Enforcement of Fuel Switching Regulations – Practices adopted in the US, EU and other regions, and lessons learned for China

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Author: Freda Fung

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Executive Summary

In 2016, China is entering a new era of green shipping with its commencement of the enforcement of the Domestic Emission Control Area (DECA) regulation at its major port regions. This regulation limits the sulfur level of fuel used on ships in and near the port areas at 0.5 per cent, 86 per cent lower than the 3.5 per cent global marine fuel sulfur standard. The DECA regulation is a big win for China's fight for clean air, as the regulation will reduce sulfur and particulate emissions from shipping in Chinese major port regions, which are the world's busiest and most populous, but are also suffering from the worst air quality among almost all the biggest port regions in the world (see Figure E1).

As with other environmental regulations, the real benefits of the DECA regulation will depend largely on how well it will be enforced. Establishing a robust enforcement program for DECA is particularly important because DECA is the first marine fuel regulation to have been enacted in China. In order to help the Chinese government effectively enforce this regulation, the Natural Resources Defense Council (NRDC) has drafted this paper to review and summarize key elements of programs adopted in other jurisdictions in order to verify compliance with marine fuel regulations and deter violations.

In brief, compliance with marine fuel regulations is typically verified by one or a combination of the following methods:

- Compliance with marine fuel regulation is traditionally verified by inspecting fuel-related documents, including Bunker Delivery Notes (BDN), Oil Record Books, representative fuel samples and the fuel changeover manual, during on-board inspections. Document inspections can be combined with normal Port State Control (PSC) inspections to reduce additional staff needs and avoid causing delay to ships. However, **BDN and log book entries are susceptible to potential fraud or forgery, so the veracity of these documents and records should be cross-checked with current and historical fuel temperature and viscosity readings, if available, as well as the alarm history.**

- **Fuel sampling for sulfur testing at laboratories is the most reliable way to verify the sulfur content of the fuel being used on board. Laboratory test results can be used as evidence for the potential imposition of sanctions. It has become a core part of the enforcement programs in an increasing number of regions.** Fuel samples should be collected from an accessible location closest to the engines, transported following a proper chain of custody procedure and tested per International Standard ISO 8754. In some countries, PSC officials are requested to present clear grounds for taking fuel samples. There are also concerns that a non-compliant ship may escape prosecution should fuel testing results come out after the ship has left the port. This concern could be partly addressed by getting the contact information of the Designated Person Ashore (DPA), who could be held responsible for any follow-up enforcement actions.

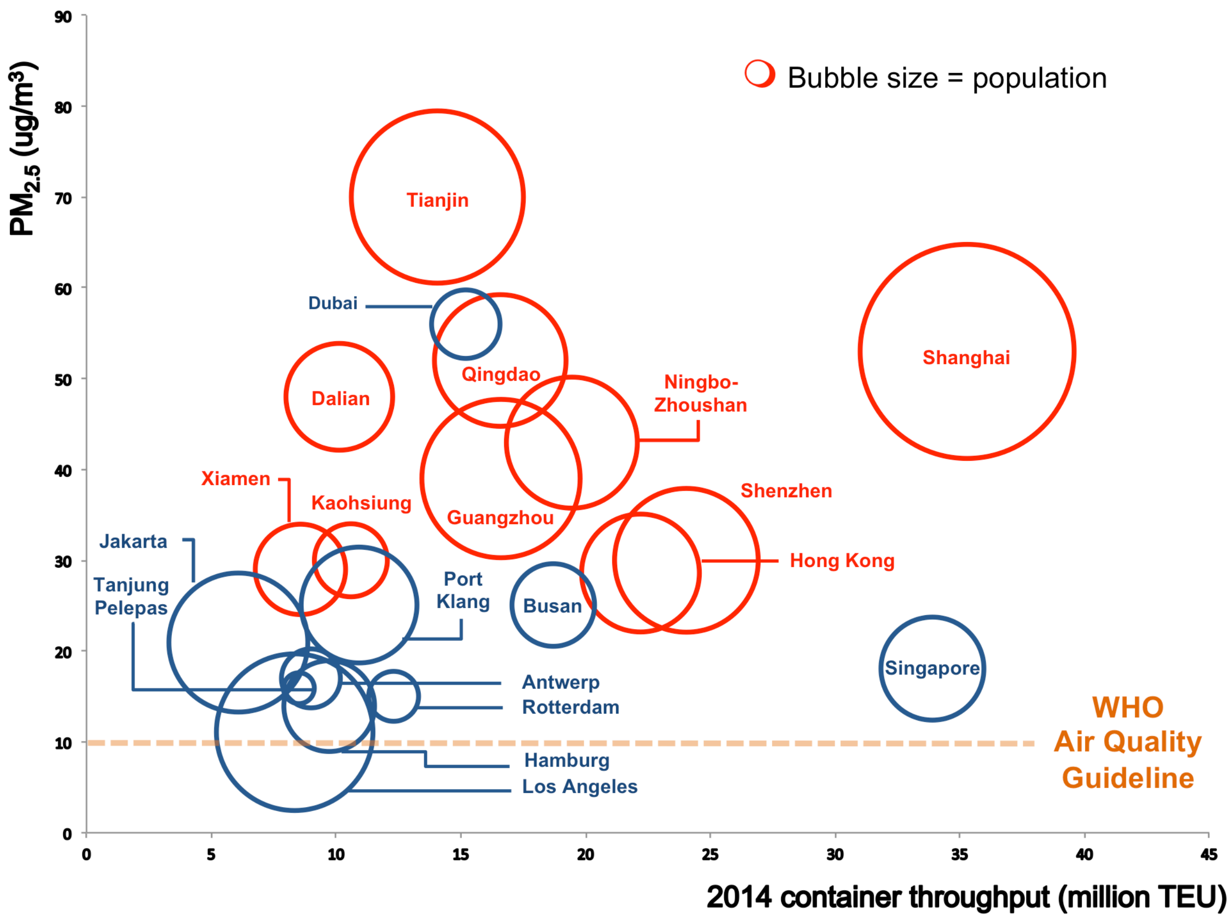


Figure E1: Container throughput, air quality and population of the world's 20 biggest container port regions[1]
Note: Ports in China are highlighted in red.

- **Remote measurement can screen air emissions from a vast number of ships in a short time, hence enabling regulators to more effectively target suspected gross emitting ships for follow-up on-board inspections. Remote measurement could also monitor compliance of ships that navigate in the DECA waters or use alternative compliance options** (such as scrubbers or liquefied natural gas). Remote measurement results could serve as clear grounds for taking fuel samples on board. Several EU countries, the US and Hong Kong have started piloting the use of remote measurement programs to support regular ship inspection programs. In addition, **EU countries have established a database for sharing enforcement inspection data, which allow enforcement officials plan their inspection activities targeting vessels or shipping companies with poor records of compliance.**

- **Instantaneous testing of sulfur in fuel using portable or handheld analyzers is another method that helps inspectors select which ships should be selected for further sulfur analysis at laboratories.** The enforcement authority in the Netherlands is now using a portable fuel sulfur analyzer that provides sulfur measurement in several minutes, and their results obtained so far compare well with those from laboratory testing. The instantaneous test results are now being used in the Netherlands for determining whether or not fuel samples should be collected for further analysis at laboratories, and if detention of the ship is needed. Other countries, like Sweden and the US, are also testing the use of the quick screening devices. While the quick screening results alone are not yet accepted as court evidence, this method can help reduce the number of samples sent for laboratory testing (and the associated costs) without sacrificing effectiveness of enforcement efforts.

Drawing from the lessons learned from the current enforcement programs adopted in the US, EU, California and Hong Kong, here are some recommendations for China to consider in enhancing its DECA enforcement program:

- With the high cost differential between using low sulfur fuels (fuels with 0.5 per cent or 0.1 per cent sulfur content) and high sulfur residual oil, ship owners/operators can be tempted to use illegal fuel if the chance of being caught is small. **Chinese enforcement officials could mandate a given percentage of ships to have DECA inspections and have fuel samples taken to establish enforcement presence. A high non-compliance penalty should also be set to deter violations**. Non-compliance penalties could be in the form of monetary penalties or non-financial penalties, such as ship detention or subjecting a ship to thorough inspections during future port visits if the given ship (or the company that owns it) has a history of non-compliance.

- While conducting ship inspections and taking spot samples of fuel is the most reliable way to monitor compliance with marine fuel sulfur regulation, these activities take time and resources. China could **pilot the use of remote measurement technologies and an enforcement database to help guide the selection of ships for on-board inspections and fuel sampling**. It could also **consider sharing enforcement data with other countries/regions that implement marine fuel sulfur regulations** in order to more effectively target unscrupulous shipping companies.

- The EU and US have established detailed enforcement guidelines to guide front-line officials in conducting compliance investigation in a fair and transparent fashion. The US has also developed a clear set of penalty policies to facilitate the speedy assessment of non-compliance penalties. **China could develop a detailed enforcement and penalty assessment guideline, using the EU and US guidelines as a reference and adapting them to China's unique situation**. These Chinese guidelines could be used when **training enforcement officials**, which would help them understand what the regulation writers expect them to do. This would help ensure that enforcement actions are consistent and predictable.

- Assurance that compliant fuel is available, and ensuring that compliant fuel is being used on board, are equally important in terms of guaranteeing the success of any marine fuel regulation. In order to help ensure that shipping companies have access to DECA-compliant fuels in China, China should **establish a clear line of responsibility and enforcement authority among relevant agencies to guarantee that marine fuels sold in China meet DECA and other international fuel quality standards**.

- Helping ship owners/operators understand how to meet the DECA regulatory requirements is important in terms of achieving full compliance. China could do so by **disseminating to the shipping industry complete, clear and timely information about the DECA regulation**, and by **offering bilingual (Chinese and English) regulatory texts and instructions** to avoid misunderstanding. China could also **offer training to companies unfamiliar with DECA regulations** to explain DECA requirements and safe fuel switchover procedures.

1. Introduction

Chinese marine trade has seen year-over-year double-digit growth in the past two decades, and China itself has become the world's biggest seaborne trading nation. With nearly a third of global container trade[2] and 13 per cent of seaborne bulk trade going through its ports each year,[3] ship traffic at Chinese ports is enormous, as is the air pollution that comes with these ships. It comes as no surprise that the marine sector has become a major cause of air pollution in the large port cities in China, including Shanghai, Shenzhen, and Hong Kong, as shown in Table 1.

Table 1: Shipping's share of local air pollution[4]

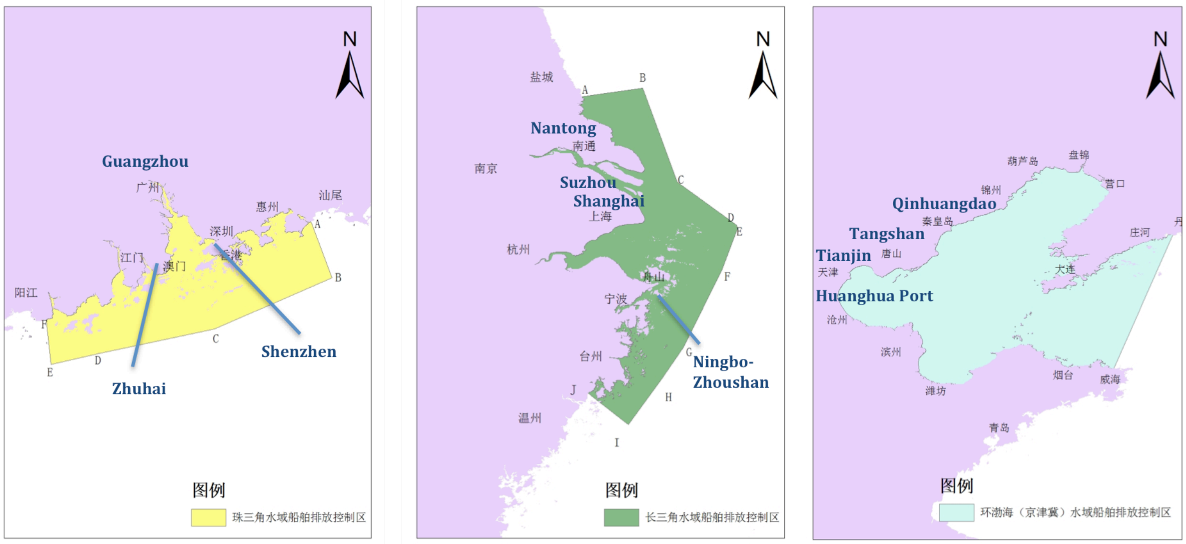
Port City	SO_x	NO_x	$PM_{2.5}$	Share of global container throughput, 2014	2014 world ranking (in terms of container throughput)
Hong Kong +	44%	33%	42%	3.2%	4
Shenzhen §	59%	16%	5%	3.5%	3
Shanghai ++	22%	17%	4%	5.2%	1

+: 2014 data, includes emissions from all vessels.
§: 2014 data, includes emissions from oceangoing vessels; accounts for share of SO_2, not SO_x.
++: 2013 data, includes emissions from all vessels.
n.a. denotes not available.

