EPM 738 Transport Energy and Emissions
The Impact of IMO 2020 Sulphur Regulation on the Maritime Industry

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London 2014

CONTROL SHEET

Project Name	Transport Energy & Emissions
Document Title	The Impact of IMO 2020 Sulphur Regulation on the Maritime Industry
Module Ref.	
Word Count	4392 excluding figures, references and appendices.

ISSUE HISTORY

Issue No.	Date	Details
Final Submit	28 April '14	Final

REVIEW

Originator	Paul Bews	
Review by:	Print	Paul Bews
	Sign	

DISTRIBUTION

City University

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1. Summary

This paper includes a discussion on the impact of the introduction of the International Maritime Organisation (IMO) 2020 sulphur regulations on the global maritime industry.

In general terms, this paper concludes that the IMO 2020 sulphur regulations will have a significant effect on the maritime industry. This is due to a number of uncertainties regarding the availability of low-sulphur fuels or alternatives, the efficacy of alternative fuels and scrubber systems, and most importantly, the cost of compliance that will have an impact on competitiveness of the industry.

The paper begins in section 2 with an introduction to the subject, and provides context in terms of sustainable transport theory. It then goes on to present a brief explanation of the IMO organisation, the International Conventions it maintains, including the Marine Pollution Convention; MARPOL and the Sulphur regulations. Section 3 outlines what the sulphur regulations mean in practical terms. Then section 4 discusses the possible methods of compliance and the relevant issues in terms of feasibility and cost-effectiveness for the industry. Section 5 concludes the paper and discusses some specific impacts of sulphur regulation on shipping and includes a discussion on the various effects that this regulation may have on competitiveness, global trade, fuel availability and modal changes.

2. Introduction

Sulphur Emissions and Sustainability:

According to Black (2010), a sustainable transport system is one that provides transport with renewable fuels, whilst minimising emissions detrimental to the local and global environment.

Whilst Black's sustainable transport definition has other elements to it, the definition is related to the sustainable mobility of people, rather than the sustainable transport of goods. However, the part of Black's definition that talks of ***minimising emissions detrimental to the local and global environment,*** is equally applicable to the sustainability of the international shipping sector.

With this element of the definition, Black is referring to the global atmospheric impacts of CO_2 emissions and ozone depleting substances. He is also referring to local air quality and health impacts from sulphur oxides (SOx), nitrogen oxides (NOx) and particulate emissions. Finally he is referring to the biological and physical impacts of acid rain created from NOx and SOx (Black, 2010).

It is air quality and acid rain that the IMO is attempting to control through the 2020 sulphur regulations in the maritime industry. (Bazari, 2014b).

Sulphur: one of the six criteria pollutants

The two oxides of sulphur; sulphur dioxide (SO_2) and sulphur trioxide (SO_3); together termed SOx, are one of six so called "criteria pollutants". These pollutants result from the combustion of fossil fuels (Black, 2010). SOx are the most ubiquitous urban air pollutant with very significant health effects (Sher, 1998). Compounding this, acid rain, which is a by-product of sulphur combustion, is a significant threat to marine life, agriculture, and to metallic or carbonate based materials such as buildings, facades and artwork. (Vallero 2007).

An analysis of the literature regarding the health and physical effects of Sulphur has been synthesised by the author and is included as Appendix A to this paper.

Regulatory Framework in International Shipping

Since 1948, the IMO has been responsible for standard and regulation setting related to international shipping (IMO, 2014a). The IMO sets shipping standards at a global level for safety, security and environmental matters, and they do this on behalf of, and in conjunction with, the 170 flag states.

Appendix B to this paper summarises the research performed by the author in this area, and provides some context for the regulatory framework within which the sulphur regulation has been developed and is being implemented. Appendix B also provides details on the committee structure of the IMO and the principal regulations.

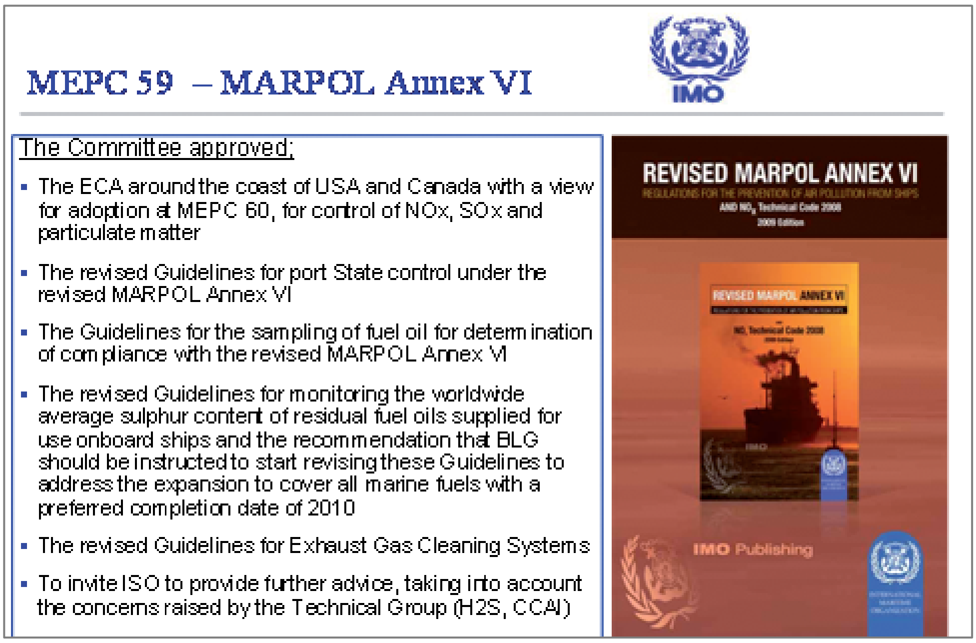
The Marine Pollution Convention (MARPOL)

