Ships' Solutions for meeting the International requirements regarding the reduction of Air Pollution

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Summary

Large quantities of harmful substances, gases and particles are released from the ships into the air. This leads to many unwanted chemical processes having a harmful effect on the entire planet and on the human health as well. In most cases, these processes result in ozone depletion, acid rain, global warming, appearance of dermatological and respiratory diseases and other undesirable impacts on the entire ecosystem.
Aiming to reduce the adverse impact on the environment, the international maritime community has decided to regulate and set rigorous requirements for ships by introducing and implementing the Annex 6 of the MARPOL Convention. On the bases of these requirements, ships and their owners will be subjected to more stringent conditions that are primarily related to adjustment of existing ships' engines and/or the use of environmentally friendly fuels.
This paper analyses air pollution deriving from ships in general and its negative effects on the atmosphere. It also presents possible methods and solutions of adapting ships to new and more stringent requirements as well as the advantages and disadvantages of relevant technical solutions.

Keywords: air pollution, Annex 6, MARPOL Convention, marine fuels, liquefied natural gas, exhaust gas scrubbers.

1. Introduction

More than 90% of the world's goods are transported by sea. When taking into the account the trends in the last 150 years, by the year 2060 this volume is expected to reach 23 billion tonnes per year, while in 2010 it amounted to 8.5 billion tonnes of cargo [14]. As the means of transportation, ships have a comparative advantage given to the amount of cargo they are able to transport. Compared to road and air transport, ships represent much more efficient means of transport in terms of the quantity of carbon dioxide emissions per ton of cargo transported and the distance passed. This makes them one of the indispensable factors in world's economy.

This does not mean that air pollution from ships is insignificant; the size of the world's fleet has to be taken into the consideration. According to UN data in January 2011, the world's fleet was comprised of 103,392 commercial vessels [15].

In view of the above, the question that has inevitably arisen is how to reduce the quantity of harmful substances released from the ships into the atmosphere. Annex VI to the International Convention on the Prevention of Pollution from Ships (MARPOL) of The International Maritime Organization regulates prevention of air pollution from ships; in the view of the requirements of the aforementioned Annex, ships or shipping companies are looking for different ways of adapting the technical features of ships engines to meet the anticipated requirements.

2. Air pollution from the ships

Air pollution from the ships is not as obvious and direct as other pollutions, but by the emission of harmful gases into the atmosphere makes a significant influence on earth pollution. As it is the case with the other pollutions, air pollution can be either intentional or unintentional.

The source of air pollution from the ships is generated from various sources, it includes loaded cargo, fuel, exhaust and technical gases as well as the gases from the crew area and engine room. Generally, the most significant pollution comes from operating of ships' engines. All these gases are released into the environment by heating, ventilating or evaporating. For decades, ships have not been considered as a significant source of pollution, especially in comparison to some land-based plants. However, more serious concern on ship pollution was noticed at the end of the 1980s [2].

According to "Third IMO GHG Study" published by the International Maritime Organization (IMO) in 2015, total quantity of emission from global shipping was 938 million tons of CO_2 and if we also count other greenhouse gases such as CH_4, N_2O and others, a total of 961 million tons is measured in CO_2 equivalents (CO_2e)[1]. The total emission of CO_2 quantity released in air by ships in international voyages amounted for 796 million tons, or when measured in CO_2 equivalent, it was a total of 816 million tonnes. Taking into account the global economy, international shipping as a source of greenhouse gases accounts for 2.2% of CO_2 and 2.1% CO_2e. This percentage is also

[1] For the purpose of a simplified calculation of the total greenhouse gas emissions, a CO_2 equivalent (CO_2e) unit has been introduced. It is equal to the product of quantity of gas, mass unit and GWP-100 value (global warming potential calculated for a period of 100 years) of a certain greenhouse gas and it represents unit of emission of any greenhouse gas.

the lowest measured in the period from 2007 till 2012 [10].