Since large ports in China are located in or near the world's most densely populated cities, air pollution from ships results in disproportionally higher health risks in China than anywhere in the world. With control of shipping emissions still lagging behind the regulatory programs of other sectors in China, curbing shipping emissions is now widely recognized as a critical step towards cleaning up the air and protecting human health.

Understanding the importance of controlling shipping emissions, China has announced a multi-step plan which phases in low sulfur fuel standards for marine fuel in its major port regions. The fuel sulfur requirement will be introduced in three Domestic Emission Control Areas (DECAs), covering major ports in the Pearl River Delta, the Yangtze River Delta, and Bohai Bay (see Figure 1). Beginning on January 1, 2017, ships calling at 11 core ports in these DECAs will be required to switch to fuel with no more than a 0.5 per cent sulfur content (i.e., 0.5 per cent sulfur fuel) while berthing.[i] The at-berth fuel switching mandate will take effect in any of the DECA ports as of January 1, 2018. As of January 1, 2019, all ships will be required to use 0.5 per cent sulfur fuel when navigating in the three DECAs.[5] In February and March 2016, the Transport Commission and the Maritime Safety Administration of Shanghai municipality, Zhejiang province and Jiangsu province (together known as the Yangtze River Delta, or YRD) announced that the YRD would take the lead in implementing the DECA regulation, to commence on April 1, 2016. All ships calling at the ports of Shanghai, Ningbo-Zhoushan, Suzhou and Nantong have to burn 0.5 per cent sulfur fuel while at berth. Ships are also encouraged to use cleaner

[i] The 11 core ports include: Shenzhen, Guangzhou, Zhuhai, Shanghai, Ningbo-Zhoushan, Suzhou, Nantong, Tianjin, Qinhuangdao, Tangshan, and Huanghua.



Pearl River Delta Emission Control Zone **Yangtze River Delta Emission Control Zone** **Bohai Bay Emission Control Zone**

Figure 1. The three Emission Control Zones designated by the China Ministry of Transport[i]
Note: The eleven core ports in the three Emission Control Zones are labeled in English in blue.

fuel (0.1 per cent sulfur content) while at berth, or switch to 0.5 per cent sulfur fuel when operating in the YRD DECA.[6]

The marine fuel regulation is slated for review by the end of 2019, to determine whether or not to lower the sulfur standard to 0.1 per cent, expand the waters coverage of the DECAs, and/or pursue other actions.

1.1 Potential benefits of implementing the DECA regulation

The DECA regulation marks an important milestone in China's fight for clean air. Ships switching from 2.5 per cent sulfur fuel[7] to 0.5 per cent sulfur fuel should reduce SO_x emissions by 80 per cent per unit of energy used; if cleaner fuel is used (0.1 per cent sulfur content), SO_x reductions in emissions could reach 95 per cent or more. In addition, particulate emission rates (in terms of PM mass) could be reduced by as much as half when switching from high sulfur residual fuel to 0.5 per cent sulfur fuels.[8]

Countries and regions that have mandated the use of low sulfur marine fuel have seen big improvements in air quality. For instance, Emission Control Areas (ECAs) for sulfur emissions have been established in the US, Canada, the Baltic Sea, and the North Sea under the International Maritime Organization (IMO). Ships operating in these ECAs must use lower sulfur fuel. Since the ECA sulfur limit ratcheted down to 0.1 per cent at the start of 2015, Denmark saw a 60 per cent reduction in SO_2 levels at Anholt (a Danish island near major shipping routes); Rotterdam (Europe's busiest port and home of a large industrial, energy and petrochemical cluster) found that SO_2 in the air dropped by about 20 per cent around the port region; and a cruise hub in western Canada, Victoria, also saw air pollution levels fall to their lowest level since monitoring began in 2006.[9]

In Hong Kong, oceangoing ships have been required to use 0.5 per cent sulfur fuel at berth since July 2015. Notable improvements in the concentration of SO_2 have been observed near the container terminal and other port areas. For instance, when wind is blowing from the Kwai Chung Container Terminal (mainly during the summer), the average SO_2 concentration recorded at the monitoring station closest to the container terminal has been reduced by about 60 per cent since the regulation took effect.[10]

1.2 A robust enforcement program is essential to achieving expected emission reductions and health benefits

The DECA regulation is expected to result in significant improvements in air quality and health benefits. However, the expected benefits can only be achieved if robust enforcement programs are in place to ensure that ships are actually switching to cleaner (but more expensive) low sulfur fuels. In addition, enforcement is critical to maintaining a level playing field among carriers, ensuring that ships that comply with the DECA regulation are not put at a competitive disadvantage.
With a strong enforcement program, the DECAs will have a higher chance of achieving a greater improvement in air quality, which could then provide stronger justifications for further tightening the DECA regulation when the MOT conducts a review of the effectiveness of the DECA regulation by the end of 2019.

Against this background, the NRDC developed this paper to inform Chinese regulators of the latest developments in enforcement initiatives abroad, and to offer recommendations for regulators when considering the development and improvement of the enforcement program for the DECA regulation. The review below mainly focuses on the enforcement program for the IMO's International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI Emission Control Areas. Where appropriate, it also highlights key features of the programs for enforcing the fuel switching rules in California and Hong Kong.

2. The fuel switching enforcement process

2.1 Verify documents on board

The quality of fuel used on ships is traditionally verified through random checks of paperwork filed by the shipping companies when ships are in port. In order to ensure that the quality of the fuel used on ships complies with ECA standards set by the IMO, the IMO requires ships to carry a number of documents and fuel samples for the demonstration of compliance with ECA standards, as detailed in MARPOL Annex VI Regulations 14 and 18:[11]

i) Bunker Delivery Notes (BDNs):
   a. Issued at the time of fuel purchases by the fuel suppliers, the BDN lists the fuel sulfur content, the quality of fuel purchased, and other information. The BDN must be kept on board for at least three years.

ii) Oil Record Books (as part of the ship's log book)
   a. The Oil Record Book records the date and time and the ship's position, as well as the volume of low sulfur fuel oils when changeover to clean fuel is completed before entry into an ECA, or when changeover to dirty fuel is commenced after exiting from such area.

iii) Representative samples of fuel oil of the fuel delivered
- A bunker supplier must provide a representative sample of the fuel delivered, which should accompany the bunker delivery note. The representative fuel sample (a so-called MARPOL sample) shall meet the ECA sulfur requirement, and must be kept on board for at least 12 months.

iv) Fuel change-over procedure
a. The fuel change-over procedure should detail how the fuel oil change-over is to be carried out, and specify the time needed for the fuel oil service system to be fully flushed of all fuel oils exceeding the ECA limits prior to entry into the ECAs. The fuel change-over procedure shall be made available for inspection during port state control visits.

If the above documents and fuel samples suggest the use of non-compliant fuel in the ECA (e.g., BDNs show that the fuel being used contains higher concentrations of sulfur than permitted), the ship owners or operators are regarded as violating the regulations.

2.1.1. Verifying the veracity of fuel changeover records

While complete and consistent information recorded in the above documents and fuel samples could suggest that compliant fuels have been used, the BDN and log book entries are susceptible to potential fraud or forgery, as they are often hand-written. In addition, BDNs are not always produced in English, and are sometimes illegible as they can take the form of carbon copies, which make inspections difficult.[12] To verify the veracity of fuel changeover records in the BDNs and ship's log books, enforcement personnel could check the current fuel temperature and viscosity, the change in fuel temperature and viscosity over the past few hours or days, as well as the alarm history to evaluate if they present consistent information.

Fuel temperature and viscosity

Since residual fuel is much more viscous than distillate fuel, it requires preheating before it can be pumped to the engines. Therefore, the temperature and viscosity of fuel being used at the time of inspection and in the past few hours or days could be used to determine whether non-compliant fuel has been used.

As a general rule, distillate fuels typically operate from 20°C - 70°C, while high sulfur residual fuel typically operate from 115°C - 145°C. On hybrid fuels and lower sulfur residual fuels, the temperature depends on the chemical characteristics of the fuel, so it would be best to refer to the specifications that the fuel manufacturer suggests for safe operation. Generally speaking, ultra-low sulfur fuel oil operates at around 60°C - 95°C. It is important to note that these are general guidelines, and inspectors should always refer to the bunker delivery notes or bunker receipts for the fuel specification.[13]

Based on the experiences of the California Air Resources Board (CARB), fuel temperature and viscosity can be observed at the following locations:
- Temperature gauges at auxiliary engines or in engine monitoring computer system provide current fuel temperature and viscosity
- Viscometer at the Supply Module in Purifier Room show fuel temperature and viscosity

- Maine engine and / or auxiliary engine fuel oil temperature trend and fuel oil viscosity trend, if available

Alarm history

As a common safety measure on board, changes in the temperature and viscosity of the fuel in the engine and fuel system will set off alarms, and those alarms are recorded on paper or in the computer. Inspectors could check the history of the fuel oil temperature alarms, fuel oil viscosity alarms, fuel inlet pressure alarms, leakage alarms, and the event logs, to identify indications when fuel switching took place.

Appendix I shows an inspection flowchart developed by CARB that outlines the steps for verifying documents, checking fuel temperature and viscosity, and taking fuel samples.[14]

Where inconsistent or conflicting information is recorded in the fuel-related documents mentioned above, and the fuel temperature and viscosity parameters, there may have been violations of the rule, so further investigation should be pursued. For instance, records in the log books may show that fuel switching occurred during the first hour after berthing, but the main engine fuel oil temperature and viscosity trend may suggest that fuel switching occurred more than one hour after the ship was at berth.

Some regions that have adopted marine fuel regulations (including California, the US, and Hong Kong) also require all information contained in the above documents to be correct and complete. Incomplete, false, or misleading information found in these documents could be considered deficient, and be subject to penalties.[15]

Even if the information on the BDNs, log books, the historical and current fuel temperature and viscosity are all consistent, they may not be sufficient for proving that compliant fuel has actually been used on board—especially when considering the numerous areas of potential fuel contamination from bunkering operations, fuel storage tank transferring to settling tanks, fuel purification to service tanks, as well as inherent contamination with previous in-use fuel within the engines themselves.[16] Therefore an increasing number of countries are collecting samples of fuel from the ship's fuel system for sulfur analysis.

2.2 Fuel sampling for sulfur testing

Collecting fuel samples from the ship fuel system for subsequent laboratory analysis offers the best evidence for verifying the sulfur content of fuel being used on board.[17] Results from fuel testing can be used as evidence for the imposition of sanctions. Compared to document inspections, fuel sampling is more costly and time consuming, so is only carried out occasionally - typically when there are clear grounds for suspicion.[18] As the costs of compliance have increased significantly since the 0.1 per cent sulfur ECA regulation came into force on January 1, 2015,[ii] an increasing number of countries have committed to increasing the frequency with which ships' fuel samples are collected and tested.

[ii] Before January 1, 2015, all ships operating in the ECAs were required to use fuel with no more than 1 per cent sulfur content. Low-sulfur residual fuel (with no more than 1 per cent sulfur) were typically used to meet the 1 per cent ECA requirement. The cost differential between 1 per cent sulfur residual fuel and the normal high-sulfur residual fuel is small—the differential was as low as 0.2% for fuels sold in the Mediterranean and Black Sea market. After the 0.1 per cent sulfur ECA regulation came into force, highly-refined distillate fuels are necessary for meeting the ECA requirement. The average price

Fuel sampling is now an essential part of EU and California marine fuel enforcement efforts. California enforcement officials for the marine fuel rule collect fuel samples of fuel in-use for off-site analysis during every ship inspection. The European Commission issued a decision in February 2015 that requires all member states to collect and test sulfur samples on 2 to 4 per cent of the total number of individual ships calling at relevant member states each year, starting in 2016 (see Section 4.2). In February 2016, the US Coast Guard initiated a voluntary fuel oil sampling program to help assess industry compliance with the ECA requirements.[19]

In China, MSA officials in Shanghai, Zhejiang, and Jiangsu started enforcing the DECA regulation on April 1, 2016, and fuel samples have been taken on board from a fraction of ships inspected to verify DECA compliance.[20]

2.2.1 Fuel sampling and testing procedure

There is no uniform procedure for sampling and verifying the sulfur content of fuel used on board ships. The IMO is now developing such guidelines, which are due for discussion at the IMO's Marine Environment Protection Committee (MEPC) meeting in October 2016 for final approval.[21]

The Fuel Inspection Guidance issued by the European Maritime Safety Agency (EMSA) includes a short guideline on taking fuel samples from the fuel system, which covers the following steps:[iii,22]

- *An on-board spot sample for marine fuel shall be taken at a location where a valve is fitted for the purpose of drawing a sample in the fuel service system*
- *The spot sample should be representative of the marine fuel being used, and should be collected in a sampling container that is large enough to fill at least three sample bottles*
- *Sampling containers should be made of metal or plastic suitable for the temperature of the fuel oil being sampled*
- *If the sampled oil is heated, the sampling container should be fitted with handles or held within a second container*
- *The sample should be shaken thoroughly straight after the primary sample is collected; the primary sample is then used to fill two clean, inspector-provided sample bottles for off-site sulfur analysis*
- *The sample bottles shall be sealed with a unique means of identification, attached in the presence of the ship's representative.*

The most critical point of the sampling procedure is the choice of sampling location. There is consensus that the sampling location should be as close to the engine as possible, which helps ensure that the fuel samples are truly representative of the fuel in use. CARB specifically recommends sampling from "final filters". Final filters may be found directly on operating auxiliary engines. Final filters may also be found in the purifier room, within supply service systems for main or auxiliary

of 0.1 per cent sulfur distillate fuel in Singapore was 73% higher than that of the high-sulfur residual fuel as of August 6, 2016. Therefore the compliance cost is much higher under the current ECA regulation.

