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ASSESMENT OF WATERBORNE TRANSPORT SECTOR IMPACT ON EUROPE AIR QUALITY WITH SHERPA MODEL

Research paper

Madalina Zot[1], Francisc Popescu[2], Luisa Izabel Dungan[3]
[1,2,3] University Politehnica Timisoara, Timisoara, Romania

Abstract: At European level, the EU's Joint Research Center (JRC) has developed the screening tool SHERPA (Screening for High Emission Reduction Potential on Air) to support decision-makers in assessing the potential to increase air quality through local emission reduction measures. This paper discusses the quantification of emissions and the analysis of the European maritime and road transport sector, evaluating the most polluted areas and the possibility of reducing emissions generated by water and road transport.
Key words: Sherpa, air quality, waterborne transport emissions

INTRODUCTION

In Europe, naval and road transport contribute to environmental pollution through various emissions, such as greenhouse gases, nitrogen oxides, sulfur oxides, particulate matter and other harmful substances. On air quality, human health, but also on the environment, emissions can contribute to a negative impact.
The use of fossil fuels on ships is the main source of emissions from water transport in Europe. Most ships use heavy fuel oil as fuel, having a high sulfur content and tending to emit SOx, NOx and PM. Another source of emissions for water transport can be the release of ballast water, chemicals, anti-fouling paints and accidental oil spills. All the emission sources mentioned have a negative impact on marine ecosystems and biodiversity, but also on human health who live near the coast or the riverbank.
The various policies and regulations desired to reduce emissions from water and road transport were introduced by the European Union, to reduce these problems. The Sulfur Directive (Directive 2012/33/EU) is just one of the regulations brought in, aimed at reducing the sulfur content of the fuels used by ships operating in EU waters and the Framework Directive on marine strategy, which aims to protect and restore the marine environment through various measures, including reducing emissions from ships, [1]. To deal with pollution from inland waterway transport in Europe, the EU has introduced several policies and measures. The most important of these policies is the Inland Waterway Vessel (IWV) certification system, which provides emission standards for NOx and PM emissions from inland waterway vessels. The EU has also developed the Blue Corridors project, which recommends promoting the use of LNG and other alternative fuels in inland waterway transport.
In 2020, the MARPOL Convention members decided under IMO 2020 regulation notes the reduction of the Sulphur content of fuel oil used for ships from 3.5 % to a maximum of 0.5 % by mass, [2]. At the European level, a significant decrease in sulfur oxide emissions from water transport is expected in the coming years. High transport loading capacities make inland waterway vessels considered environmentally friendly means of transport when CO_2 emissions are highlighted. However, as the main enforcements on limiting emissions levels only started in early 1990's, with limits for NOx and PM emissions, most of the marine and inland vessels in operation today are free of emission control. This is mostly due to the high life span of engines designed for marine and inland water transport and is expected that vessel fleet renewal with new diesel engines will not happen before 2040.
Trade and the connection between all the nations of Europe is represented by maritime and inland water transport, being an impactful sector. In the EU for foreign trade in goods, 90% of EU foreign trade is carried out by sea, [3].

[1]Corresponding author, francisc.popescu@upt.ro, ORCID: https://orcid.org/0000-0001-7736-0758

MATERIAL AND METHODS

Usually, to measure the impact of emissions produced by maritime and inland ships, chemical transport models are used that contain in their structure the transport of pollutants, the diffusion of pollutants and the atmospheric reactions of pollutants. Because the models need significant computing power, they are placed in limited and localized areas, from 50 to 500 km in diameter. The tool "Screening for High Emission Reduction Potentials for Air quality" (SHERPA) was created by the Joint Research Center with the aim of preventing these limitations and for the use of common calculation systems, throughout the European continent. The use of the screening tool is done through a chemical transport model, supported by statistical data received from the regulatory institutions of European countries and which provides a shorter waiting period for any dispersion of atmospheric pollutants, [4].
SHERPA uses source-receptor interaction as a basis and was created to analyze possible air quality improvements that can result from the implementation of emission reduction measures, within the stakeholder decision-making process. SHERPA is based on a simplified version of a chemical transport model and provides estimates of the concentrations of precursor pollutants, such as NOx, NMVOC, PPM, SO_2 and NH_3, in a single sector or group of activity sectors, [5]. In its component, SHERPA is made up of 3 independent models, these are source allocation, governance and scenario analysis, each focusing on dealing specifically with air quality issues.
The central formula implemented in SHERPA uses a cell-by-cell approach, with a cell spatial decision of 7x7km^2, with the availability of EU data with reference to source-receiver emission models and emission reduction scenarios. The relationship between the emission *ΔEj,k* and the concentration *ΔCi* is calculated cell by cell:

$$\Delta C_i = \sum_{j}^{Nprec} \sum_{k}^{Ncell} a_{i,j,k}^{1} \Delta E_{j,k} \qquad (1)$$