According to the same source, the next group of harmful gases released from ships are compounds of nitrogen oxides (NOx) and sulphur oxides (SO_X). Within the five-year period between 2007 and 2012, the global shipping averaged 20.9 million tons of nitrogen oxides and 11.3 million tons of sulphur oxides on an annual basis (figure 1). These quantities of oxide contain 6.3 million tons of nitrogen and 5.6 million tons of sulphur. The amount of these gases released from ships in international voyages represents 13% of total nitrogen oxide emissions and 12% of sulphur oxides.

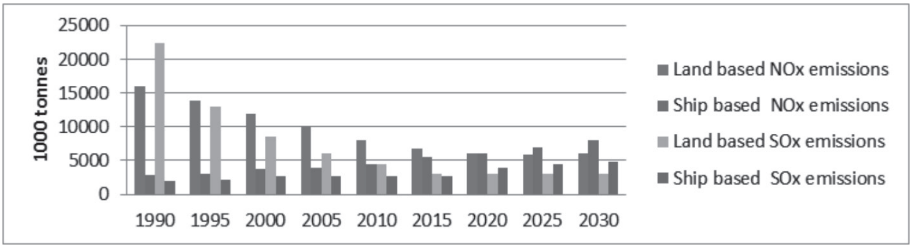

Figure 1 Comparison of SO_x and NO_x land based and ship's emissions [12]

Other harmful substances include the majority of hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs), different types of gases sourced from air conditioning refrigerants or refrigerated containers released into the air from the ships. The amount of other significant pollutants sourced from vessels such as particulate matter (PM) and non-methane volatile organic compounds (NMVOCs) depends on the quantity and properties of consumed fuel, the type of engine, etc. [10].

Air pollution generated from ships and generally other ship-generated pollution is primarily regulated by MARPOL Convention, currently comprising of six Annexes that separately regulate the prevention of marine pollution from ships at the international level. In 1973, when the Convention was adopted there was a debate regarding the control of harmful gases discharged from ships, but the decision to implement the pollution control policy was not included in the first version of the Convention. Air pollution protection issues are regulated by other UN conventions, not necessarily related to maritime transport. During the 1970s, doubts about the negative impact of acid rains had been confirmed, while damaging processes such as global warming and ozone depletion [6] were identified during the following decade.

The work of International Maritime Organization on air pollutants began in the mid-1980s, as a part of the Annex 1 of the MARPOL Convention. In 1988, the MEPC (Marine Environment Protection Committee) included this problem into its program at the request of Norway. Norway and other North Sea countries had signed a declaration in order to take steps for reducing air pollution deriving from ships. Immediately after that, during the next year, other member states sent documents that were discussing this topic. Norway did not stop there in 1990; it submitted a report on air pollution from ships to the Committee, particularly mentioning sulphur, nitrogen oxides and chlorofluorocarbons [6].

After the panel discussion conducted in 1991, there was adopted the Resolution A.719 (17) on the prevention of air pollution from ships; The Resolution also decided about creating a new Annex to the MARPOL under the title "Annex VI". The text of the Annex had been developing for six years and was finally adopted in September 1997 and it entered into force on 19th May 2005. The Annex itself is divided into three parts. The first part addresses the general requirements, the second part describes the certificate and the control methods, and the third part determines the discharge limits of the sulphur and nitrogen oxides. Provisions prohibit the intentional release of the substances from ships causing the ozone depletion. Additionally, it determines the conditions for the first tier (Tier I)[2] [2].

During same year, the Committee decided to set up stricter requirements; in 2008, after three years of monitoring there was adopted a supplementary Annex 6 with the new technical code for the control of nitrogen oxide release from marine engines (Technical Code for Control of Emissions of Nitrogen Oxides from Marine Diesel Engines - NOx Technical Code 2008) [7].

Stricter requirements include sulphur monitoring areas. Furthermore, requirements for the first, second and third tier of ship's engines [7] were also provided, having the additional measures prohibiting the burning of certain substances in the ship incinerator [6].