The Marine Pollution Convention MARPOL (IMO, 2011a), is one of three principal regulations overseen from the IMO. It contains the sulphur regulations and is a comprehensive anti-pollution convention that was developed and is maintained by the Marine Environmental Protection Committee (MEPC) of the IMO (IMO, 2014a). The committee structure of the IMO and the annex structure of MARPOL are shown in Appendix B to this paper.

Whilst it is Annex VI that regulates airborne emissions from ships, specifically, it is Regulation 14 of the MARPOL Convention that regulates SOx emissions, and also sets the limits for special geographic areas termed Emission Control Areas (ECAs) (IMO, 2011a). It also sets the timing of the step change improvements that are required (IMO, 2011a).

The development of the Sulphur Regulations

In October 2008 the MEPC revised Annex VI for a progressive reduction in shipping-related SOx emissions. The main objective of the regulation is to mandate the use of low-sulphur fuel which will drive down pollution from shipping (DfT, 2013). The revised MARPOL Annex VI and some MEPC committee approval proceedings from the 59th Session of the MEPC are shown in the figure below.



Source: IMO 2014b

Figure 1 – The Revised MARPOL Annex VI

The revision to Annex VI currently mandates a global sulphur cap of 3.5% sulphur content in fuel by mass from 1 January 2012. The regulation then mandates a progressive requirement to reduce this to 0.5% on 1 Jan 2020[1] (IMO (2011a) & IMO (2012b)). Availability of sufficient low-sulphur fuel is a major consideration for the achievement of the 2020 limit (DfT, 2013). This is discussed further in Section 4.

3.5% sulphur in the most unrefined of marine fuel, termed heavy fuel oil (HFO) equates to 35,000 parts per million (ppm), this compares with petrol for land-based use, which has had only 10 ppm since 2007 (MAN, 2010). As can be seen from this stark contrast the maritime sector is behind the land based controls on fuel sulphur content.

The fuel sulphur limits in some special geographic areas, called Emission Control Areas ECAs, are more stringent. The limits are one percent sulphur content in fuel by mass, and this will decrease

1 The 2020 cap is subject to a feasibility review on the availability of 0.5% sulphur fuel which is to be conducted before 2018 (IMO 2012b).

to a fuel sulphur limit of 0.10 %, effective from 1 January 2015 (IMO (2011a) & IMO (2012b) & DFT (2013)).

Emission Control Areas

Emission Control Areas (ECA's) are areas that require a higher level of air pollution protection compared to the rest of the international waters (Carlton, 2013). Carlton explains that ECAs are designated areas under MARPOL requiring special limits, practices and procedures in order to prevent or limit pollution.

There are currently four ECAs in effect (DfT, 2013):

1. The **Baltic Sea ECA** which is controlled for SOx;
2. the **North Sea ECA** which includes the **English Channel** and is also controlled for SOx,
3. the **North American ECA** which is controlled for SOx, NOx and particulate matter ; and
4. the **United States Caribbean Sea ECA** which is also controlled for SOx, NOx and Particulate Matter.

Generally Annex VI sets more stringent standards for SOx in all of these areas. (IMO (2011a) & IMO (2012b)).

3. What the Sulphur Regulations Mean in Practical Terms

Scope of Application

All ships that have a power output of more than 130KW have obligations under MARPOL Annex VI and the sulphur regulations (IMO, 2011a).

The sulphur regulations apply to fuel oil used in all combustion devices on board ships. This includes the main and auxiliary engines and other combustion equipment such as boilers and inert gas generators (IMO (2011a) & IMO (2014b)).

The two main fuels used in shipping are Heavy Fuel Oil (HFO) and Marine Diesel Oil (MDO). HFO contains high levels of sulphur currently regulated to 3.5% by mass, and is currently consumed at a rate of 286 million tonnes per year globally. MDO currently has a sulphur content of 1% and is consumed at a rate of 83 million tonnes per year. This combines for a total of fuel consumption by the shipping industry of 369 Million tonnes of fuel per year – approximately 2-3% of global fossil fuel consumption. (Bazari, 2014b)

The Measurement of Sulphur Emissions

According to Bazari (2014b), no direct measurement of exhaust emissions is carried out – instead, an emissions factor is applied to the fuel consumption of the global fleet. To estimate the sulphur dioxide emissions from the global fleet, the following factor is used:

*SO2 = (2*S) kg/kg fuel (where S is fuel sulphur content) (Bazari, 2014b)*

Applying this formula to the current global fuel consumption from shipping reveals that the current sulphur emissions amount to more than 20 tonnes per year. Also see Appendix C.

The Main Controls to Be Applied Internationally

Currently, the major control applied and envisaged by the regulations is by limiting the sulphur content by mass of the fuel loaded, stored and used on-board ships (IMO, 2014b). This requires oil refineries to reduce the sulphur content and will necessitate technology changes at most refineries in order to meet the long term demand and the stringent limits in 2020 (DfT (2013) & UKPIA (2014)).

