diesel engine exhaust gas; diesel particulate matter;
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FUTURE NEEDS FOR SHIP EMISSION ABATEMENT AND TECHNICAL MEASURES

Summary. The International Maritime Organization (IMO) has revised air pollution regulations in MARPOL Annex VI. In 2012 Emission Control Areas (ECA) will limit fuel sulphur content to 1% and from 2015 to 0.1%). NO_x emissions based on ships engine speed are also reduced for new vessels (2012 & 2016). Facing this legislation, ship owners have the alternative either to operate ships with costly low-sulphur fuels, or to keep using HFO but together with a gas cleaning equipment at the ship stack in order to reduce the rejected amount of SO_2 gas in the atmosphere. To achieve this requirement, research and development organizations came out with proposing a solution that uses a device for cleaning exhaust gas of marine diesel engines. The paper presents a short communication about the DEECON project, which aim is to create a novel on-board after-treatment unit more advanced than any currently available. Each sub-unit of the system will be optimized to remove a specific primary pollutant. In particular, the technology within the DEECON system is based on novel or improved abatement techniques for reducing SO_x, NO_x, Particulate Matter (PM), CO and Volatile Organic Compounds (VOC). Some of these technologies are completely new for the maritime sector and they will represent a breakthrough in the reduction of the atmospheric emissions of ships, moving forward the performance of exhaust gas cleaning systems and fostering and anticipating the adoption of future and tighter regulatory requirements. In addition, an after-treatment strategy enables the possible adoption of alternative fuels, which often have their own emissions characteristics.

PRZYSZŁE POTRZEBY OGRANICZANIA EMISJI ZE STATKÓW I TECHNICZNE ŚRODKI ICH REALIZACJI

Streszczenie. Na właścicieli statków i przewoźników morskich spadł obowiązek redukcji zanieczyszczeń pochodzących z ich działalności. Aby spełnić rygorystyczne wytyczne: dyrektyw Wspólnoty europejskiej, międzynarodowej organizacji morskiej (aneks VI, konwencji) MARPOL oraz praw wewnętrznych innych państw należałoby, w obszarach kontroli emisji, używać jako paliwa oleju napędowego o zmniejszonej zawartości siarki. Obszar kontroli emisji jest to obszar obejmujący Morze Bałtyckie, Morze Północne wraz z jego podejściami pod Kanał La-Manche oraz obszar wokół USA. Ze względu na wysokie ceny paliwa niskosiarkowego, duże koszty ewentualnych zmian technicznych przejścia na paliwo o niższej zawartości siarki spowoduje kilkakrotne zwiększenie opłat i zmniejszy atrakcyjność transportu morskiego. Naprzeciw tym wymaganiom wyszły jednostki badawczo rozwojowe, proponując rozwiązania polegające na zastosowaniu nowych, bardziej skutecznych urządzeń do końcowego oczyszczania spalin z okrętowych silników diesla. Artykuł jest komunikatem projektu o akronimie DEECON, którego głównym celem jest opracowanie innowacyjnego pokładowego urządzenia do oczyszczania spalin z okrętowych silników diesla składającego się z różnych modułów. Urządzenie to będzie optymalizowane w celu usunięcia najważniejszych zanieczyszczeń tj. SO_x, NO_x, PM, Lotnych Związków Organicznych (VOC) oraz tlenku węgla (CO). Niektóre z tych technologii są całkowicie nowe w przemyśle morskim i stanowią przełom w redukcji emisji zanieczyszczeń do atmosfery. Ponadto, takie rozwiązanie jest uniwersalne, umożliwia zastosowanie alternatywnych paliw do zasilania silników okrętowych, które często mają własne cechy emisji.

1. INTRODUCTION

The emission of exhaust gases is the main source of pollutants causing a significant exposure risk to people living in the proximity to harbors or in neighboring coastal areas and had effects on the quality of atmospheric environment and climate changes. It was recently estimated [1], that ships produce at least 15% of the world's NO_X (more than all of the world's cars, buses and trucks combined), between 2.5÷4% of greenhouse gases, 5% black carbon (BC), and between 3-7% of global SO_2 output. Due to the increasing emission of exhaust gases from ships and its impact on health of people living in harbor and coastal zones, and on local ecosystems, recent international regulations are aimed at NO_x, SO_2 VOC, and PM abatement.