2. Consequences of air pollution and requirements for the ships

Emission of harmful gases into the environment results in the development of the negative ecological processes. The entire world's economy is involved in that process, the ships as well. The ships release different gasses that are harmful not only to the environment, but also to human health and consequently for the economy as a whole.

2.1. Consequences of pollution

The consequences of negative ecological processes are:

- Global warming,
- Acid rain,
- The occurrence of ozone hole and the ozone layer depletion,
- Existence of particulate matters.

Global warming occurs due to the greenhouse effect where heat is retained on Earth. This effect appears due to the enormous amount of carbon dioxide (CO_2) emissions and other greenhouse gases such as methane (CH_4), nitrogen oxides and fluorinated gases [16].

[2] Pursuant to Regulation 13 of Annex 6 to the MARPOL Convention, the ships engines are divided into 3 classes/levels (Tier I, II and III) following the requirements they need to satisfy with respect to the emissions of nitrogen oxides.

Acid rain has a negative impact on plants, water and buildings, it occurs "when sulphur dioxide (SO_2) and nitrogen oxides (NO_X) are emitted into the atmosphere and transported by wind and air currents. The SO_2 and NO_X react with water, oxygen and other chemicals by forming sulfuric and nitric acids." [17].

Ozone holes and the ozone layer depletion were first observed during the 1970s. This process is caused by chlorine and bromine atoms that destroy ozone much faster than it may be naturally regenerated. Chlorine and bromine atoms occur in the atmosphere due to the presence of CFC and HCFC compounds which, under the influence of UV radiation, release chlorine and bromine [18].

Particulate matters are very small particles of soil, dust and various dirt, in solid or liquid state; if inhaled, they cause health problems to people[3]. They are divided into two categories: PM_{10} for particles having size less than 10 micrometres and $PM_{2.5}$ for particles smaller than 2.5 micrometres. Exposure to particulate matters can cause serious health problems, primarily to human respiratory system [19].

2.2. Requirements of the Annex VI of MARPOL Convention

In order to stop or at least to slow down aforementioned processes, there have been established strict rules on ships' emission control. The third chapter of Annex 6 of the MARPOL Convention sets the requirements for the emission control. The most important provisions of the Convention related to ships ability to adapt to requirements on reducing the air pollution are contained in the following Convention's regulations.

Regulation 4 provides other options for meeting the anticipated requirements. It allows the use of various materials, machines or systems such as air scrubbers, but with the mandatory notification to the International Maritime Organization.

Regulation 12 prohibits emission of ozone depleting substances. This regulation does not allow the use of devices and equipment containing such substances on new ships. An exception has been granted for the devices and equipment containing hydrochlorofluorocarbons, but, they will be prohibited from 01st January 2020.

Regulation 13 applies to three different engine levels/tiers associated with the emission quantity of nitrogen oxides. The regulation implies specific requirements for three engines tiers depending on the ship construction date (Table 1) [8].

[3] According to [19], more than half a million of Americans die per year due to cardiovascular illnesses connected to air inhalation of particulate matters PM_{10}. It is estimated that 310,000 of Europeans die due to polluted air every year. The British have proven a strong connection between deaths caused by pneumonia and by air pollution caused exhaust gases.

Tier	Ship construction date on or after	Total weighted cycle emission limit (g/kWh) n = engine's rated speed (rpm)		
		n < 130	n = 130 - 1999	n ≥ 2000
I	1st January 2000	17.0	$45 \cdot n^{(-0.2)}$ e.g., 720 rpm – 12.1	9.8
II.	1st January 2011	14.4	$44 \cdot n^{(-0.23)}$ e.g., 720 rpm – 9.7	7.7
III	1st January 2016 (for ECA area only)	3.4	$9 \cdot n^{(-0.2)}$ e.g., 720 rpm – 2.4	2.0

Table 1 Requirements for ships engine concerning NOx emission in accordance with the Annex VI of MARPOL Convention

Following figure show the ratio of the nitrogen oxide emission rate and engine speed, depending on the different engine levels.