[iii] See the EMSA, Sulphur Inspection Guidance for a more detailed description of the steps for taking on-board fuel samples.

engines, and sometimes boilers. Ship management companies may also designate final sampling locations. As a rule of thumb, enforcement staff should avoid sampling from storage, settling, and service tanks, day tanks (those tanks that are typically located far from the engines), flushing pumps, transfer pumps, and crossover pumps.[23] The IMO, the US Coast Guard, US Environmental Protection Agency (US EPA) and CARB require fuel sulfur content to be tested pursuant to International Standard ISO 8754:2003.[24] The analysis of the fuel sample should be done in accordance with the verification procedure in MARPOL Annex VI Appendix VI.[25]

It is also extremely important to maintain a good chain of custody for any fuel sample taken from the ships. A chain of custody is a written legal document used to track the transfer of a sample(s) from person to person. Without a continuous record of chain-of-custody, the validity of any sample or the results of any tests/analyses may be questioned. The chain of custody document must be initiated by the personnel who collect fuel samples on board. Each person who subsequently take custody of the fuel sample must provide his/her name, organization, date, time, contact information, and signature on the chain of custody document, in order to assure the integrity of the sample taken is preserved from collection to analysis, to destruction, or to further transfer.

There are concerns that, if fuel analysis cannot be completed before a ship leaves the port and the laboratory results suggest non-compliance, the ship owner and operators could easily escape prosecution. To address this concern, regulatory personnel should make sure to obtain the contact information of the Designated Person Ashore (DPA) during each inspection, as the DPA will serve as the key contact person representing the shipping company, should the fuel testing results demand follow-up enforcement actions.[iv]

It should be noted that the IMO adopted additional guidelines in 2009 for obtaining the MARPOL sample.[26] The MARPOL sample, taken during fuel delivery to ships, is solely intended to show what kind of fuel is being supplied to the ships - not the fuel actually being used on the ships. The MARPOL sample is only useful in terms of clarifying whether the fuel suppliers or the operators should be held responsible if the fuel used on board is found to exceed the sulfur standard. It is a common view that the MARPOL sample is of little use when it comes to verifying compliance with the ECA regulation.[27]

2.2.2 Quick screening devices for onboard fuel testing

The Netherlands Shipping Inspectorate (i.e., the Port State Control of the Netherlands) is using a portable screening device that can provide instantaneous measurements of fuel sulfur content in order to determine whether or not laboratory samples of fuel should be collected to confirm that the fuel exceeds the ECA sulfur standard, when the screening test shows the sulfur content higher than 0.1%; or should the ship be detained when the screening test shows the sulfur content higher than 0.15%. The quick screening results obtained to date compare well with those from laboratory testing. Enforcement personnel in the US and Sweden have also started testing the use of portable quick screening devices. These screening devices, such as those that utilize x-ray fluorescence technology, can produce results in less than five minutes.[28] The US EPA also uses such devices to screen fuel samples collected from bunkering facilities.[v] As the accuracy and reliability of the quick screening devices offered by different manufacturers vary, research and testing is needed to determine which

[iv] As an international practice, every ship company designates a person or persons ashore, called the Designated Person Ashore or DPA for each of its ships. Having direct access to the highest level of the company's management, the DPA is responsible for monitoring the safety and pollution prevention aspects of the operation of each ship.

[v] The device that the US EPA is testing conforms to ISO 8754:2003 standards; it is available for sale on the market.

type of device to use and develop a reasonable cut-off point in gross non-compliance cases. Price of a set of portable x-ray fluorescence sulfur-in-oil analyzer ranges from US$18,000 to US$39,500.[29]

2.3 Remote measurement: making traditional enforcement methods more efficient

While on-board inspections and fuel sampling are the most common enforcement methods for marine fuel standards, they have two limitations for verifying ECA compliance:

i) Document checks and fuel sampling cannot identify ships that use high sulfur fuel when transiting through the ECAs but not calling at the ports, because fuel compliance inspections can only take place in ports.[vi] This shortcoming will become relevant to China when it starts requiring all ships operating within the DECAs to use low sulfur fuel in 2019.

ii) For ships that use scrubbers or other alternative measures to meet the fuel sulfur regulation, it is possible that the emission monitoring data and parameter records onboard can be falsified (see Section 2.4), and fuel sampling is largely irrelevant.

To address these limitations and enforce the ECA regulation more efficiently, countries have been testing the use of remote measurement technologies to monitor ship compliance. An increasing number of studies have demonstrated that remote measurement technologies can identify gross emitting ships from afar, and are able to measure emissions from a large number of ships in a short time.[30]

Because of the higher uncertainty of remote measurement results compared to laboratory testing of fuel samples in a more controlled environment, and not enough data to allow comparison of remote measurements with onboard emission measurements, at the time of writing, remote sensing results cannot be used to serve as evidence for convictions.[vii] However, remote measurement offers a cost-effective means of screening ships suspected of using non-compliant fuel. It can be used to monitor shipping emissions when a ship enters or leaves a port, or on the high seas. If remote measurement findings can be passed on to PSC officials, the PSC officials could target ships that register a suspicious reading for on-board inspections at the next port of call.

Another advantage of deploying remote measurements is that their results could constitute clear grounds for taking fuel samples on board. As fuel sampling becomes more commonly used for verifying ECA compliance, there are concerns that, without a basis for justifying fuel sampling, ships would face an unfair burden for being subject to fuel testing. Remote measurement results offer clear evidence which justifies the need to take fuel samples on board.[31]

As of the date of writing, seven programs for the remote measurement of shipping emissions have been conducted, or will be deployed in 2016, in the EU, in order to improve the enforcement programs of the ECA and other fuel regulations (see Appendix II). The US EPA, California, and Hong Kong are also testing the use of remote measurement technologies.[32]

[vi] Port State Control officers cannot board a ship outside of internal waters (e.g., inside a port) unless there are clear justifications to suspect it has not respected regulations, according to the United Nations Convention on the Law of the Sea and the MARPLO code. See United Nations Law of the Sea (UNCLOS), 1982, Article 27.

[vii] There are ongoing research trying to lower the uncertainties of remote measurement, with the hope that remote measurement results could serve as court evidence in the future.

3. Overview of remote measurement techniques

Two of the most frequently used remote measurement techniques are "sniffing" technology, and optical sensing technology.

3.1 The sniffing method

The sniffing method relies on the simultaneous measurement of pollutants compared to background levels. The equipment used in building the sniffers is similar to traditional air quality monitoring equipment. When the plume of a passing ship hits the sniffer, the pollutants in the exhaust plume (NO_x, SO_x, PM, etc.) cause the measured concentration of pollutants to increase compared to the background concentrations.

The CO_2 concentration in the exhaust plume indicates the amount of fuel being burnt at a given time, and the SO_2 concentration is proportional to the fuel sulfur content. Hence, the fuel sulfur content of an individual ship can be estimated by the ratio of the SO_2 and CO_2 concentration inside the ship exhaust plume.[33]

When a ship plume hits the sniffer instrument, a spike in nitric oxide (NO) or nitrogen dioxide (NO_2) is typically observed because fuel combustion causes an increase in oxide of nitrogen (NO and NO_2).[34, viii] The CO_2 concentration also increases when a ship plume passes the sniffer instrument, but its background concentrations are larger and more variable due to surrounding vegetation, so CO_2 is not used as a marker of a shipping plume.[35]

At locations where there are other sources of pollutants nearby, such as refineries or power plants, an elevated level of NOx, CO_2 and SO_2 concentration could be caused by these other sources. However, when the air is influenced by sources such as power plants, the peaks in NOx, CO_2, and SO_2 are much longer, and the general background levels are increased.[36] Thus, only those events which show a sharp and significant increase in both NO (or NO_2)[ix] and CO_2 emissions are marked as a ship event and analyzed.[37]

In order to allocate the observed peaks to the corresponding emitting ships, data on wind speed and direction, as well as Automatic Identification System (AIS) data are analyzed.[x] As an illustration, Figure 2 shows a screen shot of an application developed by Chalmers University of Technology in Sweden to analyze the sniffer measurements. When the sniffer (marked by the star) registers an elevated pollutant level, the application automatically estimates fuel sulfur content of ships suspected of emitting high level of sulfur and CO_2. By combining the data on wind speed and direction, it estimates the exhaust plume direction. The direction of the plume, coupled with the AIS data, can then be used to associate an emission peak with an individual ship (marked by the pink rectangle). The system of Chalmers University automatically transfers the ship information in real time to port state control authorities of the ship information. These measurements are undertaken as part of the European CompMon project (see www.CompMon.eu).

[viii] In addition, NO_x is measured to correct the cross interference of SO_2. For regions that have enacted a NO_x-related regulation, such as the IMO MARPOL Annex VI NO_x ECA, estimating NO_x emissions could also support enforcement.

[ix] In the exhaust of a naturally aspirated diesel engine, the majority of the NO_x emissions is NO, NO_2 account for about 5 per cent; however, NO can be easily oxidized by oxygen into nitrogen dioxide at ambient conditions.

[x] The AIS data can be obtained from AIS data providers, or from websites that report real-time data of shipping location, such as www.shipfinder.co.

In Germany, on behalf of the Federal Ministry of Transport and Digital Infrastructure (BMVI), the Institute of Environmental Physics (IUP) of the University of Bremen, Germany is developing and optimizing a similar type of application in cooperation with the Federal Maritime and Hydrographic Agency (BSH). The application would be able to automatically track sulfur emissions from ships passing two sniffer monitoring sites near the Port of Hamburg (Wedel and Neuwerk), and report suspicious cases in near real time to an international database for targeting ships for on board inspections by local authorities (e.g., Port State Control).[38] The development of the application is one part of the MeSMarT project (Measurements of Shipping Emissions in the Marine Troposphere).[xi]

As discussed before, the measurement equipment in the sniffers is the same as that used to monitor air quality. The air quality analyzers are based on the following principles: UV-fluorescence for measuring SO_2, chemiluminescence for NO and NO_x, and non-dispersive infrared absorption or cavity ring-down spectroscopy for CO_2 concentration. The analyzers in the sniffers have been adopted for their faster response (especially for airborne measurements), smaller weight, minimum volume, and field robustness.[39]

Figure 2. A screen snapshot of the IGPS software developed by Chalmers University of Technology to calculate the position of the ship plume based on wind direction and the ship movement

Figure reprinted with the kind permission of Johan Mellqvist of Chalmers University of Technology, Sweden.