As with each of the MARPOL annexes, Annex VI requires a unique survey to be conducted in accordance with the regulations (Carlton, 2013). This is in the form of record books, procedures and fuel receipts. All of these will be the focus of on-board checks and inspections by the flag state and by Port State Control (Romeo, 2012).

Enforcement & Reporting in The EC

According to the European Commission (EC), enforcement of the Annex VI sulphur requirements will take the form of fuel sampling, dissuasive penalties and enforcement action performed by the flag states and port state control authorities. All in accordance with international maritime law (Council Directive (EC) 2005/33/EC).

In addition to this, in the EU, member states are required to report annually to the EC on the average sulphur content of liquid fuels used in shipping (Council Directive (EC) 2005/33/EC).

Abatement Technology

Abatement technology in the form of scrubbers that remove the pollutants from the exhaust gases presents a possibility to achieve the goal of reduced SOx emissions. However, even though the revised Annex VI provides guidance on exhaust gas cleaning systems, this technology is in its infancy (MAN, 2010). Therefore, the MARPOL regulations are very much focussed on a reduction of the sulphur at source by limiting the maximum sulphur content of the fuel oils used in ships (DfT (2013) & IMO (2011a) & IMO (2014b)).

Certain regional regulations also acknowledge abatement as a possibility for the future. For example, the European Council Directive (EC) 99/32/EC which limits the sulphur content of land based fuels was amended in 2005 by a supplementary European Council Directive 2005/33/EC (Council Directive (EC) 99/32/EC (1999) & Council Directive 2005/33/EC (2005)). The 2005 directive provides for the trialling of abatement technologies as an alternative to low sulphur marine oils (DfT, 2013). However, the main intention of the 2005 directive is to extend the original directive to cover sulphur levels in marine fuels in support of the IMO regulations[2].

[2] Specifically the 2005 European Directive restricts the supply and use of marine diesel oil sulphur content to 1.5% by mass for use in the ECAs of the Baltic Sea and the North Sea and English Channel and to 0.1% by mass for Marine Gas oils.

Air Pollution Performance Indicators and what they reveal

Against the background of the health and physical effects of SOx pollutants referred to above and elaborated in Appendix A to this paper, the IMO and the flag states have acted to introduce the sulphur regulations.

Despite claims by the IMO of increased efficiency of shipping in the last decade (IMO, 2012b), the emission of SOx are still disproportionately high and appear to be growing. This was highlighted by a European strategic study on air pollution from 2005 which concluded that sulphur emissions from shipping were forecast to exceed those from all land-based sources in the EU by 2020 (EC, p.31 2005). This might explain the ambition established in October 2008 when the MEPC revised Annex VI for a progressive reduction in shipping-related SOx emissions.

An analysis of the IMO air pollution performance statistics and what they reveal has been performed by the author. For completeness, this analysis has been included with this paper as Appendix C.

4. Methods of Compliance & Feasibility

Since the purpose of the sulphur regulations is to reduce sulphur-based emissions, compliance with the regulations will require ship operators to do one of four things:

1. **Use low-sulphur fuels** under strict operational procedures for switching between lower sulphur HFO and low-sulphur MDO fuels when operating inside ECAs; and/or
2. **Treat emissions** with some kind of abatement technology such as scrubbers fitted to vessels to remove the pollutants from exhaust gasses; and/or
3. **Find a suitable alternative fuel** that does not emit sulphur and other airborne pollutants, and complies with the full requirements of Annex VI of MARPOL; and
4. **Other Supplementary Alternatives** These refer to supplementary options that will augment the above three options for the achievement of the sulphur limits. They are somewhat restricted in that they do not provide a complete solution. Therefore, they have not been dealt with extensively in this paper.

Taking each one of the four alternatives in turn:

1. Use of Low Sulphur Fuels

General

The use of low sulphur fuels is currently the main method of compliance that forms the basis of the IMO regulations. (IMO 2011a) The control of sulphur in fuel also forms the main basis of the regional and national legislation that enforces MARPOL Annex VI. e.g. *Council Directive (EC) 2005/33/EC.*

This solution relies upon the feasibility of refineries to lower the sulphur content at a reasonable cost (UKPIA, 2014). There is also a question of whether there will be enough low-sulphur fuel oil available to support future needs in compliance with the regulations. This concern main surrounds the supply of sufficient low-sulphur fuel to achieve the 2020 - 0.5% sulphur target in international waters.

Currently low-sulphur fuels are much higher in price. For example HFO at 3.5% sulphur, is $600 per tonne, whereas MDO at 1% Sulphur costs $1000 per tonne (Bazari, 2014b). Since the only way to achieve the lowest SOx limits is through the use of Marine Diesel Oil (MDO) (Bazari, 2014b), the economic impact of this price difference is clear, and is likely to have a direct effect on the price of shipping per tonne of cargo. This may have a knock-on-effect for the competitiveness of the maritime freight industry.

According to the UK Fuel Refiners association UKPIA, the investment and energy required for the creation of low sulphur fuel is very high, requiring high pressure, high temperature processes, that consume large volumes of hydrogen which must also be manufactured, thereby releasing further CO_2 (UKPIA, 2014).