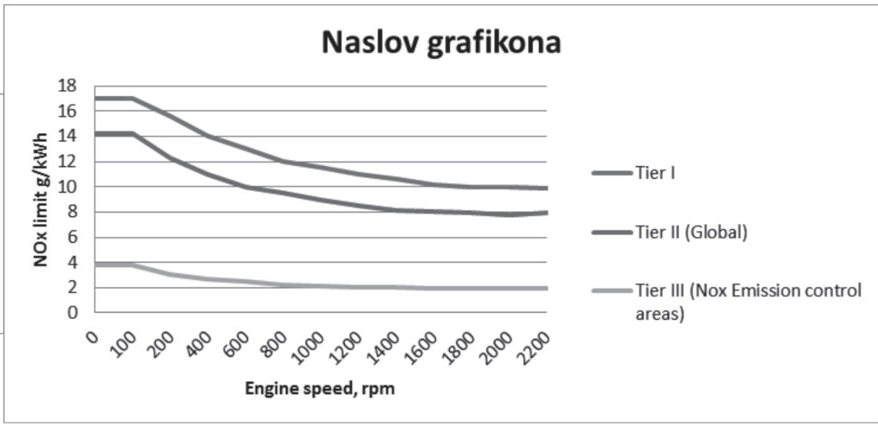

Figure 2 MARPOL Annex VI NO_X emission limits [11]

Regulation 14 was originally prohibiting the use of any fuel on ships having the sulphur content greater than 4.5% m/m. The same regulation determines the Sulphur emission control areas for the Baltic and North Sea. Subsequently, two additional control areas were established in the North American area and Caribbean Sea area within which sulphur content should not exceed 1.5% m/m. Additionally, in the area of North America, there is also the control of nitrogen quantity and particular matters in the air. Since 2005, when the regulation was put into the force, a few changes were made to the existing requirements for the year 2020; they are 0.1% m/m of sulphur in fuels within the emission control areas and 0.5% m/m for the rest of the world.

Date	Sulphur limit in fuel (% m/m)	
	SO_X - ECA	Global
2000	1.5%	4.5%
07/2010	1.0%	
2012		3.5%
2015	0.1%	
2020		0.5%

Table 2 MARPOL Annex VI fuel sulphur limits by years [11]

There are currently four Sulphur emission control areas in the world i.e. in the Baltic Sea, North Sea, the major part of the USA and Canada and the part of the Caribbean Sea. Regulation 15 controls volatile organic compounds. This regulation applies only to tankers using the gas management system during the stay of the ship in the port.

Regulation 16 regulates burning and prohibitions of burning of certain types of waste as well as types of the incinerators.

Regulation 18 deals with the issue of fuel quality control and fuel availability.

MARPOL convention regulates two more mandatory mechanisms which increase ships' energy efficiency. The ships are divided into two groups: new ships that will be covered by the Energy Efficiency Design Index (EEDI) mechanism and other ships that will be covered by the Ship Energy Efficiency Management Plan (SEEMP). The first one regulates installation requirements while the other one improves the current energy efficiency [11]. The EEDI mechanism requires the proper performance of ships' engines by transportation unit in such way that the performance meets the pre-determined defined value in terms of pollutant quantity emissions (e.g. $gCO_2/t*M$).

3. Methods of adjustment for the purpose of meeting the requirements of Annex 6 - ADVANTAGES AND DISADVANTAGES

MARPOL Annex 6 assumes several ways of adapting to its requirements and the most commonly mentioned ones are:

- Use of low sulphur fuel oil,
- Use of heavy fuel oil with the installation of exhaust gas scrubbers,
- Use of liquefied natural gas.