To address these new and future restrictive regulations, the research DEECON project (Fig. 1) in unprecedented manner combines dry plasma and catalytic methods for VOC and NO_x abatement with wet electrostatic techniques for PM and SO_2 removal. The project is aimed at the development of novel, low-cost, highly efficient and low energy consuming gas cleaning technology. The system will be designed for fast and easy "plug-and-play" on-board installation.

Fig. 1. DEECON = innovative after-treatment system for marine **D**iesel **E**ngine **E**mission **CON**trol
Rys. 1. DEECON = innowacyjny system oczyszczania spalin z okrętowych silników diesla

2. BACKGROUND

The International Maritime Organization (IMO) has issued revised air pollution regulations in MARPOL Annex VI. In 2012 Emission Control Areas (ECA) will limit fuel sulphur content to 1% and from 2015 to 0.1%). NO_x emissions based on ship engine speed have also been revised. Existing Emission Control Areas include:

- Baltic Sea (SO_x, adopted: 1997 / entered into force: 2005),
- North Sea (SO_x, 2005/2006),
- North American ECA, including most of US and Canadian coast (NO_x and SO_x, 2010/2012),
- US Caribbean ECA, including Puerto Rico and the US Virgin Islands (NO_x and SO_x, 2011/2014).

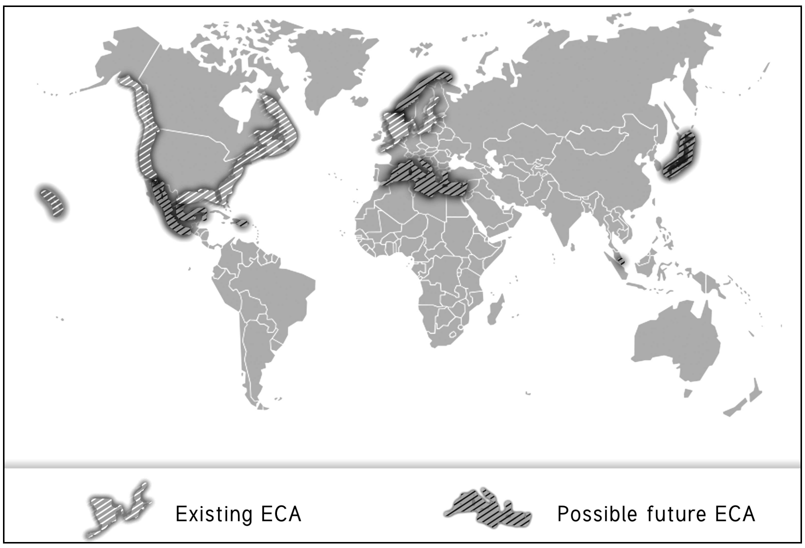
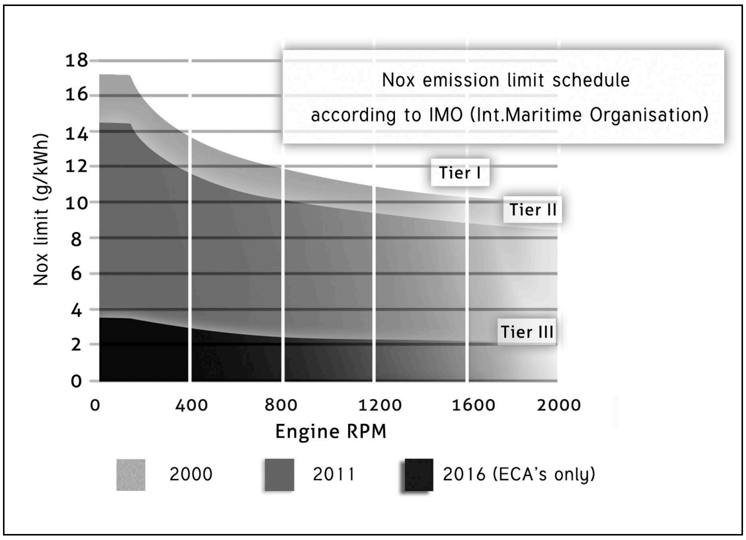