On the other hand, economies of scale and market forces could create a situation where the low-sulphur fuel reduces in cost compared to today. This is an unknown that will depend upon the supply and demand situation and the degree to which refineries can spread the additional cost to produce the low-sulphur fuels.

Engine Wear

Some stakeholders claim that, since sulphur has a lubricating property, then the sustained use of low sulphur fuels may result in accelerated abrasive engine wear, with the resultant additional maintenance checks and increased costs (Romeo, 2012). Romeo also suggests that low sulphur fuels may encourage the practice of adding other additives to the fuel that may defeat the object of removing the sulphur in the first place. However, MAN (2010) state that for their engines, additional abrasive wear is only in the case where static engines are being operated at 100% load, at 100% RPM and in high ambient conditions. However, MAN do point out that acid corrosion can occur in the engine liners due to the use of low sulphur fuels, and that this must be mitigated through the retro-fitment of dedicated lubrication equipment. This will clearly create an on-cost for the industry.

MAN 2010 does cite some examples of poor fuel blending in the refineries that has led to engine wear and failures through poor ignition qualities of the fuel. These cases have resulted in very large litigation claims. MAN warns that fuel companies should ensure that low-sulphur fuels do not put the operational reliability of marine engines at risk.

2. Treating Emissions with Abatement Technology

Whilst the reduction of oxides of nitrogen (NOx) can be dealt with in terms of engine design and certification (Bazari, 2014b), reduction of SOx cannot be dealt with in this way. Some argue that rather than seeking a technical solution for each vessel for SOx, such as flue gas cleaning systems in the form of exhaust gas scrubbing abatement technologies, the more efficient solution to the problem is eliminating it at source via the refineries. UKPIA by contrast, advocate the scrubbing solution rather than the refinery solution, and even support the idea of a sulphur trading scheme. (UKPIA, 2014).

Abatement technology is well understood in the energy generation sector, and has been used extensively in the world's power stations. However, the current scrubber technologies including Selective Catalytic Reduction supported by *Council Directive (EC) 2005/33/EC* will need to be significantly adapted for Maritime use (MAN, 2010).

One of the biggest issues with current abatement technology when applied to ships is that scrubbers use water and operate much less efficiently with sea-water than they do with fresh-water. Moreover there is a large issue associated with the storage, cleaning and disposal of the contaminated waste water (MAN, 2010).

Many scrubber solutions have been tested. A selection of these and their effects are shown in the figure below:

Objectives	Participants	Scrubber	Goals	Test results	Ship test	Ship test
Development and test of scrubber for after - treatment	Clean Marine MAN Diesel		PM trapping: >90% SO_Xremoval: >67%	PM trapping: 35% 80% (salts add.) SO_Xremoval: 73% 95% (salts add.)	Banasol 7S50MC-C 9MW	
Development and test of scrubber for after - treatment	Aalborg Industries Alfa Laval DFDS MAN Diesel		PM trapping: >75% SO_Xremoval: >95%	PM trapping: 79% SO_Xremoval: 100% (NaOH)	Tor Ficaria 9L60MC-C 20MW	
Development and test of scrubber for after - treatment and EGR	APM MAN Diesel		PM trapping: >75% SO_Xremoval: >90%	PM trapping: 73% SO_Xremoval : 96% (NaOH)	Alexander 7S50MC 9MW	

Source MAN 2010 © MAN 2010 Subject to modification in the interest of technical progress

Figure 2 – Examples of exhaust scrubber technology and their effects

The IMO has accepted abatement technologies as an alternative to low-sulphur fuel (IMO 2014a). The industry consider that exhaust gas scrubbers represent a realistic solution for ships operating in ECA areas and, in the longer term, in international waters, when the 2020 sulphur limit of 0.5% comes into force (MAN, 2010).

Synthesising the research and views of the stakeholders in this area, it seems that the uptake of flue gas cleaning systems will be driven by three fundamentals:

1. The speed at which they are developed and proven to be effective;
2. the solution regarding the disposal of the waste water; and
3. the business case for the installation of abatement systems, which will need to be balanced with the cost of low-sulphur fuels in the future.

3. Finding a suitable alternative fuel

ECA limits on SOx emissions are driving the search for suitable alternative fuels in shipping (Romeo, 2012). Whilst the use of biofuels is being investigated, Liquefied Natural Gas (LNG) is emerging as an effective way to achieve the ECA SOx requirements (Bazari, 2014b). The reason for this is that if no other technical measures are implemented to reduce the SOx emissions, then LNG is expected to be a less costly alternative to low-sulphur marine gas oil (Germanischer Lloyd, 2011). According to Bazari (2014b), since LNG is cheaper than diesel, it may well emerge as significant alternative fuel in shipping.

Germanischer Lloyd (2011) explain that using LNG as a fuel can reduce SOx emissions by up to 95% without the use of scrubber technologies. Moreover they point out that LNG is a cleaner burning fuel with a lower carbon content that reduces (CO2) emissions by 20-25%. However, according to Romeo (2012), the cleaner burning nature of LNG can mean reduced power, and for this reason some shippers are using the fuel in auxiliary engines to supplement power and to support the achievement of the overall sulphur limits. One further drawback of LNG is the need for much larger fuel tanks which can reduce cargo carrying capacity (Romeo, 2012).