3.1.1. Sensitivity of sniffers in differentiating non-compliant ships

Studies have found that sniffer measurements of fuel sulfur content from land and mobile platforms (the latter installed on airplanes and ships) showed good agreements with on-board stack measurements of SO_x and NO_x emissions.[40] Sniffer measurements near the Port of Gothenburg show a drop in the overall fuel sulfur estimates in 2010, which is consistent with the ECA sulfur limit ratcheting down from 1.5 per cent to 1 per cent on July 1, 2010 (see Figure 3). Similarly, sniffer

[xi] More information about the MeSMarT project can be founda at www.mesmart.de.

measurements taken near the Port of Hamburg also demonstrate that the equipment is sensitive to changes in fuel used by ships before and after the ECA fuel sulfur standard ratcheted down from 1 per cent to 0.1 per cent on January 1, 2015. Figure 4 shows the remote measurement results of NO and SO_2 emissions in Wedel, Germany. NO concentration is largely the same from December 2014 to January 2015, while the plot of the measured SO_2 concentration shows a significant drop, as expected, in January 2015.[41]

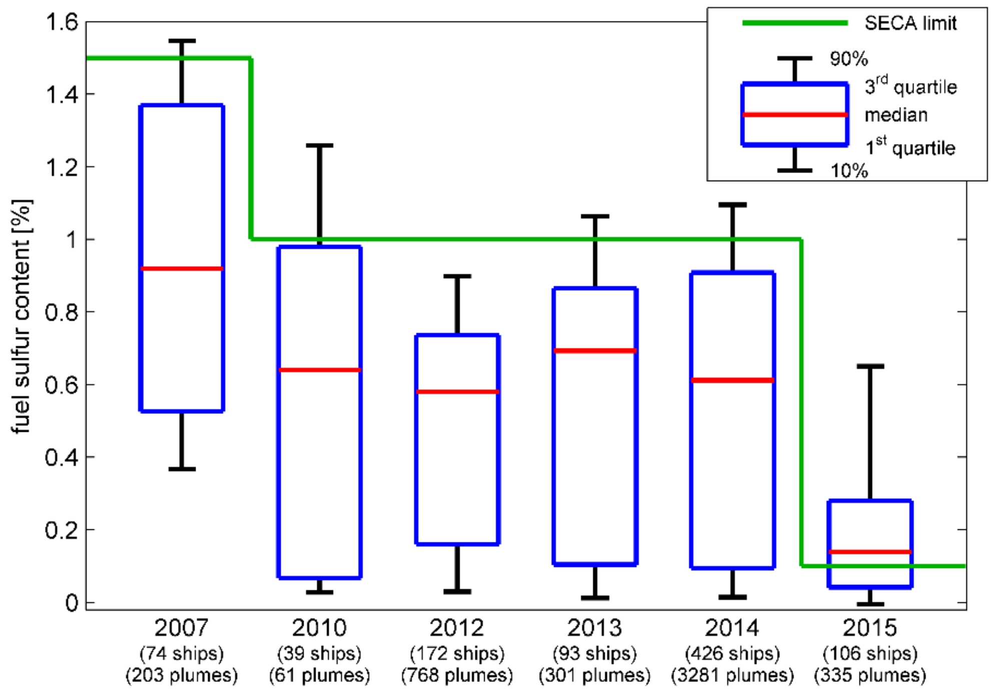


Figure 3. Sniffer measurements of the fuel sulfur content of ships entering and leaving the Port of Gothenburg in 2007, 2010, 2012 to 2015[42]

Figure reprinted with the kind permission of Johan Mellqvist and Jörg Beecken of the Chalmers University of Technology, Sweden.

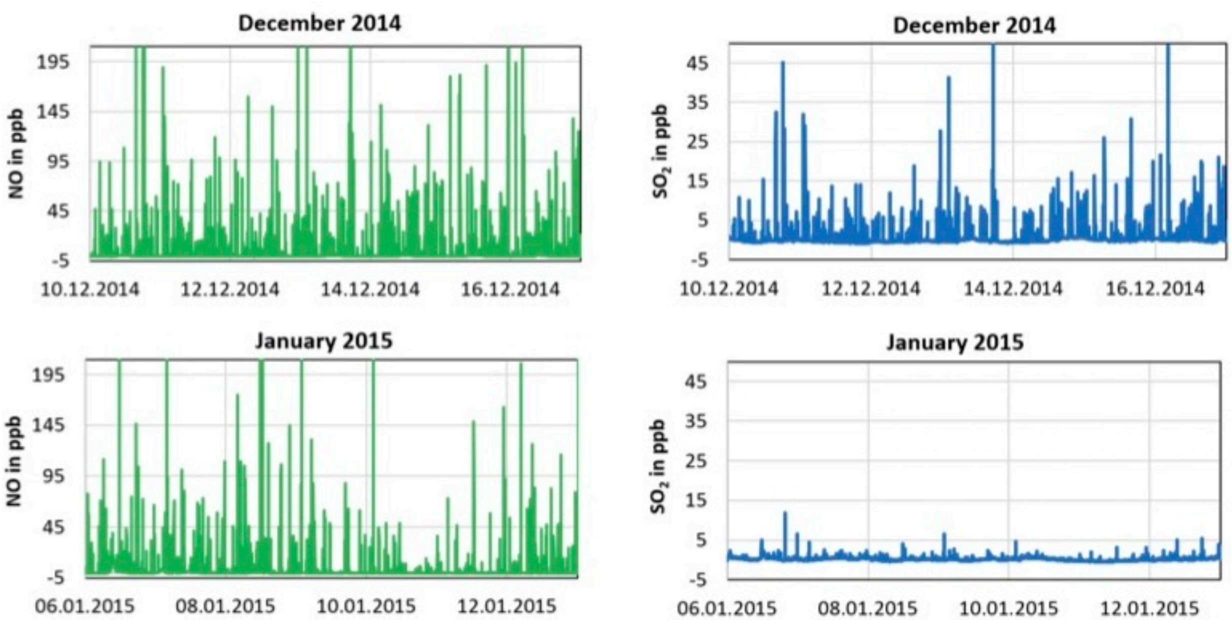


Figure 4. NO and SO_2 volume mixing ratio measured over two weeks at Wedel (near Port of Hamburg) with comparable wind directions[43]

Note: These charts show that NO emissions have not changed significantly since the 0.1 per cent ECA sulfur limit became effective in 2015, while the SO_2 values have been substantially lowered.
Figure reprinted with the kind permission of Lisa Kattner of the University of Bremen, Germany.

3.1.2. Strengths, limitations and uncertainty

The sniffer system is easy to implement and is readily deployable, as it is composed of commercial air quality analyzers. It can be used to remotely measure both SO_x and NO_x emissions from ships, so could be used to monitor compliance with the ECA and Chinese DECA standards, as well as NO_x ECA requirements.

A challenge for using the sniffer system is to distinguish exhaust plume from ships with that from other combustion sources that can also cause a simultaneous increase in NO/NOx and CO_2. Hence, the siting of the fixed-point sniffer stations is especially important. These stations need to be placed in the main wind direction to ensure that ship exhaust plumes can always reach the sniffers. It would be best to place the sniffers away from major emission sources, if possible, and at a primarily downwind position from major shipping lanes to maximize sampling rates. This shortcoming could also be addressed by conducting emission measurements on mobile platforms, such as ships and airplanes.

Assuming that a predominantly downwind fixed site can be located, or measurements can be conducted on mobile platforms, the more complicated task is to developing the software for automated analysis of the plume and assigning the ship plume to an individual ship. Such a system with appropriate software has been developed by Chalmers University of Technology and implemented at the harbor inlet of Göteborg and the Great Belt bridge in Denmark and elsewhere.[44] In close to real time the system automatically reports the fuel sulfur content of by passing ships to database of the Danish environmental authority. In Germany, the Institute of Environmental Physics (IUP) of the University of Bremen, in cooperation with the Federal Maritime and Hydrographic Agency (BSH), are developing and optimizing such software, as mentioned in section 3.1.

Another shortcoming of the sniffer approach is that the sniffers require regular calibration. For instance, the sniffers used for airborne measurements need to be calibrated before every measurement flight; [45] the sniffer equipment at Wedel (near Hamburg) is automatically controlled every 25 hours, and is manually calibrated every few months.[46]

The uncertainty of the sniffer measurements has to be calculated for each ship, and depends on many factors.[xii] The absolute overall uncertainty level of the sniffer system used at Wedel near Hamburg lay between 0.03 and 0.1 per cent sulfur m/m, even though much higher uncertainty levels (as high as 0.42 per cent sulfur m/m) were registered when the signal-to-noise ratio was very bad.[47] The uncertainty of the sniffer system deployed near Gothenburg is reportedly around 0.1 to 0.2 per cent sulfur m/m.[xiii] Therefore, under the current 0.1 per cent ECA sulfur limit, only ships whose sulfur emissions indicate a 0.3 per cent or higher fuel sulfur content would be subject to further compliance investigations.

3.2 The optical sensing method

3.2.1 How it works

The optical method measures the variations of light properties after interaction with pollutants, and has been used for years for the measurement of atmospheric trace gases.[48] A study which compares various optical remote measurement technologies found that the Differential Optical Absorption Spectroscopy (DOAS) technique is the most reliable optical method for the measurement of shipping emissions.[49] The Multi-Axis DOAS (MAX-DOAS), a specific type of DOAS equipment, has been successfully used to estimate air pollution.

The principle of optical absorption spectroscopy is that the intensity of light decreases as it travels through an absorbing medium, such as SO_2, NO_2, and ozone. There is a relationship between the number of pollutant molecules in the light path, and the amount of light being absorbed. By analyzing the spectra of the light that has passed through the exhaust plume, the concerned pollutants can be identified, and the amount of pollutants along the light path can be estimated.

An active DOAS instrument consists of a continuous light source, and an optical setup to send and receive the light through the atmosphere. The measurements for the passive DOAS rely on natural light sources, such as the sun and moon. In the DOAS equipment used for measuring shipping emissions, sunlight is often used.

This method has been used by several research groups for monitoring air pollution from ships. Chalmers University of Technology in Sweden has developed a passive airborne system that is used to measure SO_2 and NO_2 emissions from individual ships, in order to rapidly screen a large number of ships for high sulfur fuel content.[50] This system is being used operationally from a Danish fixed-wing aircraft for the past two years, on behalf the Danish Environmental authorities, and several tens of

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[xii] Factors that affect the uncertainty include the signal-to-noise ratio of the SO_2 and the CO_2 measurements, the emissions and dilution, instrument accuracy, calibration accuracy, repeatability, as well as the uncertainty of assuming complete conversion of carbon and sulfur to CO_2 and SO_2, respectively.

[xiii] Chalmers University reported an uncertainty of about 20 per cent at 1 per cent fuel sulfur content for measurements obtained by its sniffer equipment, see Johan Mellqvist et al., *Identification of Gross Polluting Ships to Promote a Level Playing Field within the Shipping Sector*, and Beecken, J. ; Mellqvist, J. ; Salo, K. 2014. "Airborne emission measurements of SO_2, NO_x and particles from individual ships using a sniffer technique", *Atmos. Meas. Tech*., vol. 7(7), pp. 1957-1968.

gross polluting ships running on high sulfur fuel content have been found with this system. Chalmers is also applying this system from fixed stations or from harbor crafts to monitor emissions in and around Rotterdam.[51]

The University of Bremen has developed a multi-axis DOAS system (MAX DOAS) system which is used to monitor the air over a larger shipping lane area (6-10 km), and can be used to measure emissions of individual ships. Figure 5 shows a schematic of the MAX-DOAS instrument which is used to measure shipping emissions from ships and airplanes.

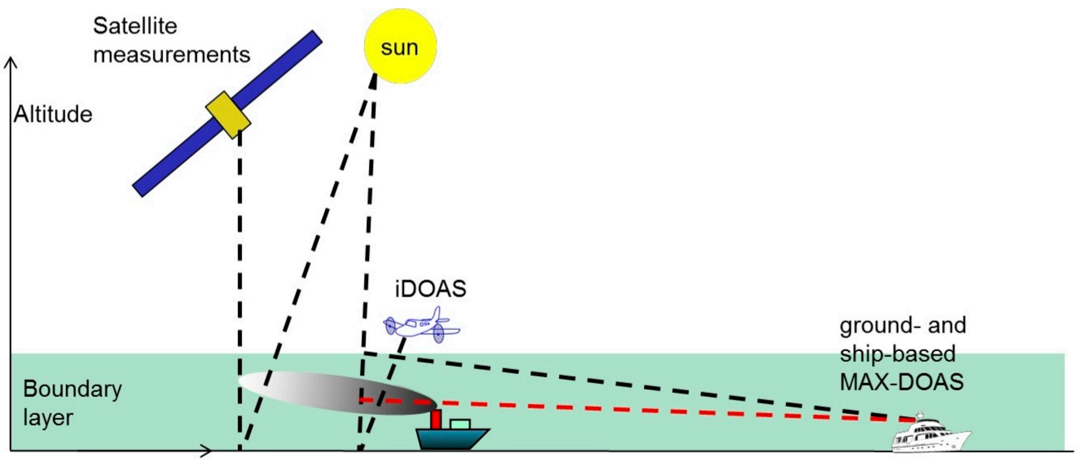


Figure 5. Schematic diagram showing how the MAX-DOAS instrument can be used to monitor shipping emissions from a ground-, ship- or airplane-based platform[52]

Figure reprinted with the kind permission of IUP, University of Bremen, Germany.

The MAX-DOAS measures the absorption of sunlight at certain wavelength, characteristic for specific gases such as SO_2 and NO_2. To analyze the spectra, the user needs a radiation transport model that includes several parameters, such as true local time, the true measurement angle relative to the sun, etc. The result will be a column density (e.g., pollutant counts per cm^2). The length of the measured column can vary, depending on the visibility at the measured wavelength, but that can be estimated. From the column density, a volume mixing ratio can be estimated. However, the user will obtain information on SO_2 from a MAX-DOAS, but not information on CO_2, so the measured SO_2 concentration will need to be correlated to the NO_2 concentration to indirectly derive the fuel sulfur levels. The NO_2 concentration, in turn, depends on the current load of the ships, the engine temperature, and the age of the plume (the older the plume, the more NO is transferred to NO_2). In order to develop an MAX-DOAS based tool for compliance monitoring of individual ships, more research is needed on developing the radiation transport model and obtaining estimates of the parameters for the model, and estimating the ship-specific information for deriving the NO_2 concentration.