3.1. Low sulphur fuel

The easiest way to meet the requirements for 0.1% of sulphur within the special monitoring areas and 0.5% of sulphur in the rest of the world, is by using Low Sulphur Marine Gas Oil (LSMGO) and Marine Diesel Oil (MDO). All ships using Heavy Fuel Oil (HFO) may easily use low sulphur fuels by making small modifications that primarily reflect in increasing of the tank capacity and installing a fuel cooling system for the purpose of increasing the fuel viscosity. Using low sulphur fuel oil is the least risky because it does not differ much from the current operational mode. There are no big changes regarding the engine construction, and the difference is that there is going to be a replacement of the heating system by the fuel oil cooling system. Using low sulphur fuel oil requires less maintenance and thus, it reduces operation costs. Since the system is very similar to the present one, it may be expected that the cost of crew training will not be increased. [20].

Reduction of the sulphur oxide level and particulate matters is due to the fuel oil itself, which contains less impurities. Reduction of sulphur oxides is 96% compared to HFO, and the level of particulate matter is lower between 50% and 85% [11]. Contrary to this, the biggest disadvantage of low sulphur fuel oil is the price. Compared to the classic HFO, these fuel oils are 50% to 70% more expensive [11].

In order to reduce NO_X emissions and meet the requirements for Tier III engines, there may be presented some technological changes. There are two most commonly used options. The first option is to install Selective Catalytic Reduction (SCR) plant, which reduces nitrogen oxide levels to an acceptable level. The SCR works by adding the ammonia in the exhaust gases which reduces nitrogen oxides to nitrogen and water. In order to work properly, the SCR needs a high exhaust gas temperature that is usually more than 350°C, all for the purpose of reducing nitrogen oxide levels in the exhaust. This process cannot be done by fuel oils having high sulphur content and at low exhaust gas temperatures. Another option is to use Exhaust Gas Recirculation (EGR). This option reduces the combustion temperature in the engine cylinders which results in the formation of less nitrogen oxides.

Similarly, one option can be the use of ultra-low sulphur heavy fuel oil (ULSHFO). The production and consequently, the price of that fuel is relatively high compared to HFO. Residual fuel oils with low sulphur content reduce the level of sulphur oxides but not the particulate matter.

3.2. Exhaust gas scrubbers

Another way of adjusting to the requirements of Annex 6 is the use of Exhaust Gas Scrubber (EGS). The main advantage of the exhaust gas scrubber is the retention of the existing propulsion system and fuel oil, that is, it is possible to continue to use the HFO.

Using HFO is 50 to 70% cheaper than using low sulphur fuel oil, which is currently the most efficient method regarding the fuel oil costs. It will be difficult to predict the HFO price fluctuation after 2020, when global sulphur content shall drop to 0.5%, therefore, this solution does not have a very secure future.

On some ships installing the exhaust gas scrubber may be complicated and impractical. There may be installed several smaller scrubbers for each individual exhaust gas line or one large scrubber for all exhaust lines. The technical details of the scrubbers are specified in the resolution MEPC 185 (59).

The scrubber reduces sulphur oxide levels like the fuels having 0.1% sulphur content but it fails to lower the level of particulate matter more than 30% to 60% [11]. In the event of modification of the environmental conditions (stricter requirements) in respect of the particulate matter, the scrubbers may not be the satisfactory solution. Also, the scrubber is not the satisfactory method for future limitations in terms of limiting nitrogen oxide emissions. Therefore, additional equipment (i.e. the use of SCR or EGR) is needed in order to meet the NO_X conditions for Tier III engines.

Since the scrubber works on the principle of cooling of the exhaust gases, the reduction of NO_X must be performed before the scrubber. When dealing with slow speed diesel engines, there are two possible solutions to this problem. The first solution involves the installation of a SCR between the engine and turbocharger inlet. This solution requires fuel oil having a lower sulphur content to enable the SCR to work normally because in the case of high sulphur content there would be created compounds that prevent the contact of ammonia with exhaust gases. The second solution is the exhaust gas recirculation system (EGR) which uses a smaller scrubber that cools only small portion of the exhaust gases and removes sulphur and particulate matter and then turns them back to the engine. Cooled exhaust gases result in lower combustion temperature and lower nitrogen oxide levels (NO_X). This mode allows the use of higher sulphur content fuel oils. A similar technique that would meet the requirements for medium speed diesel engines is currently unavailable. The only solution for those engines is the installation of SCR system for each engine and the use of low sulphur HFO fuels.