It is worthy of note that there are advances in green ship technologies in the development of dual-fuel engines that burn both diesel and natural gas (Bazari, 2014b).

All of this said, the distribution of LNG is still in the early stages and will need to be addressed (Germanischer Lloyd, 2011). Also, the cost and utility of LNG as a main propulsion fuel will need to be demonstrated if it is to become a viable alternative. (Germanischer Lloyd (2011) & Romeo (2012)).

Synthesising the views of Romeo (2012) and Germanischer Lloyd (2011), the determinant factors of whether ship operators move to LNG rather than employing scrubber technologies will depend upon five main variables:

1. The share of operation inside ECAs and the introduction of other LCAs
2. The future distribution network for LNG
3. The utility provided by LNG as a fuel for propulsion, particularly in terms of power losses
4. The price differential between LNG and HFO
5. The Investment costs for LNG tank system and the losses in cargo carrying capacity

4. Other Alternatives

Each of the above three approaches can be supplemented with alternative or supplementary propulsion technologies such as wind power and hoteling or green-port and green-ship technologies by connecting to an on-shore clean power supply when in port. A further possibility, not discussed in this paper, is the prospect of an emissions trading scheme for sulphur and nitrogen oxides (Sjofartsverket, 2007). The reason that this is not discussed here is that the debate on such a scheme is by no means settled.

5. Impacts of the Sulphur Regulations in Shipping

Impacts in Shipping

Following a wide review of the literature and synthesising all of the views put forward by the many scholars and marine industry stakeholders, it is apparent that the impact of the sulphur regulations on shipping are wide and varied. They include the following:

Supply concerns

1. Concerns regarding the availability of sufficient supply of low sulphur fuel – Particularly after the Annex VI step-change in 2020 to 0.5% sulphur content, meaning that Marine Gas Oil is required to get to the lowest SOx limits (Bazari, 2014b).
2. Availability of sufficient bunkering facilities of LNG (Germanischer Lloyd, 2011)

Cost Driver Impacts for Ship Operators and Global Trade

3. The additional costs associated with the increased cost per tonne of low-sulphur MDO compared with HFO (Bazari, 2014b)
4. Large investments that may be required in the conversion to the use of alternative fuels such as biofuels or Liquid Natural Gas (LNG) – EG investment costs in the tank system (Germanischer Lloyd, 2011).
5. Loss of power through the use of LNG over HFO or MDO for propulsion (Romeo, 2012)
6. Uncertainties regarding the introduction of new ECAs in addition to the 4 already identified having a further cost impact on global trade (IMO, 2014c)
7. Uncertainties regarding additional engine wear as a result of the loss of the lubricating properties of sulphur in fuel oils (MAN (2010) and Romeo (2012)).
8. Additional costs involved in the retrofit of automatic lubrication technology as a compensation for the reduction of sulphur in fuel (MAN (2010) and Romeo (2012)).
9. Concerns regarding the ignition qualities of low sulphur fuels and the detrimental effects these have had in the past on operational reliability (MAN, 2010)

10. Additional costs involved in the fitting of exhaust gas scrubbers as abatement devices and the relative pilot nature of their development in a marine environment (MAN, 2010)
11. The business case for fitting abatement devices against the uncertainty of supply and cost for low-sulphur fuels or LNG in the future.

Enforcement, Procedures and Workload

12. Additional stringent procedures for hoteling or switching to use 0.1% sulphur fuels when in ECAs and when berthing in certain ports and ensuring that there is sufficient compliant fuel on board (Romeo, 2012)
13. Workload requirements for the crew from the additional procedures. (Author)
14. Anxieties regarding penalties for non-compliance with procedures and the impacts those restrictions, and being reported or possibly detained can have on trade. (Author)

Safety Risks

15. Safety Risks associated with the use of ships' boilers that have not been adapted or certified for use with the marine diesel and marine gas oil (Germanischer Lloyd, 2011).

Specific Comments on Fuel availability

Currently, low sulphur marine fuels are not being produced at the refineries at the level that will ultimately be required to provide sufficient supply to comply with the step change decreases mandated over time by the regulations (UKPIA, 2014). Moreover, this global low sulphur fuel demand requirement will be compounded by the long term (2015) ECA limit to have fuels with a fuel sulphur limit of less than 0.1% for all ECAs.

For this reason, the IMO has proposed a review before 2018 to ascertain whether it is possible for the regulatory induced demand for these cleaner fuels combined with the projected growth of shipping to be met with adequate supply (IMO, 2014c). Depending on the outcome of this review, it could be that the 2020 date for the final step to 0.5% sulphur fuels in international waters could be postponed to 2025 (DfT, 2013).

An analysis of the pre-2018 review and what it could mean has been performed by the author. For completeness, this analysis has been included with this paper as Appendix D.

Specific comments on competitiveness,

It is likely that the sulphur regulations will have an impact on the cost of the fuel or other technical and operational work-a-rounds that will have to be employed by ship owners and operators. This will inevitably have impacts on competitiveness through the inflationary effect on the cost of goods transported.

Impacts on competitiveness will be centred on the issue of the additional cost of fuel or the additional cost of installing technical systems on-board ships as well as specific operational trade-offs in order to achieve compliance. Each of these aspects will have an impact on the cost per tonne of cargo carried and in ECA areas which typically surround coastal areas such that which surrounds Europe. In these areas, there are often viable alternatives for the carriage of freight such as road and rail. Therefore, if shipping becomes disproportionately more expensive in these areas there could be a loss of market share from shipping to cheaper and more "sustainable" means of freight transport.