Fig. 2. The Emission Control Areas- existing and in the future [4]
Rys. 2. Obszary kontroli emisji – obecne oraz przyszłe [4]

Considering the statistics on yearly pollutant emissions due to international shipping from 1970 to 2004 [1], it is found that pollutant emissions roughly tripled in this period made some further projections of expected yearly emission levels based on the assumption that all ships are operated under the Tier I regulation of MARPOL Annex VI (Fig. 3), which was the regulation that entered into force on 1st January 2010 for all new vessels [1-3, 9, 10].

The same data were revised by the proponents taking into account the future tightening of IMO regulations expected in the next ten years (Tier II and Tier III standards for NO_x etc.), not considering ECA's [1-3, 9, 10].



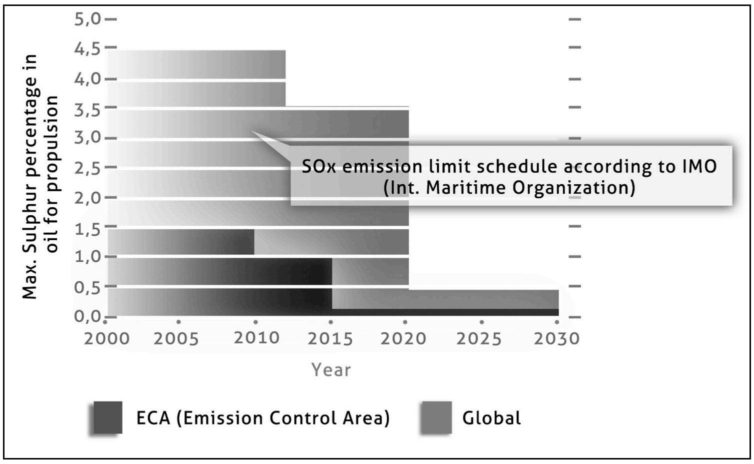


Fig. 3. MARPOL Annex VI NO_x Emission Limits and Fuel Sulfur Limits [4, 16]
Rys. 3. Limity NO_x oraz zawartości siarki w paliwie zgodnie z MARPOL Annex VI [4, 16]

Facing this legislation, ship owners have the alternative either to operate ships with costly low sulfur fuels. The other way to keep using HFO and pass IMO requirements is possible together with a gas cleaning equipment at the ship stack in order to reduce the ejected amount of SO_2 gas in the atmosphere.

In Fig. 4 is shown a diagram of the Legislative Fuel Sulfur Limits and time when that will be introduced [3, 4]. The Legislation has already had an effect on the fuel markets in the regulated areas. The price difference between low sulfur fuel and residual fuel has grown and shows increased volatility [3]. When the North American ECA was introduce in 2012 and the 0,1% fuel sulfur limit enters into force in 2015 this divergence will grow further.

