the number of ships in the sample with MARPOL annex VI deficiencies, thereby gaining more inspection experience and improving inspection performance for those issues. However, for estimating overall MRV&E system results to gain an accurate count of the diverse kinds of issues that arise and how they are addressed by PSC procedures, random sampling would be more appropriate. A solution for the future would be to have both kinds of samples. Although this approach would require smaller samples and/or larger administrative expenditures, it could be considered at least for the few very large MOUs with many thousands of ships in their samples in the recent past.

For all three potential uses – compliance assurance, administrative evaluation, and pilot exercises – the MRV&E processes should be assessed at all five levels of governance:

1. local ports, which have direct operational responsibilities;
2. sub-national regional areas near ports and other coastal areas, where ship traffic is unusually heavy and where the human health and food production impacts of ships’ emissions are a particular concern;
3. national, where supervisory and legal authority for port operations usually lies;
4. international regional, for the special requirements of regional Emission Control Areas (ECAs);
5. global, where the IMO has the institutionalized responsibilities and forums in the United Nations system to be attentive to the global commons effects on climate change of international shipping.
Conclusion

At every governance level, specialized and tailored evaluations of the MERV&E systems are needed because of the variations in the MERV&E systems’ requirements and the variations in governmental responsibilities. The standardized list of questions in the 2018 CIC exercise provides the potential for these multiple uses across governance levels. However, there needs to be greater disaggregation of the data in some MOU reports so that the results of individual reports can be assessed at the port level.

There is also a data aggregation issue: the port level data for each of the regional Emission Control Areas (ECAs) needs to be available for separate analysis of each ECA.

Although the SPC system of relying on ports for inspections is producing sufficient data quantity and quality in many respects, the development of new technologies for monitoring ships’ emissions should become more widespread and more integrated into emissions data at all governance levels. There have already been significant systems deployed and many studies published about the use of such technologies in the ECAs of the Baltic and North Seas (Mellqvist et al. 2017a, 2017b) as well as other applications (Brewer 2019, 2018). As these technologies continue to be developed and applied more widely, they will become increasingly useful for MRV&E systems.

As for transparency, the current systems are quite transparent in many ways; for instance, the annual PSC reports provide much data about the identities of flag states and recognized organizations. However, the MOU reports are not uniformly informative about activities at the port level: while some MOUs include port level results, others do not. In addition, IMO audits do not identify countries without the permission of the countries involved.

Initiatives for the many improvements that could be made in the MRV&E systems could be undertaken by several IMO committees beginning in 2022. In the meantime, specialists in think tanks, industry associations, governmental organizations and non-governmental organizations, as well as IMO secretariat could begin to develop specific proposals to revise the MRV&E network, especially in regard to enforcement.

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Author’s declaration

I have written the paper on my own initiative, and I am solely responsible for its contents. There are no conflicts of interest. There was no outside funding.

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