Due to the fact that the coefficients $a_{i,j,k}$ are relatively approximated by a distance function, the main gain is given by its spatial flexibility:

$$a_{i,j,k} = \propto_{i,j} (1 - d_{i,k})^{-\omega^{i,j}} \qquad (2)$$

In which *i* represents the grid cell where the concentration is estimated and $d_{i,k}$ represents the distance between cells *i* and *k,* [6].
The definition of areas of interest in SHERPA can be found in the European Nomenclature of Territorial Statistical Units (NUTS) and the Gridded Nomenclature for Reporting (GNFR). For this study we used the entire European territory and focused on GNFR7, Shipping, national shipping, including the inland waterways sector.

RESULTS AND DISCUSSION

The SHERPA approach is based on GWR (Geographically Weighted Regression) and local modelling approaches, methodologies who uses bell-shaped kernel functions to determine weighted regressions of input versus output variables, [7, 8, 9].
In the scenario assumed in this study we focused mainly on NMVOC, SO_2, NOx and PPM emissions generated from marine and inland shipping sector with inclusion of EMEP total emissions per sector (GNFR 7), countries (EU28 and outside) and applying automated SHERPA gridding methodologies, for the year 2022. The results obtained are presented in figures 1 to 4.

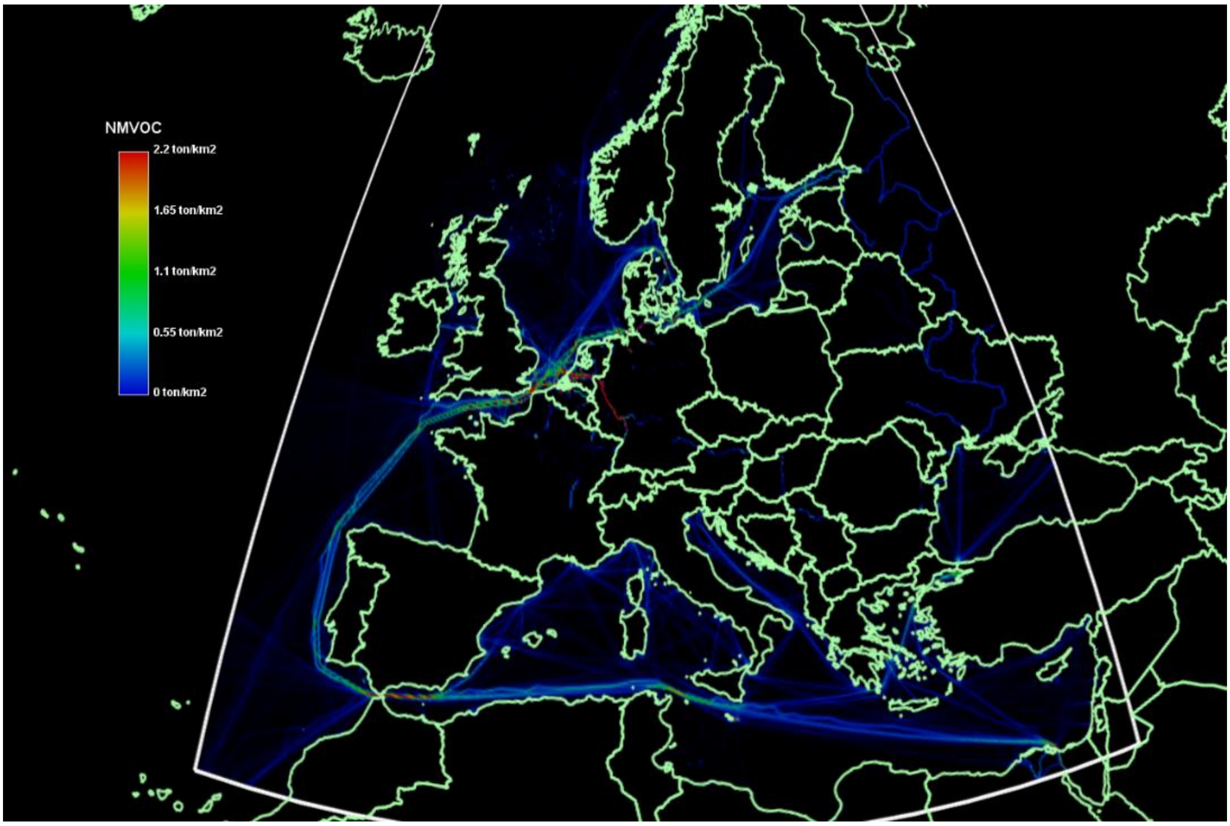

Fig.1. *Europe-region level, NMVOC annual average concentration, exclusively GNFR7 water shipping navigation transport sector*

