

СЕКЦІЯ XI. ТРАНСПОРТ ТА ТРАНСПОРТНІ ТЕХНОЛОГІЇ

INNOVATIVE TECHNOLOGIES AND REGULATORY MEASURES TO REDUCE ENVIRONMENTAL RISKS IN THE SHIPPING INDUSTRY

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Introduction. Shipping is a key element of the global economy, but its environmental impact raises significant concerns. Maritime vessels are a source of ocean and air pollution, greenhouse gas emissions and the spread of invasive species through ballast water. Given the growing demands for

environmental safety and sustainable development, it is necessary to consider the environmental risks of shipping and seek ways to minimize them.

Problem Statement. The established systems for managing environmental risks in shipping, such as MARPOL and the Ballast Water Management Convention, while important, are not always effective enough to minimize damage to ecosystems. Major problems include incomplete compliance with existing environmental regulations, technical limitations in reducing emissions of harmful substances and the lack of a comprehensive environmental risk management system that covers the entire life cycle of ships.

Goals and Objectives. Development of an integrated system of environmental risk management in shipping, which combines modern methods of monitoring and prevention of environmental impact. The objectives are to analyze existing methods of environmental risk assessment in shipping, assess the most common sources of pollution and threats to ecosystems and develop proposals for modernization of the regulatory system and introduction of new technologies to reduce environmental risks.

Core Material. Судоходство играет важную роль в мировой торговле, однако оно также оказывает значительное негативное воздействие на окружающую среду. Основными источниками загрязнений, возникающими в результате эксплуатации судов, являются:

- Emissions of sulphur oxides (SO_x), which are produced by burning fuels with a high sulphur content. They lead to acid rain, which negatively affects ecosystems and can even destroy buildings and structures;
- Nitrogen oxide emissions (NO_x): which are produced by the high-temperature combustion of fuels and cause the release of nitrogen oxides that contribute to smog formation and further ozone depletion;
- Emissions of carbon dioxide (CO₂) which is a key contributor to global warming and shipping is estimated to account for 2-3% of the world's emissions of this gas;
- Fine particulate matter (PM) emitted with smoke adversely affects air quality, especially in coastal areas, leading to serious health problems for people;
- Ballast water pollution in which shipping plays a negative role and contributes to the transfer of invasive species through ballast water, which disrupts ecosystems and causes economic damage to coastal regions.

These factors pose serious environmental threats that require modern solutions and innovative approaches.

In order to minimize the environmental impact of shipping, various innovative technologies are used that aim to reduce pollutant emissions and prevent devastating effects.

Distribution of Shipping Emissions (CO₂, NO_x, SO_x, PM) - 2023

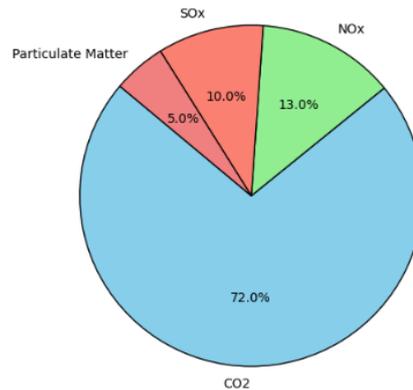


Fig. 1. Percentage data on CO₂, NO_x, SO_x and fine particulate matter emissions (2023)

Exhaust gas cleaning systems, also known as scrubbers, play an important role in reducing air pollution caused by emissions from ships. These devices filter exhaust gases and significantly reduce emissions of sulphur oxides (SO_x) and other harmful substances. The use of scrubbers helps prevent phenomena such as acid rain, thereby minimizing harmful effects on the environment and human health. One of the key areas in the fight against pollution is the use of alternative fuels. Switching to liquefied natural gas (LNG) and biofuels has a significant impact on reducing carbon dioxide (CO₂) and oxides of nitrogen (NO_x) emissions. LNG, in particular, is considered one of the cleanest fuels, significantly reducing greenhouse gas and other pollutant emissions, providing a more sustainable future for the shipping industry. Ballast filters and ballast water management systems are used to prevent the transfer of invasive species that can disrupt ecosystems and economies in coastal regions. Modern technologies such as ultraviolet purification and mechanical filters can destroy harmful microorganisms in ballast water before it is discharged, helping to keep marine ecosystems stable. Finally, pollution monitoring systems allow for real-time monitoring of ship emissions levels and necessary adjustments to be made if limits are exceeded. Digital technology and automation systems ensure

that emissions are monitored quickly to ensure compliance with environmental standards and help companies minimize their environmental impact.

All of the above technologies provide significant emission reductions and help reduce the negative environmental impact of shipping.

The effectiveness of international environmental regulations, such as MARPOL and the Ballast Water Management Control Convention, plays a key role in ensuring the environmental safety of the marine environment. These regulations aim to regulate the release of harmful substances from ships and prevent the transfer of invasive species. However, despite their importance, the implementation and enforcement of these standards face a number of significant challenges.