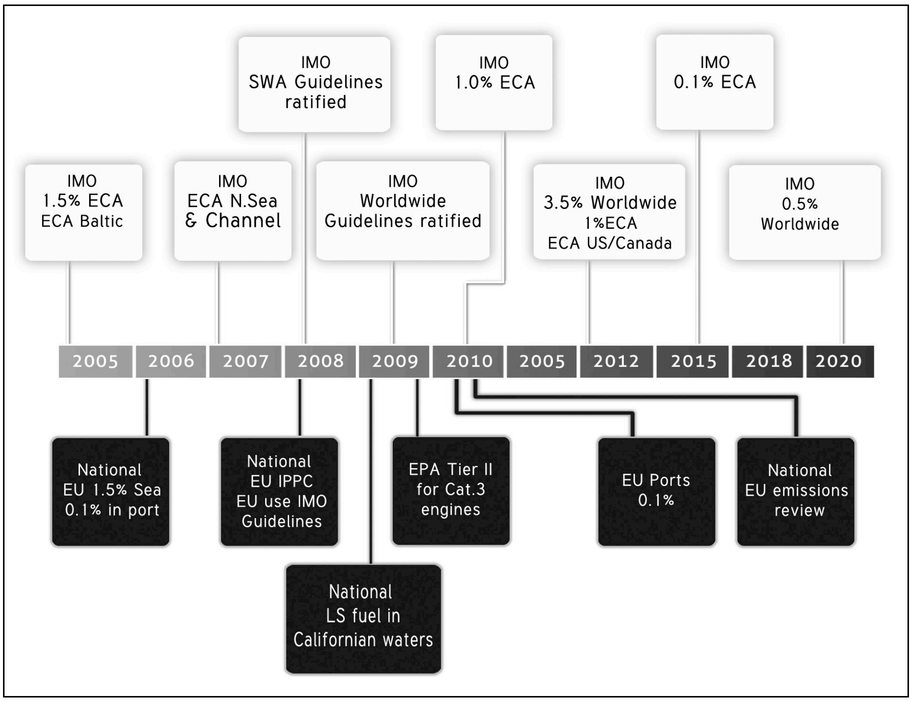


Fig. 4. The IMO Legislative Fuel Sulfur Limits requirements schedule [3, 4]
Rys. 4. Harmonogram wymagań IMO dotyczący zawartości siarki w paliwie [3, 4]

3. PURPOSE

The main objective of the DEECON project is to create a novel integrated on-board, retrofit, after-treatment unit for ships that combines different sub-units, each of which will be optimized to remove specific primary pollutants (SO_x, NO_x, PM, VOC and CO) and specifically designed for on-board application to allow an easy and fast installation on existing and new ships.

It is expected that the designed system will fulfill the following performances [11]:

- Reduction of NO_x >98%,
- Reduction of PM 90% in number,
- Reduction of PM >99% by weight,
- Reduction of HC > 80%,
- Reduction of CO > 80%,
- Reduction of SO_x >98%.

The results of the research will be adopted to upgrading the cleaning systems design and to develop a new, pilot scale, prototype to test on a 300 kW two-stroke marine diesel engine.

4. METHODS

The following sub-units designed in the DEECON project are assumed to be assembled into one integrated system for ship-engine exhausts cleaning (Fig. 5):

- NTPR – Non-Thermal Plasma Reactor, which combines the action of electron beam with microwave to generate reactive species, which convert NO_x VOC and CO [9-12];
- ESWS - Electrostatic Sea Water Scrubber, which is a device utilizing charged droplets spray for the removal of PM from gases with efficiency higher than that inherent to conventional inertial scrubbers; at the same time the So_x contaminants and other soluble gases will be absorbed by the droplets [5-8], the absorbed products from water leaving the ESWS, allow safe discharge of the water into the sea;

- SCR - Selective Catalytic Reactor, which consists of an appropriate catalyst, on the surface of which the NO_x reduction to elemental nitrogen takes place. By this way the removal of any residual NO_x in the gas will be accomplished [13],
- ESWS Wash Water Treatment Unit, which will be designed for the treatment via suitable physical and chemical processes, the by-products from water leaving the ESWS, to allow safe discharge of the water into the sea.