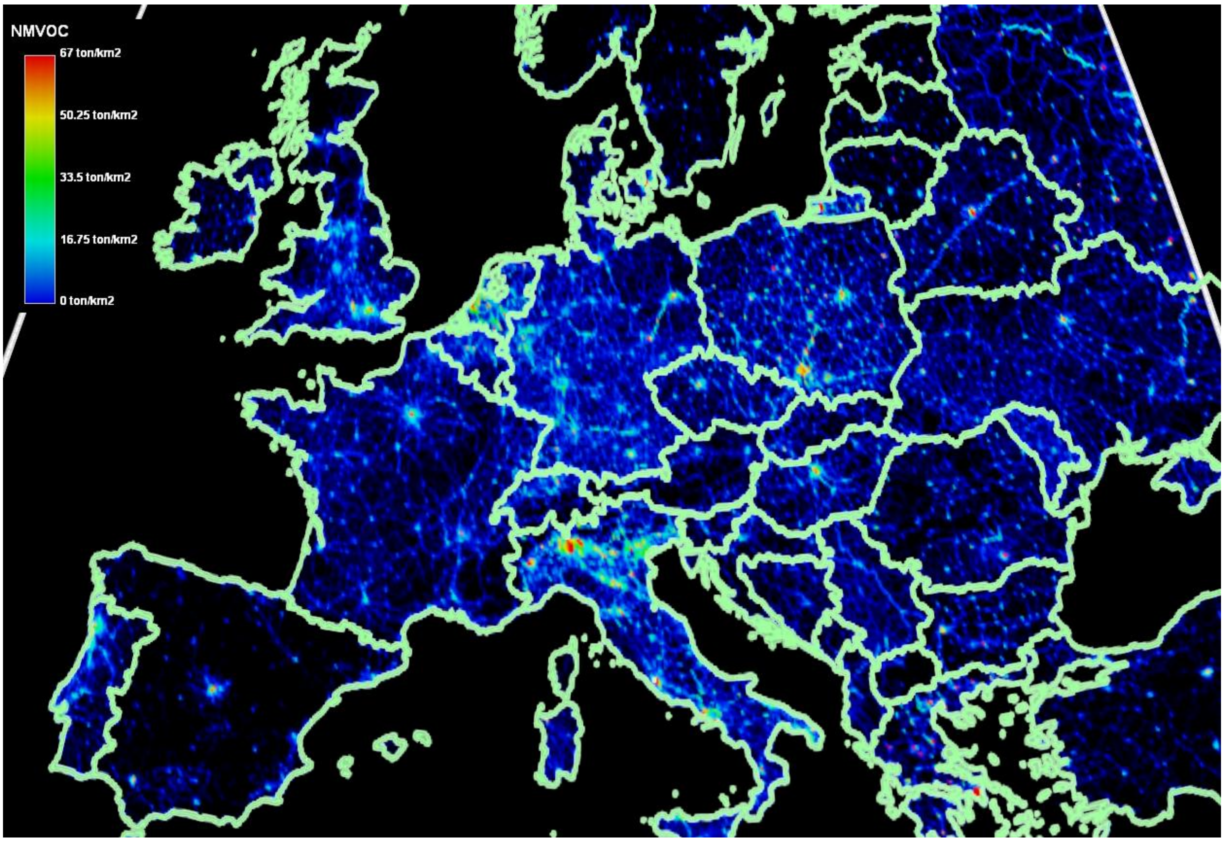

Fig.2. *Europe-region level, NMVOC annual average concentration, exclusively GNFR6 road transport sector*