3.2.2 Strength, weakness, and uncertainty

The biggest advantage of the DOAS system lies in its ability to target the measurement of an exhaust plume from afar-measurements can be as far as 6 km from the ships. The DOAS measurement system operated by Chalmers University of Technology is less accurate than the sniffer system, but it can be used to discriminate between ships running on high and low sulfur fuel content respectively.

Another advantage of DOAS is that the system does not need calibration. In addition, the optical measurement is less affected by the background pollution level, or by emissions from other passing ships, than the sniffer technology.

The biggest challenge of using the MAX-DOAS system, in particular, for compliance monitoring of an individual ship is the need to develop the radiation transport model for analyzing the observed spectra as discussed above, and to develop ship-specific estimates of ship engine load and temperature, and the age of plume for deriving the SO_2 to NO_2 mixing ratio, as mentioned above.

As the passive DOAS system relies on the change of sunlight to estimate the concentration of pollutants, it can only operate in the daytime. This shortcoming could be addressed by using an active instrument with an external light source.

The uncertainty of the DOAS method strongly depends on the instrument. The better the light through-put, the better the accuracy. In addition, it depends on the concentration of pollutants and the type of pollutant, as some gases have a strong absorption so can be measured better. Studies have found that the overall uncertainty of a downward looking DOAS instrument (such as one that is mounted on an airplane) could be as high as 30-45 per cent, and the uncertainty of a horizontal and upward looking DOAS (e.g., one used at a land location) could be about 10-30 per cent.[53]

3.3 Indicative cost of remote measurement equipment

The costs of the remote sensing equipment vary widely, depending on the type of sensors, the size of the equipment, and the pollutant species being monitored. Based on the sniffer and optical systems developed by researchers at the Chalmers University at Gothenburg, Sweden, the indicative cost of building a fixed site sniffer instrument is €130,000-150,000 (RMB 964,00-1,110,000).[xiv] The instrument includes sensors for SO_2, NO_x, CO_2, and CH_4, and instruments for measuring wind speed (to estimate plume direction) and integrating AIS data for vessel identification.

The indicative costs of building a set of sniffer instruments and optical instruments that are applicable for airplane surveillance is €200,000-240,000 (RMB 1,480,000-1,780,000) and around €150,000 (RMB 1,110,000) respectively.

3.4 Location of measurements

In order to measure air emissions from ships, the sniffer and DOAS equipment can be set at fixed locations, or on mobile platforms, such as trucks, airplanes, and vessels. Fixed-point measurement offers the advantage of lower costs, and could be run fully automatically, so a large number of measurements could be obtained (see Figure 6 for two fixed-point measurement sites outside the Port of Gothenburg and the Port of Hamburg). However, it is worth noting that, once ship operators learn the locations of the measurement equipment, they can adapt to it by switching to low sulfur fuel only when the ship is close to the measurement equipment. Since it can take one to a few hours for the fuel system to be fully flushed of all high sulfur fuel oils when switching from high sulfur residual fuel to low sulfur fuel, the concern that ship operators may adapt could be addressed by setting up a number of unannounced fixed known measurement sites. A given ship with "clean" exhaust gas measurements at multiple sites would represent a consistent use of clean fuel.

[xiv] Exchange rate as of July 7, 2016 is used throughout the document.

Fixed-point measurements at locations with other emission sources or heavy ship traffic also require corrections for background pollution or the interference of emissions from other vessels. For sniffers, in particular, the sampling probability of a fixed-point sniffer measurement is greatly affected by the wind direction and the sniffer location. This would, in turn, limit the sites available for measuring shipping emissions.

Airborne surveillance offers the advantage of covering a much wider range of areas, so that a large number of ships can be reached and inspected within a short time. Another benefit of airborne surveillance is that changing wind direction has less impact on the measurement results, particularly if the sniffer technology is used. During airborne measurement campaigns, an airplane could follow a ship, and transact multiple times across the plume in order to obtain a more reliable estimate.[54] Helicopters and drones are now being tested in the Netherlands and Germany. Both helicopters and drones can fly inside an exhaust plume for a given amount of time to allow the sniffers obtain more accurate emission estimates.[xv]

The main drawback of airborne surveillance is its high cost (of around €2,000-3,000 per hour, or RMB 17,400-22,200 per hour).[55,xvi] It would be more cost effective to deploy this at locations with a high probability of finding ships using non-compliant fuel. In addition, costs could be lowered if air-borne measurements could be combined with existing aerial surveillance work for detecting operational or accidental spills by oil or other harmful substances from ships.[56]

[xv] For safety reasons, helicopters and drones are not allowed to fly directly over a vessel, so emission measurements can only be obtained when exhaust plumes are blown sideway.

[xvi] This covers the cost of operating the aircraft, the cost of installing the sniffer, and the costs of certification with the European Aviation Safety Agency (only for civil aircraft), assuming no need for purchasing the aircraft.

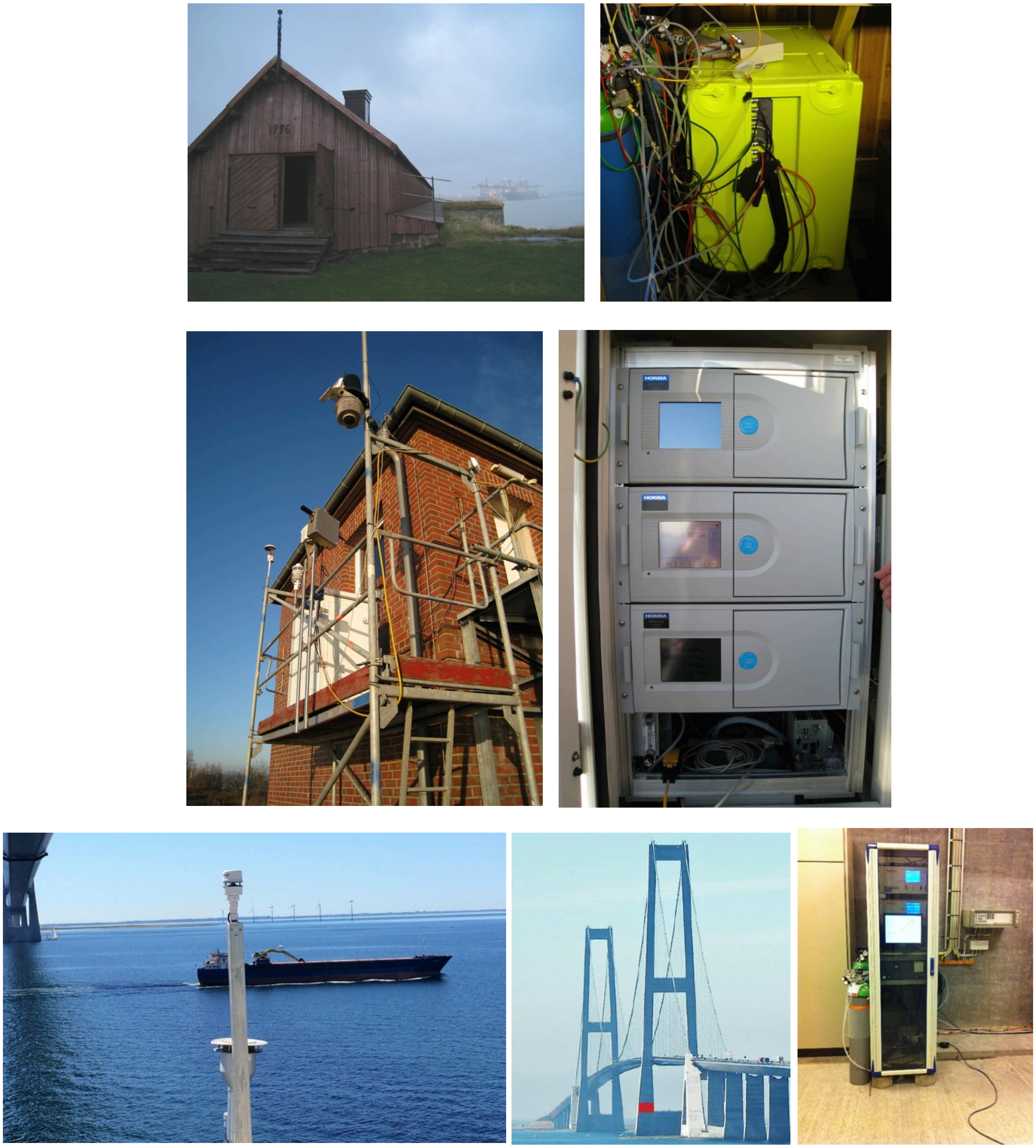


Figure 6. Fixed-point sniffer devices near the Port of Gothenburg in Sweden, the Port of Hamburg in Germany, and on the Great Belt Bridge in Denmark

The upper left picture shows the building on Älvsborg Fortress, at the entrance to the Port of Gothenburg, where the sniffer instrument is placed. The upper right picture shows the sniffer instrument placed in an all-weather protective box; middle left, the picture shows the sniffer and DOAS telescope placed outside a building in Wedel, near the Port of Hamburg; middle right, the picture shows the air quality monitoring equipment inside the all-weather sniffer protective box; lower left, the picture shows a ship passing by Chalmers' sniffer instrument on the Great Belt Bridge; lower middle, the red mark in the picture shows the location of the sniffer equipment inside the pillar of the Great Belt Bridge; lower right, the picture shows the sniffer equipment and analyzer inside the bridge pillar. About 25,000 ships pass by the Great Belt Strait in 2015 as it is the main gateway to the Baltic Sea.

4. Verifying compliance of ships adopting alternative equivalent compliance methods

Regulation 4 of IMO MARPOL Annex VI allows ship owners/operators to adopt alternative methods to comply with the Annex VI requirements, as long as those methods are at least as effective in terms of emissions reductions as that required by the Annex VI.[57] Exhaust gas cleaning (EGC) systems (also known as scrubbers for SO_x) and liquefied natural gas (LNG) engines are the two most common equivalent compliance methods for meeting the fuel switching requirements.

In China, the DECA regulation also allows the use of equivalent compliance measures, including EGC systems, clean fuels, and shore power, if those alternative methods can achieve equivalent emissions reduction to that required by the regulation.[58]

4.1 Exhaust Gas Cleaning (EGC) System

As per the *Sulphur Inspection Guidance* issued by the EMSA,[59] onboard inspections for ships fitted with EGC units could focus on the following documents:

- i) Documents issued by the Flag State for approving the use of scrubbers:
    - a. MARPOL Annex VI performance Scheme A or B certification for non-EU and non-US flagged ships, or
    - b. Marine Equipment Directive (MED) certification for EU flagged ships[xvii]
- ii) Documents issued by the Flag State regarding approval of the trial, if the use of EGC system requires a trial to be undergone
- iii) Documents specifying the type of fuel and its sulfur content allowed
- iv) Records in the ship log books
- v) Bunker delivery notes.

The above documents are maintained on board to demonstrate that: (1) the EGC units have been approved by the relevant regulatory authorities, (2) the EGC units are in proper operational order, and (3) emissions from every fuel oil combustion unit fitted with an EGC unit, with that system in operation, would result in the emission levels at or below the levels for complying with the fuel sulfur regulation.

Specifically, the first document—MARPOL Annex VI Performance certification—refers to two approaches for demonstrating EGC compliance with MARPOL Annex VI SO_x requirements, as stated in the IMO *Guidelines for Exhaust Gas Cleaning Systems*[60] (named *IMO EGC Guidelines* hereafter)[61]:

- Scheme A requires initial certification of EGC performance, followed by a periodic survey with continuous operating parameters and daily emission checks to verify performance in service;
- Scheme B requires continuous monitoring of actual ship emissions and daily operating parameter checks to confirm EGC performance.

Scheme B is currently that preferred by ship owners as the daily emission check required by Scheme A is onerous.[62]

[xvii] In EU, EGC systems on EU-flagged ships can be certified for a Marine Equipment Directive (MED) in lieu of a MARPOL Annex VI Scheme A or Scheme B certification. See EMSA, *Sulphur Inspection Guidance*, endnote 22.