6. Conclusion

This paper has thoroughly examined the background, nature and impact of the IMO 2020 sulphur regulations. It concludes that these regulations will indeed have a significant impact on the global shipping industry. This is because of a number of uncertainties regarding the availability of low-sulphur fuels or alternatives, the efficacy of alternative fuels and scrubber systems, and importantly, the cost of compliance that will have an impact on competitiveness of the industry.

Ends –

Word count: 4392 excluding figures, references & appendices

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Appendices

A. Sulphur and its Effects

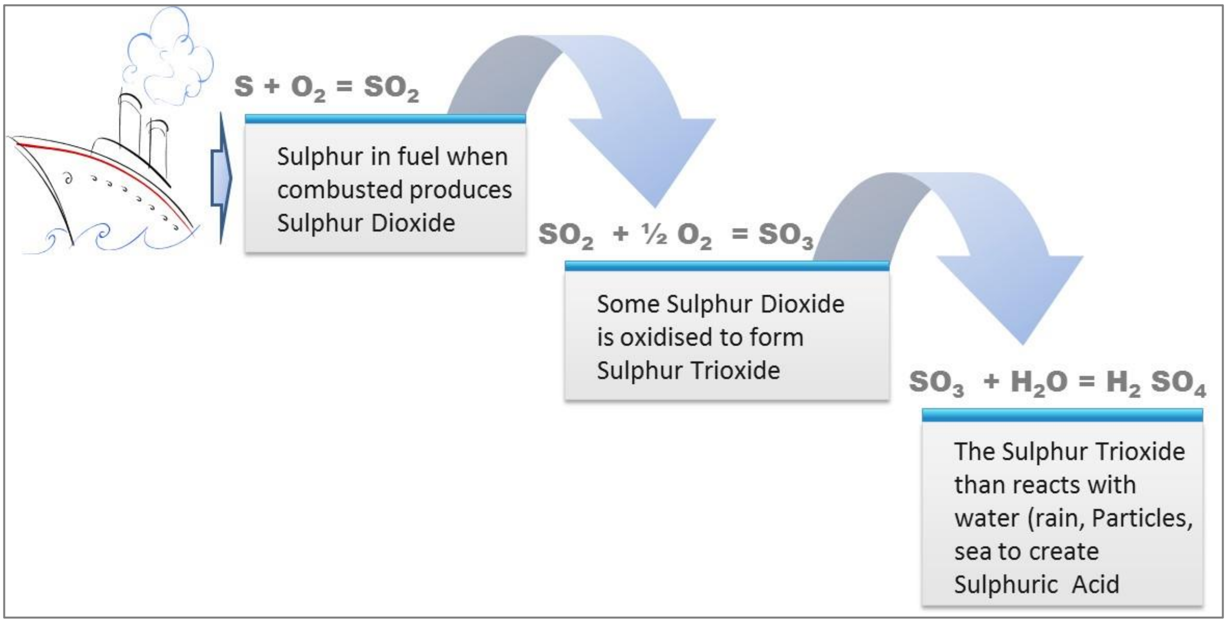
Health effects

According to Sher (1998) SO_2 is the primary pollutant form of sulphur that results from the burning of fossil fuels in combustion engines. Sher asserts that it is the most ubiquitous urban air pollutant. Sher explains that SO_2 is a highly irritating gas that in mild concentrations causes eye, throat, and lung irritation. In cases of repeated exposure to higher concentrations, SO_2 can cause asthma and bronchitis. In extreme situations, SOx can cause throat spasms and fluid accumulation in the air spaces of the lungs, and both of these conditions can be fatal. According to a more recent study performed in the Netherlands, evidence is increasing that long-term exposure to ambient air pollution that includes oxides of sulphur and particulate matter is associated with deaths from cardiopulmonary diseases (Beelen et al., 2007). Whilst this most recent study was based on a review of urban areas and the health effect of traffic, it follows that since international shipping contributes 7% of the world's SO_2 (Bazari, 2014b), the impact on the environment and people living in port and coastal are particularly affected by pollution from ships with high sulphur fuels. According to *Council Directive (EC) 2005/33/EC* measures are therefore required in this regard.

Sher (1998) also points out that pollutants may have greater effect on health when in combination (smoke particles and sulphur dioxide, for example) than separately. He gives another example that ozone in combination with sulphur dioxide can have a more severe effect on human health than either pollutant can separately.

Acid Rain:

Burning sulphur based fuels contributes to acidification (*Council Directive (EC) 2005/33/EC)*. Acid rain is also one of the by-products of the fossil fuel combustion process and contains relatively strong sulphuric and nitric acids. Vallero (2007 p.234) explains that nitric acid is produced from the oxidisation of nitrogen during combustion. The nitrogen being naturally present in the air. Vallero also explains that the sulphuric acid comes from the burning of fossil fuels that have sulphur content. According to Vallero, the production of sulphuric acid occurs in three stages. First sulphur dioxide is produced from the oxidisation of sulphur within the fuel during the combustion process. Then as the Sulphur dioxide is released through ships' exhausts, some of the sulphur dioxide is further oxidised to Sulphur trioxide (SO3). This sulphur trioxide then reacts with water – either in the air, or with the sea, or other large bodies of water, to create sulphuric acid. The process that leads to sulphuric acid production is shown in the figure below.