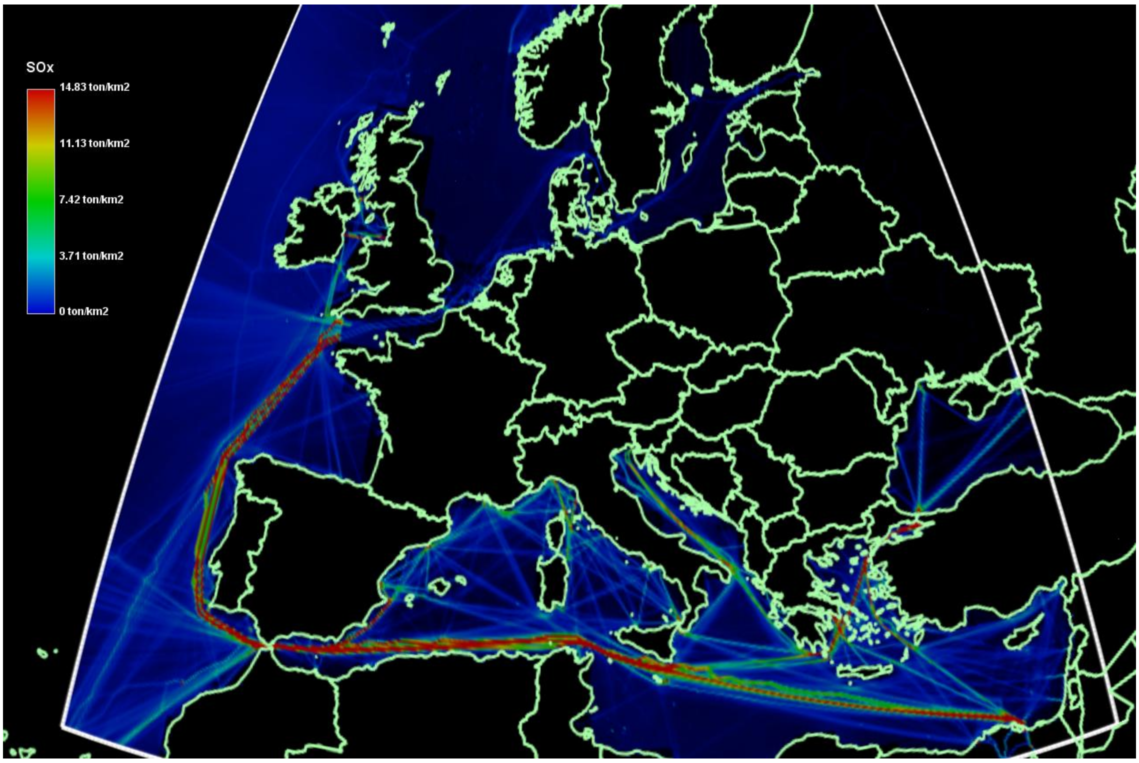

Fig. 3. *Europe-region level, SO_2 annual average concentration, exclusively GNFR7 water shipping navigation transport sector*