For every EGC unit, the *IMO EGC Guidelines* require that the manufacturers generate the following documents and obtain approval for these documents from the Flag State, as a way to meet the MARPOL Annex VI regulation. Ship-owners or operators should be prepared to show these documents during inspections (see Appendix III for details of each of these documents): [63]

Table 2: Documents developed for EGC units for approval by the Flag State Administration

Documents developed for EGC system approval	Scheme A	Scheme B
SO_x Emissions Compliance Plan (SECP)	✓	✓
Onboard Monitoring Manual (OMM)	✓	✓
EGC Record Book or Electronic Logging System	✓	✓
SO_x Emissions Compliance Certificate	✓	
EGC system – Technical Manual for Scheme A (ETM-A)	✓	
EGC system – Technical Manual for Scheme B (ETM-B)		✓

An EGC unit can be demonstrated to meet an equivalent level of performance as using the MARPOL Annex VI-compliant fuel if the ship exhaust, in terms of SO_2 (ppm)/CO_2 (%v/v), is less than the SO_2 to CO_2 ratio corresponding to the IMO fuel sulfur limits, as shown in the table below:

Table 3: IMO regulation fuel oil sulfur limits and corresponding SO_2 to CO_2 emission ratios[64]

Fuel Sulfur Content (%m/m)	Corresponding emission ratio SO_2 (ppm) / CO_2 (% v/v)
4.50	195.0
3.50	151.7
1.50	65.0
1.00	43.3
0.50	21.7
0.10	4.3

During inspections on ships with EGC units that are certified under Scheme B, or certified under Scheme A and are fitted with continuous exhaust gas monitoring systems, regulatory personnel could review the data from the continuous exhaust gas monitoring system to check whether the SO_2 to CO_2 ratio exceeds the respective fuel sulfur requirement (see Table 3). The results of daily spot checks of the operation parameters should also be inspected to verify proper operation of the EGC unit.

For inspections of EGC units that are certified under Scheme A but have not been fitted with continuous exhaust gas monitoring systems, fuel regulation compliance can be verified by inspecting the results of the daily spot check of the exhaust gas quality (in terms of SO_2 to CO_2 ratio). Proper operation of the EGC units can be verified by examining the results of parameter checks.

Regardless of which scheme an EGC unit is certified under, the data recording and processing device should automatically record the continuous monitoring data of the SO_2 and CO_2 ratio (if applicable), as well as the operation parameters of the EGC units.[xviii] All monitoring data are required to be maintained for not less than 18 months.[65]

In addition to inspecting documents, physical inspections should be conducted to verify that:

i) All EGC systems are in operation at the time of inspection

ii) All fuel combustion machinery are connected to EGC systems, unless listed in the SECP

iii) Tamper-proof continuous-monitoring systems are in place (mandatory for system certified by Scheme B method, optional for Scheme A)

iv) All EGC units are well maintained

4.2 Ships powered by LNG or other alternative fuels

Regulatory personnel should inspect the following documents and records:

- Any supporting documents from the Flag State or the Classification Society showing approval of the use of the specified alternative fuels
- Appropriate records in the ship log books showing the consumption of the alternative fuels
- For dual fuel engines, historical records of the date, time, and position of the ship when it completed switching to alternative fuels, and when it began switching back to conventional fuels
- Bunker delivery notes, if feasible, showing the type of fuel used.

In addition, regulatory personnel should visually inspect the alternative fuel combustion (consumption) system to verify that it is functioning correctly, is in operation during the time of inspection, and is connected to all fuel combustion machinery on board.

4.3 Shore-power

Before January 1, 2019, the DECA regulation requires 0.5 per cent sulfur fuel to be used only at berth, so the use of shore power can be accepted as an equivalent compliance strategy. For ships that are connected to shore power, the following documents should be inspected:

- Engine log books showing the date and time by which shore power was connected
- Records showing the shore power system has been properly maintained

In addition, regulatory personnel should conduct visual inspections to ensure that all auxiliary engines are turned off once the shore power is properly connected and in operation.

[xviii] Such as washwater pressure and exhaust flow rate at the inlet connections, exhaust gas pressure before the EGC units and pressure drop across the EGC units, etc.

5. Penalties and target enforcement efforts

The deterrent effect of an enforcement program depends on two factors: The level of penalties being imposed, and the likelihood of apprehension and punishment. For any enforcement program to be effective, the penalties must be higher than the illegal gains from breaking the rules. Increasing the chance of catching violators is equally important in terms of discouraging violations.

5.1 Penalties imposed by ECA countries

There is no uniform sanction for ships found to be using non-compliant fuel after entering any of the ECAs for SO_x (SECAs) or ECAs. Those countries and regions that require the use of low sulfur marine fuel (including ECA regions or regions adopting low sulfur marine fuel rules) have developed their own compliance and enforcement programs. The table below summarizes the penalties for violations of the SECA or fuel switching regulations.

In the EU, the basic principle for setting non-compliance fines is to make sure that businesses cannot make any financial gain from cheating.[66] It is argued that a penalty that barely matches the financial reward from violations is not big enough to act as a true deterrent, as rule-breakers are not always being caught - particularly in regions where enforcement practices are lenient.[67] As the table above shows, the size of the penalties adopted by EU member states varies significantly from one country to another. This has led to calls to set a more consistent and clear basis for determining the size of penalties.

In the US, the US Coast Guard classifies non-compliance as “non-criminal deficiencies” if the vessel crews demonstrate good faith to comply and present justifiable reasons for non-compliance. In such case, deficiencies would typically be recorded, logged in the US Coast Guard database, and reported to US EPA for trend analysis. No further action would be taken by the US Coast Guard unless there were safety issues. If the data submitted to the US EPA indicate a trend that suggests a ship owner or operator is not acting in good faith, US EPA can launch compliance investigations, and impose penalties if applicable for those cases that are officially referred to US EPA by the US Coast Guard. On cases where the US Coast Guard suspects that an intentional non-compliance act can be categorized as “criminal deficiencies”, such as falsifying information on the BDN, the US Coast Guard handles these investigations directly, and can order vessel detention for investigations, fines, and probation for the vessel owner(s).[68]

Table 4: Summary of penalties for violation of SECA regulation and other local marine fuel sulfur regulations[69]

Countries/ regions	Maximum financial penalties / fees [xix]	Other penalties	Regulations
Belgium	€6 million (RMB 44.5 million)	Fining of crew; Vessel detention	SECA
United Kingdom	£8,000 – £3 million (RMB 69,000 – 25.9 million)	Imprisonment of crew; confiscation of vessel	SECA
Sweden	SEK 10 million (RMB 7.83 million)	Vessel detention	SECA
Finland	No maximum penalty is set (€800,000 range, or RMB 5.93 million)	Vessel detention	SECA
France	€200,000 (RMB 1.48 million)	Imprisonment of crew; vessel detention	SECA
Norway	NOK 300,000 (RMB 238,000)	Imprisonment of crew	SECA
Germany	€350 - €22,000 (RMB 2,590 – 163,000)	Vessel detention	SECA
Latvia	€2,900 (RMB 21,500)	-	SECA
Denmark	No maximum penalty is set	Imprisonment of crew; vessel detention	SECA
United States	US$70,117 (RMB 468,520) per diem (after adjusting for inflation)	Vessel detention	ECA
California	US$10,000 (RMB 66,820) per day per violation for strict liability violation	-	California Ocean Going Vessel (OGV) Fuel Rule
Hong Kong	HK$200,000 (RMB 172,000)	Ship owner, master or agent liable to up to 6 months' imprisonment	Hong Kong Air Pollution (OGV) (Fuel at-berth) Regulation

The regulators in the US can impose a maximum statutory penalty of US$70,117 (RMB 468,520) per diem per violation of MARPOL protocol.[70] A penalty policy document issued by the US EPA establishes a method for calculating the non-compliance penalties, which depend on: (i) the economic gains from non-compliance, and (ii) the seriousness of the violations. The US Coast Guard uses their penalty metrics and the US EPA uses their US penalty policy document to allow for speed assessment of penalties. In determining the final penalties, the US Coast Guard and US EPA also consider other

[xix] Exchange rate as of July 7, 2016. In California, non-compliance fees are levied if ships are found violating the OGV fuel rule.

aspects of the company in question, which could result in a lowering or increase of the total fines.[71,xx]

In addition to financial penalties, the US Coast Guard, the US Customs and Border Protection board, and a number of EU countries have the authority to detain vessels during the course of investigations. For instance, if an inspection indicates a violation, the US Coast Guard could issue a "no-sail" (for domestic vessels) or detention (for foreign vessels) order during the investigation. Depending on the severity of a violation, the vessel's customs clearance could be revoked or withheld.[72] The vessel may be granted clearance when the deficiency is resolved, and a Letter of Undertaking (LOU),[xxi] bond, or other security, is posted on the maximum penalty amount.[73, xxii] For ship owners and operators, ship detention could have severe financial and legal consequences, so the ship detention and custom revocation/suspension post a strong deterrent effect against cheating.[74]

In Hong Kong, while the maximum financial penalty for non-compliance is not particularly high compared to other regions, a ship master or owner could be subject to six months' imprisonment if its ship is found to be violating the fuel switching rule. The imprisonment penalty, which can lead to revocation of the ship master license, is considered to be an effective deterrent even though it has not been used.[75] Since the OGV Fuel At-Berth Regulation took effect in July 2015, the Hong Kong government has successfully convicted three shipping companies of using non-compliant fuel at berth: the first company convicted was fined HK$3,000, and the second company was levied HK$15,000 each on the ship owner and the staff-in-charge.[76]

5.2 Increasing the probability of apprehension and punishment

The experiences of EU member states in implementing the SECA regulation offer the best evidence in terms of underscoring the importance of robust enforcement programs to deter violations. Before the EU stepped up SECA enforcement efforts in 2015, only 0.1 per cent of ships visiting European ports were inspected for fuel compliance. Half of those inspected were found to be using non-compliant fuel.[77]

Responding to calls for stronger enforcement of the SECA in Europe,[78] the European Commission, together with EU member states and Norway, issued a decision detailing a harmonized program for monitoring SECA compliance, and specifying a minimum percent of ships being inspected and fuel samples analyzed by each member state. Key elements of the program include:[79]

- ***Frequency of on-board inspections:*** Each member state must inspect the log book and BDN on board at least one tenth of the total number of individual ships calling in the relevant member state per annum.

[xx] Five aspects relating to the company in question will be taken into account in determining the final fines: degree of willfulness or negligence, degree of cooperation, history of noncompliance, litigation risk and other unique factors, ability to pay, and performance of a supplemental environmental project. More information can be found in *EPA Penalty Policy for Violations* in endnote 71.

[xxi] The Letter of Undertaking (LOU) is a legal document issued by the ship owner or captain to the US Coast Guard that it will fulfill the obligation of paying the penalty of violations in the event that a violation is "proved" and a civil penalty is imposed. After receipt of a LOU, the Coast Guard may allow the release of a detained ship while it continues the compliance investigation.

[xxii] The LOU is an important tool to deter violations for those ships that may never come back to the port but there are clear evidences suggesting non-compliance.

- ***Frequency of fuel sampling or analysis***: As of January 1, 2016, the sulfur level of fuel being used on board must be verified by sampling, analysis, or both of at least the following percentage of the ships that are being inspected of log books and BDNs:
    - Member states that fully border SECAs: 40 per cent of the 10 per cent of inspected ships
    - Member states that partially border SECAs: 30 per cent of the 10 per cent of inspected ships
    - Member states that do not border SECAs: 20 per cent of the 10 per cent of inspected ships.[xxiii]

- ***Reduced fuel sampling or analysis for member states with stronger ship inspection programs***: A member state can reduce by up to half the share of ships to have fuel sampling or analysis if it deploys remote measurement technologies or quick scan analysis methods to screen for possible non-compliant ships, or if it inspects the log books or BDNs of over 40 per cent of individual ships calling in its ports per annum.

- ***Reporting inspection results:*** Member states shall report the findings of each sulfur inspection in THETIS-EU, the Union information system developed to support the enforcement of the EU Fuel Quality Directive. Member states shall also prepare an annual report to the European Commission on compliance with sulfur standards and summarize the results of onboard inspections, fuel sampling, and analysis. Details of the reporting requirements can be found in the EMSA *Sulphur Inspection Guidance*.[80]

Compared to the fact that half of the ships being inspected were in violation of SECA requirements before 2015, the latest data from the THETIS-EU database found significantly lower non-compliance rates in 2015 (around 5 per cent). Denmark and Sweden ramped up their enforcement efforts in 2015 to meet, or exceed, the minimum EU requirements for the number of ships having samples taken for sulfur testing,[81] and the non-compliance is even lower (below 3 per cent).[82] For other EU countries, an aerial surveillance pilot program carried out around Belgium waters indicated that the non-compliance rate could still be as high as 20 per cent.[83] This suggests that, despite great progress in some EU countries, there is room for improvement on SECA enforcement for some other EU countries.

In California, where the OGV Fuel Regulation has been implemented for more than six years, hundreds of on-board inspections are conducted each year (see Table 5). In 2013 and 2014, inspections were made at about 12 per cent and 10 per cent of vessel calls in California ports, respectively.[xxiv] During each inspection, the staff of the CARB takes fuel samples from the fuel system to be tested at the CARB laboratory in order to verify fuel sulfur compliance. CARB staff also inspects documents and reviews readings on engine room fuel temperature gauges and viscometers as well as data from the control room computer for changes in the temperature and/or viscosity of fuels, in order to identify any sign of violations.[84]

[xxiii] Member states that do not border SECAs will have to test the fuel of 30 per cent of the 10 per cent of inspected ships as from January 1, 2020.