One of the main problems is the lack of control and monitoring equipment. Many ships are still not equipped with modern emission monitoring systems, making it difficult to monitor their compliance with international standards. This creates blind spots in the process of monitoring compliance with environmental standards and jeopardizes the effectiveness of the entire regulatory mechanism.

In addition, there are significant technical and financial constraints. Not all shipping companies can afford to modernize their fleet to meet modern requirements. The introduction of innovative technologies such as scrubbers, ballast water treatment systems and digital monitoring systems requires significant financial investments, which limits the pace of implementation of environmental standards, especially among smaller companies and countries with limited resources.

Problems with international coordination are also worth noting. Different countries apply different standards and levels of control, leading to inconsistencies and making it difficult to implement international environmental agreements. This is especially true in the global shipping industry, where vessels cross the borders of different jurisdictions, each of which may have different environmental requirements.

Nevertheless, despite these limitations, international regulatory systems continue to improve. The introduction of new monitoring technologies, such as real-time automated emission control systems, and vessel modernization are helping to improve compliance. An integrated combination of technical innovation, strict standards and international cooperation is gradually

improving the situation and creating conditions for the sustainable development of the shipping industry.

Thus, to maximize the effect of marine pollution control, it is necessary not only to improve control systems and introduce new technologies, but also to ensure effective international coordination and support for shipping companies, especially those facing financial constraints.

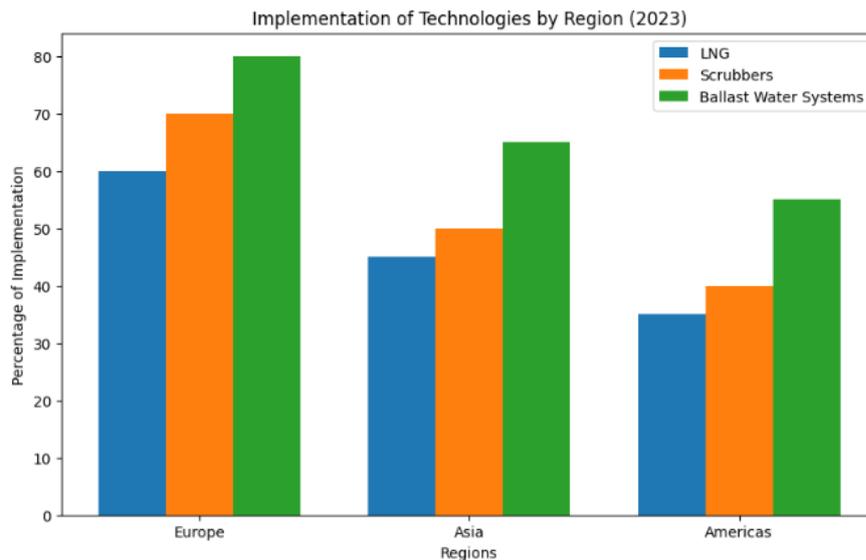


Fig. 2. Implementation of emission reduction technologies such by regions

For 2024, the International Maritime Organization (IMO) continues to implement its strategy to reduce greenhouse gas emissions. The IMO's emissions reduction strategy was updated in 2023 with ambitious targets to reduce emissions by 20-30% by 2030 and reach zero emissions by mid-century. The strategy also includes the gradual introduction of alternative low and zero carbon fuels such as hydrogen and ammonia, and the deployment of technologies to improve the energy efficiency of ships. Key interim targets for the coming years are to reduce greenhouse gas emissions by at least 20% by 2030 compared to 2008 levels, increase the share of low and zero carbon technologies to 5-10% of total energy used in shipping by 2030. As well as further development of carbon pricing mechanisms to incentivize shipping companies to switch to more environmentally friendly solutions.

Conclusion. Shipping continues to be a significant source of environmental pollution, in particular CO₂, NO_x, SO_x and fine particulate matter (PM) emissions. Current data shows that for 2023, CO₂ emissions

represent about 72% of total emissions, indicating that further reductions in greenhouse gases are needed to meet IMO targets. Current technologies to reduce emissions are showing positive results, but the pace of implementation needs to be accelerated. Technologies such as the use of liquefied natural gas (LNG), scrubbers and ballast water management systems are being actively adopted in Europe and Asia, but still require greater investment and coordination at the global level. Regulation and control play an important role in reducing the negative environmental impact of shipping. International initiatives, such as the IMO's Emissions Reduction Strategy, require greater compliance and support from all industry participants. However, significant challenges remain with monitoring, technical and financial constraints that are slowing progress. Further efforts to develop and deploy alternative fuels and technologies are needed to meet the 2050 emission reduction targets. The introduction of low- and zero-carbon fuels such as hydrogen and ammonia will be a critical step in achieving the shipping industry's decarbonization goals.

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