3.3. Liquefied natural gas (LNG)

The third solution of adapting to the requirements of Annex 6 is to use liquefied natural gas as a fuel. In the last few years, the use of liquefied natural gas in marine diesel engines is an already proven solution with the favourable price and increased availability of fuel. It does not contain almost any of the sulphur and ash, therefore, in the exhaust gases there are no sulphur oxides and particulate matters. When compared to classical fuel oils, gaseous fuel contains 10% to 13% less carbon per kilogram, ultimately leading up to 25% to 30% lower CO_2 emissions [20]. It is suitable for use within the same navigation routes and also meets the requirements of EEDI rules [5].

Gas combustion in slow speed diesel engines and medium speed diesel engines operating on the Otto principle (low gas injection pressure) does not develop high combustion temperatures and thus produces less nitrogen oxides. Thanks to the low level of formation emission of nitrogen oxides they fully meet the Tier III engines requirements. On the contrary, engines in which LNG is injected into the cylinders under the high gas pressure do not meet the Tier III requirements because they produce NO_X similar to HFO combustion, therefore they must have the additional equipment (i.e. SCR or EGR) that will reduce the level of NO_x to the acceptable level.

Liquefied natural gas requires specially designed tanks, specific handling and expensive equipment for reliquefaction, storage and delivery to the engine. Since the price of liquefied natural gas is approximately the same as the price of HFO, it makes it an acceptable solution.

Experiences coming from LNG vessels say that gas explosions should not be the problem but it should be careful and follow the management procedures. Materials that come into the contact with liquefied gas also must be of a higher quality and resistant to low temperatures. One of the major disadvantages is the need for space (for tanks) that is higher than for other fuel oils [17].

3.4 Selection and experience

Several factors should be taken into the consideration while choosing the most appropriate solution to meet the provisions of Annex 6. Those are: ship types, time spent in emission controlled areas, emissions of sulfur and nitrogen oxides and etc. One of the most important factors is the price of fuel oil. The price of the fuel oil is difficult to predict, therefore, the decisions on the application of the appropriate vessel adaptation method are made for the period of at least 10 years [20].

Each adaptation system has its advantages and disadvantages. The decision primarily reposes on shipping companies and their business policy. They will look for the lower initial and operation costs when making such decisions, while employees who work and manage systems want a certain level of safety and easy maintenance.

Using MGO has the lowest initial cost. There is no significant change in operation, the maintenance is simpler. The adaptation is simpler but the underlying disadvantage is high MGO price. When selecting a scrubber, investors decide to choose the first expensive investment, which will be paid off on fuel cost savings on a yearly basis. The same thing applies to the use of LNG as a fuel, which will certainly lead to savings at the level of annual fuel consumption but, the investment in plant and additional training of employees needs to be justified. [20].

Experience from some of today's largest shipping companies suggests different approaches to the problem solving. The world's largest container ship company, Danish A.P. Møller Mærsk decided to make the adjustment in a way that they would use cleaner fuel oils and thus satisfy the low levels of sulphur in fuel oils. First estimations indicate that the total adjustment will cost approximately 200 million $.On the contrary, the requirements for meeting the level of nitrogen oxide levels are planned to be adjusted by incorporating the EGR system [14]. Japanese ship-owner Mitsui OSK lines, running a fleet of approximately 1,000 ships, has currently optioned for the dominant use of low sulphur fuel oils, while requirements for nitrogen oxide emission will be met by installing the SCR system. The ship-owner estimates that adjusting to ecological requirements for a period of 10 years will cost them between 670 and 750 million $ [14]. Carnival ship-owner decided to install the exhaust gas scrubbers and expects an annual cost between 270 and 280 million $ [14]. Several ship-owners having the ships in the ECA area (Baltic and North Sea) have already decided for LNG fuel which they see as an ideal solution for a longer time period.