[xxiv] California ports handled 8,690 port calls in 2013; as there is no public 2014 data available, the number of port calls in 2014 is assumed the same. California vessel call data for 2013 can be found at United States Maritime Administration (MARAD), MARAD Open Data Portal, Maritime Data & Statistics, http://www.marad.dot.gov/resources/data-statistics/ (February 16, 2016).

Table 5: Summary of CARB's OGV Fuel Regulation inspection program[85]

Year	No. of vessels inspected	Notices of violation issued / cases closed	Non-compliance rate
2009	134	7	5%
2010	313	18	6%
2011	493	26 / 27	5%
2012	575	33 / 20	6%
2013	1004	46 / 45	5%
2014	861	27 / 27	3%
2015	987	28/28	3%

As shown in Table 5 above, the non-compliance rate in California has been no more than 6 per cent in the past six years. Since the inspections conducted by CARB focus mainly on ships with a higher chance of violating the rule (e.g., ships that are new to California, and hence are unfamiliar with California's fuel switching requirements, or ships that have not been inspected in over 12 months), the overall average non-compliance rate, including those ships with a higher chance of violating the rule and other ships, should be lower than 6 per cent.[86]

5.2.1 Exchange of compliance and inspection data: THETIS database

Given the global nature of the shipping business, exchanging compliance information, such as the compliance record of individual ship and shipping companies, among countries implementing marine fuel sulfur regulation could help PSC officials more efficiently target enforcement efforts against repeat offenders.

In January 2015, the EMSA developed a THETIS-EU information system for use by EU member states to facilitate consistent and centralized recording and exchanging of information on sulfur inspection and compliance results. The data in the THETIS-EU are meant for use by PSC officials to better arrange future inspection efforts, shifting more focus on to ships or shipping companies that show a poor record of compliance. THETIS-EU recorded 6,801 ship inspections in 2015.[87] The EMSA and Denmark EPA have expressed their intention to include other SECA countries in the THETIS-EU cooperation, with the goal of enabling all SECA countries to make enforcement more effective and targeted.[88]

6. Lessons learned and recommendations for China

Chinese regulatory agencies are now preparing for the implementation of the DECA regulations, with Yangtze River Delta taking the lead in implementing the regulations since April 1, 2016. On January 29, 2016, the National Maritime Safety Administration (MSA) of the Ministry of Transport of China issued a *Guideline for Regulating and Managing Emission Control Zones for Vessels* (see a summary of the guideline in Appendix IV).[89] Shanghai, Jiangsu, and Zhejiang MSA have subsequently developed more detailed guidelines for their frontline inspectors. At the Yangtze River Delta core ports, over 1,850 ships have been inspected for DECA compliance in the past 2.5 months (April 1 to mid-June 2016); among these inspected ships, over 360 ships have had fuel samples taken, and 58 vessels were found to be using non-compliant fuels (i.e., 3.14 per cent of the ships inspected for DECA compliance, but more than 16 percent of the ships that have had fuel samples taken). Work is now under way by local governments and local MSAs in other DECA regions in order to develop more detailed guidelines for enforcing the DECA regulations.

Drawing from the lessons learned from the enforcement programs adopted in the US, EU, and other regions, below are a few recommendations for Chinese regulatory agencies to consider as they prepare for the implementation of the DECA regulations around DECA.

6.1 Mandating a given percentage of ships to have fuel samples taken to establish enforcement presence and setting high non-compliance penalties to deter violations

There is common agreement that BDNs and log books are prone to fraud, and that taking spot samples to check the sulfur content of fuels used on board is the most reliable way to verify compliance with fuel switching regulations. The IMO and the ECA countries are putting more resources into sampling and testing of the fuel being used on board.

As mentioned above, as of January 1, 2016, EU member states are required to take fuel samples from 2 to 4 per cent of individual ships visiting EU ports. California enforcement staff took fuel sample every time they conduct onboard inspection. The US Coast Guard, which mainly relied on document checks, also launched a voluntary fuel sampling program in February 2016 to assess compliance with ECA requirements.[90] Uniform guidelines for on-board fuel sampling to check sulfur compliance are being developed at the IMO and will be completed for IMO members' approval in October 2016.[91]

Given that the DECA is the first marine fuel regulation to have been enacted in China, a culture of compliance has not been well established. As fuel sampling can more reliably identify non-compliance,[92] China should consider mandating that a given percent of ships calling at DECA ports be inspected, and have spot fuel samples taken and analyzed. The enforcement officials should not limit fuel sampling only to ships that present documents suggesting an act of violation. They should also mandate the taking of fuel samples on a random basis from ships that do not show any sign of violations based on document checks, in order to create a stronger deterrent effect.[93,xxv]

[xxv] In the MSA enforcement guideline, MSA officials shall take fuel samples for sulfur analysis if fuel-related documents are incomplete or incorrect, or there are indications suggesting possible violations. MSA officals may collect fuel samples if all documents appear to be correct and there is no suspicions of violation, but that is not required.

In addition to increasing the chance of catching non-compliant ships, raising the opportunity costs of being caught is important for deterring DECA violations. Given that the amended Air Pollution Prevention and Control Law limits maximum financial penalties to RMB100,000 (~US$15,000) per violation, Chinese authorities could impose higher non-financial penalties, such as the detention of a ship suspected of violating the rule, or subjecting all ships owned by companies with a history of noncompliance to more thorough inspections.

6.2 Using remote measurement technologies and establishing enforcement database to guide selection of ships for on-board inspection and fuel sampling

Although onboard inspections and spot sampling of the fuel in use takes time and resources, the higher quality of compliance monitoring makes this a worthwhile approach wherever feasible. A more efficient way to undertake these enforcement investigations would be to target inspections on ships that indicate signs of non-compliance, or those that are more likely to violate the rule. China could consider one or both of the following options on selecting ships for onboard inspections:

- ***Conducting remote measurements of sulfur emissions from the exhaust to identify ships that are suspected of using illegal fuel***. Key port regions could jointly launch remote measurement programs to guide and support on-board inspections. A first step would be to launch pilot projects at key ports to test the feasibilities of remote measurement technologies, and select such technologies as are most suited for use under the conditions of ports in China.

- ***Develop a national DECA enforcement database***, wherein enforcement officials could record the results of on-board inspections. Based on the inspection data, enforcement officials could identify a "black list" of ships or shipping companies, and then focus a large part of their on-board inspection efforts on those on the list. Going forward, China could look into collaborations with the EU, US, California, and Hong Kong to promote the sharing of inspection data across countries/regions which have adopted marine fuel regulations.

Based on results from remote measurement programs and/or entries in the enforcement database, enforcement officials could verify ship compliance in a cost effective manner following the steps below:

i. Select a given percentage of ships calling at Chinese ports for onboard inspections; part of the vessels selected should be based on remote measurement results and/or records in the DECA enforcement database, and part of them based on random selection.
ii. During onboard inspections, inspect and verify documents and the MARPOL sample, and from a given percentage of ships inspected collect representative samples of the fuel in use for laboratory analysis. Ships that have fuel samples taken could be selected based on: a) whether the documents or fuel samples indicate possible violations, or b) random selection.

At ports that handle a high number of port calls, requiring a given percentage of ships inspected to have fuel samples collected for laboratory analysis may put too much pressure on existing enforcement resources. In such cases, enforcement agencies could consider testing the use of the quick fuel sulfur screening devices, and only perform laboratory analysis on fuel samples from ships that show a high sulfur reading from the screening tests.

It is worth noting that results from these screening devices may have higher uncertainties than those from laboratory tests conducted in a controlled environment. If a quick screening test approach is adopted, it is critical to evaluate the technologies carefully, and understand their tolerances and acceptance in the scientific community. This evaluation could help determine a reasonable cut-off point, over which a fuel sample must be collected for laboratory analysis in order to confirm the fuel is non-compliant.

6.3 Establishing detailed enforcement guidelines that specifies the basis for determining non-compliance and assessing penalties to ensure that sanctions are fair, equitable, and have a strong deterrent effect

In order to set up a fair and equitable penalty system, and to create a strong deterrent effect, it is necessary to have clear, detailed, and transparent guidance for enforcement officials. The detailed enforcement guideline should specify the methods and procedures for verifying DECA compliance, and the principles based on which non-compliance penalties are set. For instance, the guidance issued by the China National MSA stipulates that any ship found using non-compliant fuel, depending on its severity, should be subject to one or more of the following four types of penalty: (i) warning, (ii) correction of breaches, (iii) detention, and (iv) financial penalties (see Appendix IV). It would be helpful to provide more guidance on the conditions under which the ship operator/owner would be subject to each of the four penalties, and what factors are to be considered when determining the magnitude of financial penalties.

Clear penalty guidance would help ship owners and operators understand the consequences of violating the regulation. It would also enable inspectors and other enforcement officials to take swift action, and would thus avoid delaying any vessel any longer than is essential for the compliance investigation and penalty determination.

For instance, companies that are found to have inadvertently violated the rule, such as by not properly following fuel switching procedures, could be considered as being subject to lighter penalties; repeated offenders or shipping companies which intentionally violate the rule (e.g., with falsified BDNs) should be subjected to a heavier penalty, and greater scrutiny going forward.

The ECA Job Aid developed by the US Coast Guard, and the Sulfur Inspection Guidance developed by the EMSA, offer useful points of reference (see for example Section 2 to 4 of the ECA Job Aid, Appendix I of the EU Sulfur Inspection Guidance, for examples of the checklist, table, and flowchart developed to facilitate the compliance verification process). [94] The US EPA Penalty Policy could be a helpful reference for developing a guideline for assessing penalties.[95]

6.4 Offering training for enforcement officials

The DECA regulation is the first fuel-switching mandate to be enacted in China. It is essential that enforcement officials are provided with sufficient training to enforce the rule. The main goal of such training is to prepare regulatory officials to understand (i) which documents should be inspected (ii) what evidence should be collected during on-board inspections to determine compliance; (iii) what further compliance investigations are appropriate given the specific outcomes; and (iv) if a ship is found violating the rule, what steps should be taken to determine and impose penalties. Consistent and predictable enforcement in all DECA regions is essential for avoiding the industry making mistakes that result in unintentional non-compliance.

By stating the range of possible actions based upon the inspection outcomes, enforcement personnel will better understand what the regulation writers expect of them. It would also be useful to publicize the inspection procedures, so ship owners and operators will have a clear understanding about what to prepare and expect.

At the time of writing, two sets of international training workshops have been successfully organized in China, where enforcement officials from European countries, California, US EPA and Hong Kong shared their experiences with Chinese officials from DECA ports.[96] Going forward, Chinese authorities could organize similar training workshops for frontline inspectors at future DECA ports. MSA officials from YRD ports could become one of the trainers to share their experiences with inspectors of other DECA regions.

6.5 Assuring the quality of bunker fuel

Assurance that compliant fuel is available and accessible is as important for guaranteeing the success of the China DECA regulation as ensuring that compliant fuel is being used on board. In the US, US EPA is in charge of setting fuel quality standards (including marine fuel), and has the lead on shore-side fuel supplier inspections, and the US Coast Guard has the lead on vessel inspections. US EPA also manages a long-established and comprehensive fuel quality assurance program, which covers bunker fuel on the shore.[97, xxvi] The main goal of the US EPA program is to ensure that ships calling at ports in the US can access fuel that complies with US and international standards. It is reported that the rate of compliance with ECA and US federal marine fuel standards is very high.[98]

In China, the amended Air Pollution Prevention and Control Law clearly gives the MSA authority to enforce the DECA regulations, but it is less clear which agency should take the lead in assuring marine fuel quality. Article 103 of the amended Air Pollution Prevention and Control Law gives the local Quality Supervision and Inspection (QSI) agencies and the Industry and Commerce agencies the authority to penalize companies that produce or sell subpar fuel for use on vessels. However, it is unclear what roles each agency will play in terms of assuring fuel quality, and how they will coordinate their efforts. In addition, in the past few years, local QSI agencies and Environmental Protection Bureaus (EPBs) have jointly checked the quality of motor and non-road fuels. A clear line of responsibility and enforcement authority among the QSI, Industry and Commerce agencies, local EPBs and MSAs could help ensure that the marine fuel sold in China actually meets DECA and other international fuel quality standards.[99]

[xxvi] The US EPA fuel quality assurance program has a presumptive liability structure where every party in the distribution chain (including refiners, distributors and retailers) is liable for a violation due to the fuel exceeding the applicable standard (for example, sulfur content). A party could present defensible evidences demonstrating that it is not responsible to the violation, and those evidences should include demonstration that it did not cause the violation, evidence that the party has put in place a fuel quality oversight program, and test results showing compliance when the product was delivered. See Anthony Miller, "Ensuring Compliance with the North American" in endnote 32 and US Code of Federal Regulations - 40 CFR 80.613 (https://www.law.cornell.edu/cfr/text/40/80.613) for more information about US EPA's fuel program and the presumptive liability structure.