Authors own work – adapted from text Source: Vallero 2007 p 234

Figure 3 – The Production of Sulphuric Acid from Sulphur in Fuel

In some areas this phenomenon creates an acid with a pH of less than 3, which is some 10,000 times more acidic than neutral pH[3] and is much more acidic that unpolluted rain that has a pH of around 5.6[4]. As well as the health effects to humans explained above, this level of acidity is a threat to marine life, agriculture, and to metallic or carbonate based materials such as buildings, facades and artwork. (Vallero, 2007).

[3] The pH range goes from 0 – 14 with 7 being neutral, Values below 7 are acidic and above 7 are alkaline. A H of 3 represents a relatively strong acid (Vallero, 2007)

[4] Unpolluted rain is already slightly acidic due to the dissolved atmospheric carbon dioxide (Sher, 1998)

B. The Regulatory Framework in International Shipping

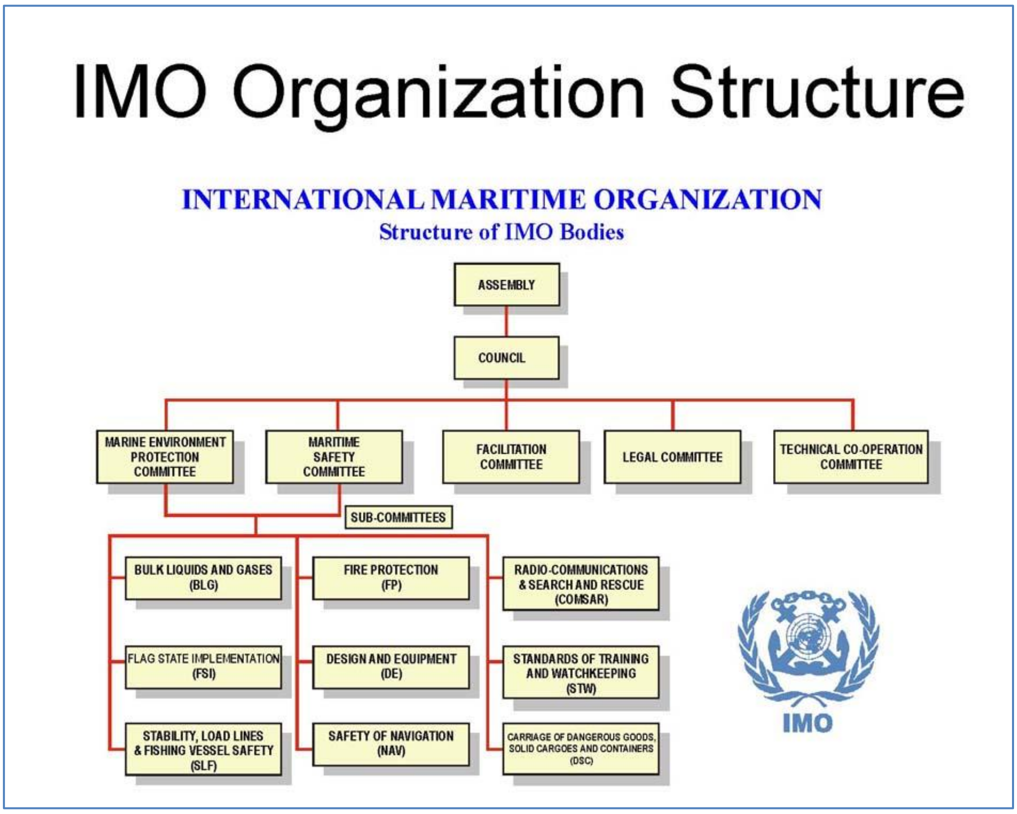
The following gives some context for the regulatory framework within which the sulphur regulation has been developed and is being implemented.

Since 1948, the IMO has been responsible for standard and regulation setting related to international shipping (IMO, 2014a). The IMO sets shipping standards at a global level for safety, security and environmental matters, and they do this on behalf of, and in conjunction with, the 170 flag states. In doing so the IMO creates and maintains an agreed regulatory framework for the global shipping sector. The individual flag states then implement the standards and enforce regulation over the vessels registered under their flags (Carlton, 2013). In the case of some conventions and regulations, these are also overseen and enforced by Port State Control. Port State Control being the inspection of foreign ships in other national ports (IMO, 2012a). Port State Control also applies to the enforcement of the IMO Convention that contains the Sulphur Regulations.

The structure of the IMO and the Principal Regulations

The IMO conduct business through a series of 5 committees as shown in the figure below, from where they develop and maintain 3 Principal International Conventions/Regulations:

1. SOLAS: which is the International Convention for the Safety of Life at Sea (IMO, 2009)
2. MARPOL: Which is the International Convention regulating the Prevention of Pollution from Ships (IMO, 2011a)
3. STCW: Which is the Standards of Training, Certification and Watchkeeping (IMO, 2011b)



Source: IMO 2014a

Figure 4 – IMO Organisation Showing the 5 Main Committees

The Marine Pollution Convention (MARPOL)

The Marine Pollution Convention MARPOL (IMO, 2011a), is one of three principal regulations overseen from the IMO. It contains the sulphur regulations and is a comprehensive anti-pollution convention that was developed and is maintained by the Marine Environmental Protection Committee (MEPC) of the IMO (IMO, 2014a).