4. Conclusion

In the sense of world's economy, the ships are the strategic means of transportation. They represent the cheapest and the most efficient manner of transport in terms of transported cargo unit. It is to expect that the role of ships will not change in the future; when comparing them to other transport modes, we may anticipate that the quantity of cargo transported by sea will grow. A great number of ships also implies a significant environmental impact having the negative affects to the air. Large amounts of harmful substances are emitted from ships causing harmful processes to ecosystem. In cooperation with the Member States, the International Maritime Organization has adopted measures that should encourage progress in environmental protection and reduction of air pollution deriving from ships.

The basic regulation governing the prevention of air pollution from ships is Annex 6 of the MARPOL Convention which explicitly regulates air pollution control deriving from ships and sets clear requirements for ships to comply with. It should be noted that MARPOL requirements are continually changing and becoming more stringent, all in order to improve the environment protection.

Simultaneously, by following strict legal regulation, technological development and emerging trends, shipping companies face the challenge to adapt ships to prevent air pollution, primarily regarding sulphur and nitrogen oxides. In general, the biggest modifications for ships for reducing sulphur oxide emissions are reflected in using new, less harmful and more environmentally friendly fuels. The companies mostly accept modifications to ships, they include shifting to MGO, scrubbers or liquefied natural gas.

Additionally, ships adapt to the anticipated requirements for reducing nitrogen oxide emissions and increasing engine efficiency. The choice depends on the type of the vessel, the time spent in emission control areas, changes of requirements and unpredictable market regarding fuel prices and used technology.

Having in mind the global trend of reducing all harmful emissions and the use of environmental fuels as well as technology development for the use of LNG as fuel for engines and an increased interest for LNG fuel, it is likely that in the near future a solution of using LNG as fuel will become dominant. Although initial investment is higher than for MGO, it is a better option than SCR and EGR. Certainly, the price of LNG and legal and ecological requirements are one of the most important parameters that will influence the final decision to choose the best solution.

Regardless of the chosen adjustment method, meeting the MARPOL Convention requirements in order to reduce air pollution from ships leads to the necessity of modifying business policy that may have long-term consequences for the operations of the shipping companies, primarily because of the volatility of fuel prices as the most important issue in the process of reducing air pollution from ships.

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Prilagodba brodova međunarodnim zahtjevima za smanjenjem onečišćenja zraka

Sažetak

Brodovi u zrak ispuštaju velike količine štetnih tvari, plinova i čestica. To dovodi do mnogih neželjenih kemijskih procesa koji imaju štetan učinak na okoliš cijelog planeta pa tako i na zdravlje čovjeka. Procesi se najčešće ostvaruju kroz stanjivanje ozonskog omotača, pojavu kiselih kiša, globalno zatopljenje, pojavu bolesti dermatoloških i respiratornih organa, te druge neželjene posljedice na cjelokupni ekološki sustav.
S ciljem smanjenja štetnog utjecaja na okoliš Međunarodna pomorska zajednica odlučila je pravno urediti te postaviti stroge zahtjeve za brodove uvođenjem i implementacijom priloga 6 MARPOL konvencije. Temeljem navedenih zahtjeva pred brodove i njihove brodare postavljeni su strogi uvjeti koje moraju zadovoljiti koji se ponajprije odnose na prilagodbu postojećih tehničkih rješenja brodskih motora i/ili korištenje ekološki prihvatljivijih goriva.
U radu se analizira onečišćenje zraka s brodova i njegove negativne posljedice na atmosferu te se prikazuju mogući načini prilagodbe brodova novim i strožim zahtjevima odnosno prednosti i nedostaci pojedinih tehničkih rješenja prilagodbe.

Ključne riječi: onečišćenje zraka, MARPOL konvencije, brodska goriva, ukapljeni prirodni plin, pročistači ispušnih plinova.