6.6 Assisting ship owners /operators to comply with the DECA regulations

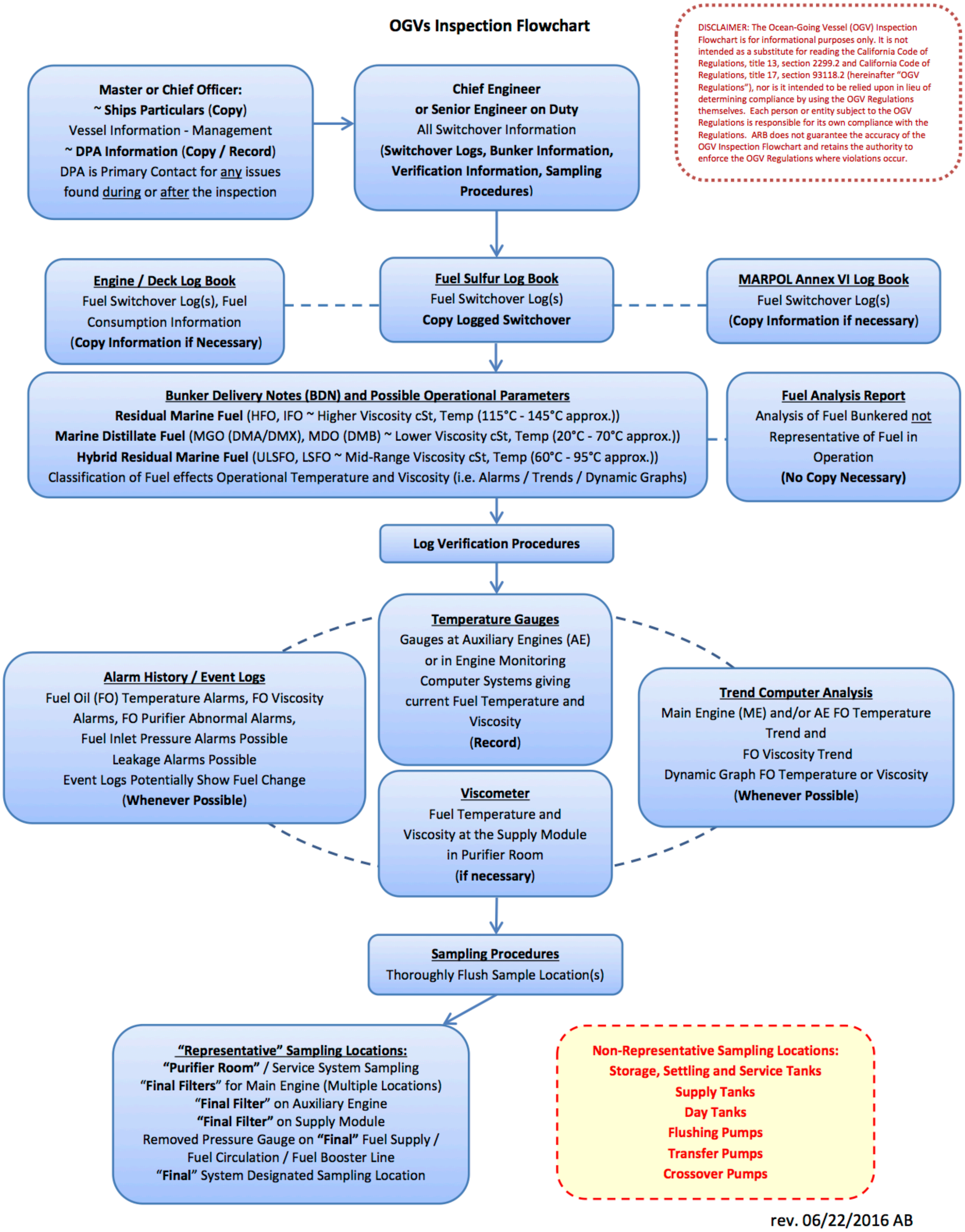
Helping ship operators understand how they can comply with the China DECA regulations is important to improve the culture of compliance, especially for ships that have never operated in regions adopting the fuel switching regulations.

To ensure full compliance, it would be most effective for regulatory authorities to disseminate complete, clear, and timely information to the shipping industry about the DECA regulation as soon as the enforcement timeline is set. It would also be helpful to release official English versions of the legislative text and instructions at the same time as the Chinese version, to minimize misunderstanding.

The fuel sulfur standards of the IMO ECA regulation and the California OGV Fuel Regulation have ratcheted down over the past few years. Before the fuel standards were tightened, the US Coast Guard and CARB usually issued marine safety alerts or marine notices to inform about the upcoming changes of the fuel standards. The marine alerts and notices also cover the safe fuel changeover procedure, record keeping requirements for demonstrating compliance with the fuel switching regulations, and other issues that companies should be aware of.[100] Chinese enforcement authorities could consider issuing similar type of notice to make sure that ship owners and operators are well prepared for the DECA regulations.

Lastly, China could arrange training sessions for shipping company representatives and crews, introducing the DECA regulatory requirements and guidelines, and the documents and fuel samples that are needed to demonstrate compliance, and highlighting the need for a good fuel changeover procedure to ensure effective and safe fuel switching. Such training sessions should mainly target those shipping companies that have the least experience of fuel switching, such as companies that have not operated in ECA regions in the EU and US.

Appendix I: A sample OGV inspection flowchart for verifying compliance with the California OGV Fuel Regulation[101]



Appendix II: Remote measurement programs for ship emissions in the EU and US

Country	Launch and completion date	Technologies used	Agency in charge	Ships targeted
Port of Los Angeles and Long beach[102]	**Oct 2015**	Sniffers & DOAS from harbor craft and fixed stations	South Coast Air Quality Management District, supported by Chalmers University of Technology	Ships operating in surrounding waters and port (650 ships)
Denmark[103]	Since early 2014	Sniffers (at Stora Bält Bridge) Sniffers & DOAS (airborne surveillance)	Danish Environmental Protection Agency, supported by Chalmers University of Technology	Ships entering and leaving the Baltic Sea and Danish waters
Gothenburg, Sweden[104]	Since 2006	Sniffers (at Älvsborg Fortress) Sniffers and DOAS (airborne)	Chalmers University of Technology funded by EU project CompMon and Swedish Vinnova	Ships entering and leaving the Port of Gothenburg, and Swedish waters
Hamburg, Germany[105]	Since Sep 2014	Sniffer and MAX DOAS (at Wedel and Neuwerk)	Federal Maritime and Hydrographic Agency (BSH), in collaboration with the University of Bremen	Ships entering and leaving the Port of Hamburg
Antwerp, Belgium[106]	Sep– Oct 2015 (1st campaign) Aug – Dec 2016 (2nd campaign)	Sniffer (airborne surveillance)	Royal Belgian Institute of Natural Sciences of Management Unit of North Sea Mathematical Models (Belgium), Federal Public Services (FBS) Mobility (Belgium), and Human Environment and Transport Inspectorate (ILT) (the Netherlands)	Belgium and Dutch waters
Rotterdam[107]	Sep 2009	Sniffer and optical instruments, including DOAS, light detection and ranging (LIDAR) and the ultraviolet camera (UV-CAM)	European Commission's Joint Research Centre[xxvii]	Ships entering and leaving the Port of Rotterdam
Neva Bay and the Gulf of Finland[108]	Aug and Sep of 2011 Jun and Jul of 2012	Sniffer (on ground and boat)	Chalmers University, with financial support from the Baltic Sea cooperation for reducing ship and port emissions, BSR InnoShip.	Ships operating in the Neva Bay area and the Gulf of Finland
Feasibility study at Hamburg - Ship Sulfur Trails Emissions Aerial Measurements (STEAM)[109]	Jun/Jul 2016 (9-month test and demon-stration study)	Sniffer on Remotely Piloted Aircraft Systems (RPAS)	European Space Agency, supported by CLS, Delair-Tech, EMSA, BSH, Danish Shipowners Association, and Trident Alliance	Waters outside the Port of Hamburg (pilot phase)

[xxvii] With support from Chalmers University of Technology, the Netherlands Organization for Applied Scientific Research (TNO), the National Institute for Public Health and Environment (RIVM), and the Norwegian Institute for Air Research (NILU).

Appendix III:Documents required for certification of EGC units per requirements of IMO's *Guidelines for Exhaust Gas Cleaning Systems*[110]

	Scheme A	Scheme B
SO_x Emissions Compliance Plan (SECP), ***specifying information such as:*** ▪ Listing all fuel oil combustion equipment onboard, and which of them are connected to the EGC units ▪ Listing all fuel oil combustion units that are not practical for fitting with EGC units ▪ Presenting how compliance can be demonstrated through continuous monitoring of exhaust gas emissions (Scheme B), daily recording of key parameters (Scheme B), or daily exhaust gas emission recordings (Scheme A)	✓	✓
Onboard Monitoring Manual (OMM) ▪ Listing all the essential sensors used to demonstrate system compliance[xxviii] ▪ Specifying how monitoring system surveys should be performed (e.g., the position at which exhaust gas samples should be taken)	✓	✓
EGC Record Book or Electronic Logging System: The EGC Record Book is a set of forms required for logging events that affect the sensors monitoring EGC system compliance (e.g., maintenance, servicing and re-calibration events, offloading of wash water residues/sludge)	✓	✓
SO_x Emissions Compliance Certificate: Certifying that the EGC unit has been surveyed in accordance with the requirements under Scheme A	✓	
EGC system – Technical Manual for Scheme A (ETM-A): Specifying a variety of key processing parameters concerning the correct operation of a particular EGC unit; the EGC unit shall operate within the parameter limits at all times to ensure compliance	✓	
EGC system – Technical Manual for Scheme B (ETM-B): Specifying a variety of key processing parameters concerning the correct operation of a particular EGC unit; the EGC unit shall operate within the parameter limits at all times to ensure compliance		✓

[xxviii] Essential sensors include exhaust gas monitoring, key-process parameters (such as scrubbing water pressure and flow), and discharge water quality monitoring.

Appendix IV: China MSA enforcement guideline

The Maritime Safety Administration (MSA) of the Ministry of Transport of China issued a guideline for regulating and managing Emission Control Zones for vessels on January 29, 2016.[111] The document is to provide guidance for MSA officers at all levels on verifying compliance with the DECA regulations in the Yangtze River Delta, the Pearl River Delta, and Bohai Bay.

The guideline comprises three components:

i) Specifying the documents to examine during onboard inspections:

- *Ship log books:* Verify that the recording of the date and time by when fuel switching took place is consistent with the DECA fuel switching requirements
- *Bunker delivery notes:* Verify that the sulfur content stated complies with the DECA requirement
- *Fuel oil change procedure*: Make sure the procedure is kept on the ship; check the procedure to ensure that it is complete; and comply with the vessel safety management requirements.

If inspection of the above documents suggests an act of non-compliance, MSA officials shall take fuel samples to verify compliance with the sulfur requirement. Even if the documents do not suggest an act of non-compliance, MSA officials may take fuel samples for sulfur analysis.

ii) Specifying non-compliance penalties

Ships that are found violating the DECA regulations are subject to one or more of the following actions:

- Warning
- Correction of breaches
- Detention
- A financial penalty ranging from RMB10,000 to 100,000 (~US$1,500 to 15,000), according to Article 106 of the amended Air Pollution Prevention and Control Law.

Ships that fail to keep the fuel supply document and fuel sample as requested are subject to a penalty ranging from RMB2,000 to 10,000 (~US$300 to 1,500).

iii) Specifying the inspection requirements for ships using alternative compliance options, including shore power, LNG, and scrubbers.

- Ships using shore power:
  - Verify that the recording of the date and start and end time of using shore power in the ship log books complies with the DECA regulation
  - Check whether the ship is actually capable of using shore power.

- Ships using clean energy (such as LNG):
  - Verify whether the International Air Pollution Prevention (IAPP) Certificate/Record states that the ship is designed for using clean energy
  - For vessels using dual fuel, verify that a complete record is maintained with regard to the amount of each type of fuel used, and the date and time and location of ship when fuel switching took place (latitude and longitude)
  - Verify that switching to clean fuel took place at a location that complies with the DECA requirement.

- Ships using after-treatment devices:
  - Verify the completeness of the records of the date and time when the after-treatment devices were turned on and off, and that the device was in operation in line with the DECA requirement
  - Verify the exhaust after-treatment certificate was issued
  - Check whether the IAPP certificate notes the use of an after-treatment device.

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7 While the global sulfur cap for marine fuel stipulated by the IMO is 3.5%, the annual average global sulfur content of marine residual oil (HFO) was 2.5% in 2012, according to the latest available data in the *Third IMO Greenhouse Gas Study 2014*. See IMO, *Third IMO Greenhouse Gas Study 2014,*

http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Documents/Third%20Greenhouse%20Gas%20Study/GHG3%20Executive%20Summary%20and%20Report.pdf.

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