The MARPOL Convention was adopted in 1973, and is now updated via a protocol that was agreed in 1978 (IMO, 2011a). MARPOL has six annexes, each one providing regulation for a specific area of marine pollution control (Carlton, 2013):

1. Annex I Oil Pollution Prevention (1993)
2. Annex II Noxious Liquid Bulk Substances Pollution Prevention (1983)
3. Annex III Harmful Substances Pollution Prevention (Packaged goods) (1992)
4. Annex IV Sewage Pollution Prevention (2003)
5. Annex V Garbage Pollution Prevention (1998)
6. Annex VI Air Pollution Prevention (2005)

The dates in brackets signify the date that the regulation was brought into force. It is interesting that ship air pollution and emissions were one of the last major ship pollutants to be regulated.

Whilst it is Annex VI that regulates airborne emissions from ships, specifically, it is Regulation 14 of the MARPOL Convention that regulates SOx emissions, and also sets the limits for special geographic areas termed Emission Control Areas (ECAs) (IMO, 2011a). It also sets the timing of the step change improvements that are required (IMO, 2011a).

C. Air Pollution Performance Indicators and What They Reveal

Against the background of the health and physical effects of SOx pollutants elaborated in Appendix A to this paper, the IMO and the flag states have acted to introduce the sulphur regulations.

According to the latest facts and figures from the IMO, atmospheric pollution from ships has generally reduced in the last decade. This, they say, is as a result of improvements in engine efficiency as well as better hull design and new ships with larger cargo capacities. The IMO claim that this has combined to create a reduction in emissions through increased fuel efficiency. (IMO, 2012b). However, these efficiencies do not appear to have reduced SOx emissions.

The IMO monitor ship-generated air pollution as one of 20 performance indicators. The air pollution indicator (indicator no.9) measures and reports on three elements (Taken from (IMO, 2010):

(a) 3-year rolling average of the sulphur content of fuel oil delivered to ships;

(b) Tonnes of NOx, SOx and CO2 released from ships; and

(c) Ratio of estimated tonnage of SOx, NOx and CO2 released annually per tonne-mile of cargo carried by sea.

Whilst the sulphur content of fuel delivered to ships has reduced from a reference value of 2.7% in 1999, to 2.38% in 2009, the estimated release of SOx per tonne-mile of cargo carried by sea has remained static at around 0.46 grams of SOx per tonne-mile. Moreover, the IMO report that emissions of SOx released from ships almost doubled between 1999 and 2007 from 6.5 tonnes to 12 tonnes (IMO, 2010).

Moreover, by applying the SO_2 emissions factor to the current world shipping fuel consumption and the relevant sulphur content of HFO and MDO, the formula reveals that more than 20 tonnes of SO_2 are now emitted per year (Bazari, 2014b). Bazari points out that this represents 7% of the world's SO_2 emissions. This is a significant increase on the sulphur emissions of 2007 and is disproportionate with the level of CO_2 produced by shipping, which is around 2-3% of world emissions. This increase in SO_2 presents a stark contrast to land based transport improvements in the EU which has decreased its SO_2 emissions by 80 percent since 1990. During the same period the European shipping industry has increased its emissions of SO_2 by more than 70% (Bazari, 2014b).

D. Fuel availability

Currently, low sulphur marine fuels are not being produced at the refineries at the level that will ultimately be required to provide sufficient supply to comply with the step change decreases mandated over time by the regulations (UKPIA, 2014). Moreover, this global low sulphur fuel demand requirement will be compounded by the long term (2015) ECA limit to have fuels with a fuel sulphur limit of less than 0.1% for all ECAs.

For this reason, the IMO has proposed a review before 2018 to ascertain whether it is possible for the regulatory induced demand for these cleaner fuels combined with the projected growth of shipping to be met with adequate supply. Depending on the outcome of this review, it could be that the 2020 date for the final step to 0.5% sulphur fuels in international waters could be postponed to 2025.

Essentially, synthesising a review of IMO MEPC minutes and communications from the Correspondence Group reviewing regulation; The ability to supply the new low sulphur fuels in the quantities required by the regulation will depend on the following 5 elements:

1. Regional Fuel demand forecasting accuracy as a result of global and regional economic activity or other influences.
2. Refinery supply and distribution capabilities
3. The introduction of any new Environmental Control Areas that might be proposed and adopted
4. The impact of the introduction and take-up of alternative fuels such as biofuels or LNG
5. The impact of the use of alternative technologies to achieve the overall aim of the regulation such as abatement technologies that would remove the SOx elements and avoid the emissions.

The above information was taken from IMO 2014b, for example, at the 66th session of the Marine Environment Protection Committee in February 2014, the various impacts of Sulphur regulation on and the ability to achieve it was debated by the United States, BIMCO, the International Association of Independent Tanker Owners (INTERTANKO) and the Cruise Lines International Association (CLIA). The conclusion was that the 2018 feasibility review date should be brought forward to 2016/17 in order that appropriate modelling could be performed and in order for the refinery sector to have adequate time to make the necessary technical and operational modifications (IMO, 2014c). The UK view is that this review should commence in January 2015 (DfT, 2013)