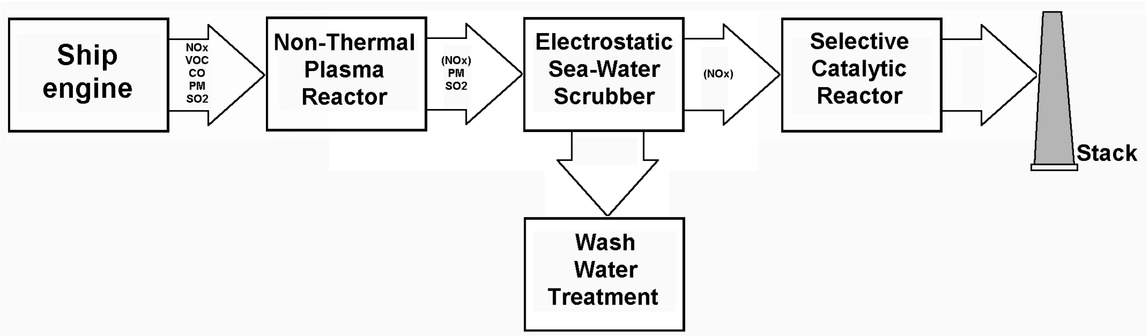


Fig. 5. Possible scheme of the system for ship-engine exhausts cleaning
Rys. 5. Możliwy schemat systemu oczyszczania spalin z okrętowych silników diesla

5. CONCLUSIONS

The DEECON system will produce a substantial reduction in the environmental footprint of ships and marine propulsion systems with a consequent improvement in airborne pollution around coastal areas and harbors, and even minimizing the possible water pollution commonly associated with the use of wet-based retrofitting units.

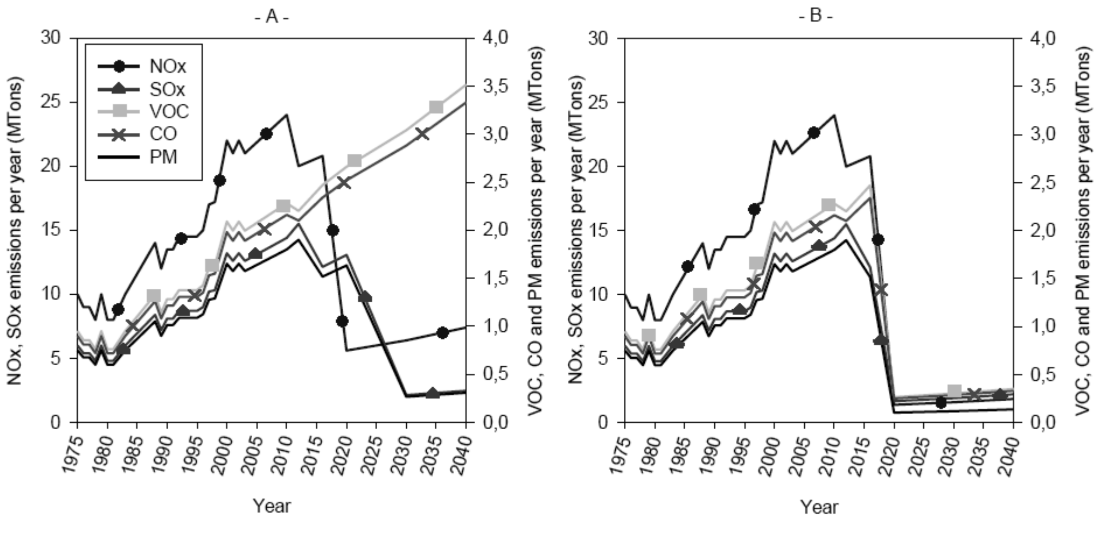


Fig. 6. Estimated emissions of atmospheric pollutants for the maritime shipping under IMO regulation (A) [1], and with adoption of DEECON systems (B)
Rys. 6. Szacunkowa emisja zanieczyszczeń powietrza w przemyśle morskim zgodne z rozporządzeniami IMO [1] (A) oraz z zastosowaniem systemów DEECON

Results in Fig. 6A [1] shows how the regulations affect the expected emission of NO_x, SO_x and PM, while leaving unaltered the levels of VOC and CO. It should be noted that even currently available retrofitting technologies are actually able to reach even lower values of NO_x and SO_x. In contrast, figure 6B shows the expected results coming from the application of the exhaust treatment systems such as DEECON, under the hypothesis - based on the data of pilot and lab scale studies that a

90% efficiency should be guaranteed for SO_x, CO and VOC and a 95% value can be fixed for PM and NO_x [8]. This shows that, if the DEECON system is applied to all existing ships from 2015, the emissions inventory will reduce far more than that required by MARPOL Regulation 13 and 14.

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