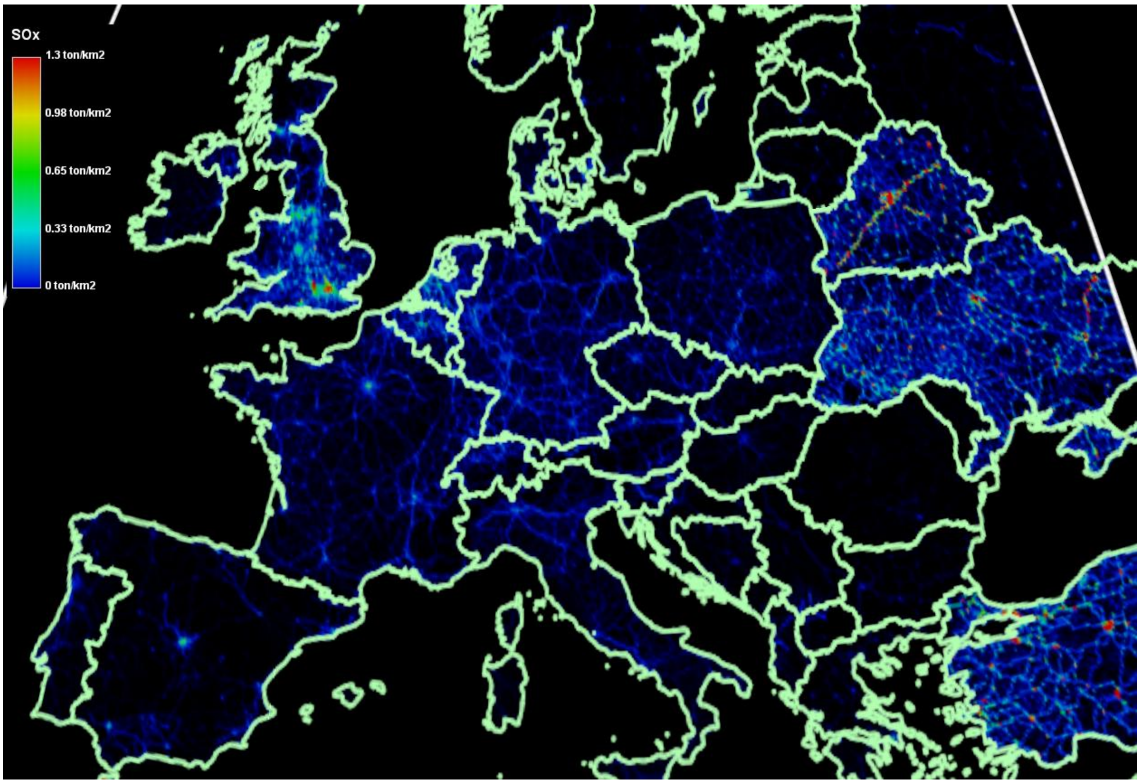

Fig. 4. *Europe-region level, SO_2 annual average concentration, exclusively GNFR6 road transport sector*

The results obtained for Figures 1 and 2 for NMVOC emissions, shows an average of 2.2 ton/km^2 for waterborne transport and up 67 t/km^2 for road transport. In case of SO_2

emissions, an average of 14 ton/km^2 for waterborne transport and 1.3 ton/km^2 for road transport are estimated.

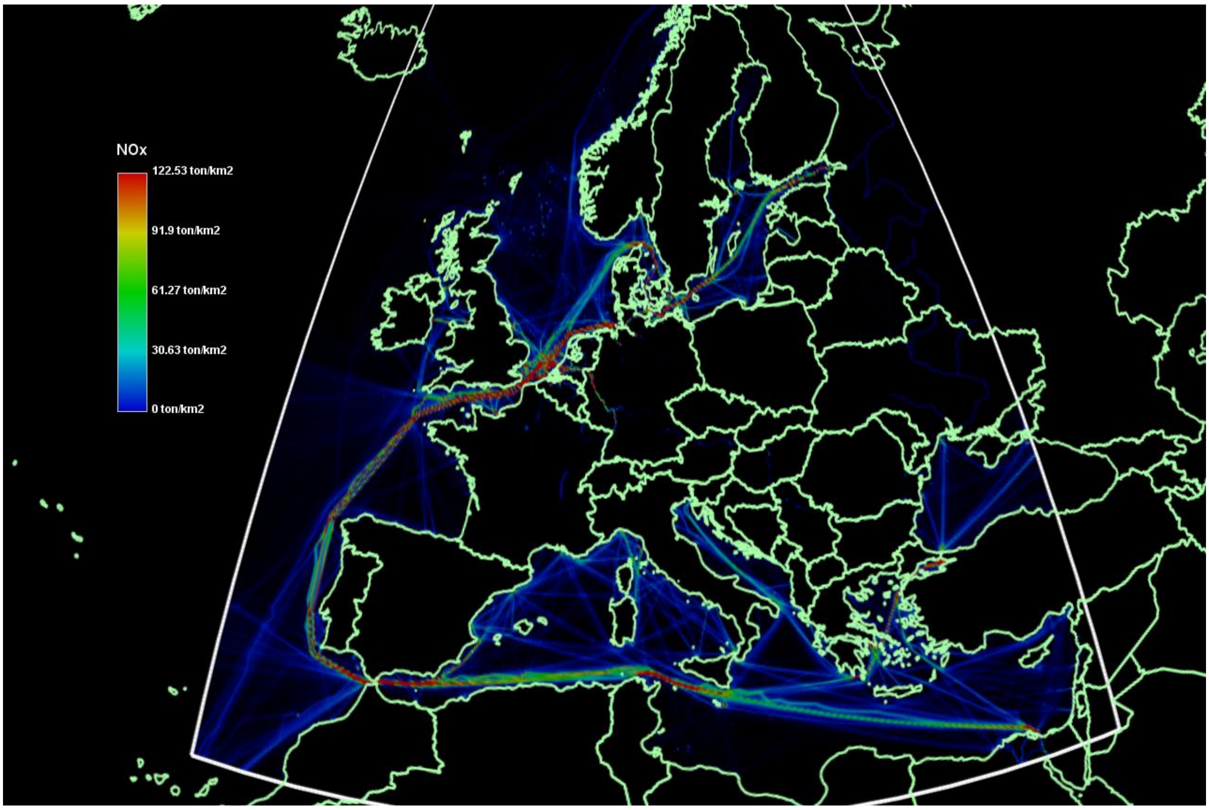

Fig. 5. *Europe-region level, NOx annual average concentration, exclusively GNFR7 water shipping navigation transport sector.*

Figure 5 presents the results obtained for NOx emissions, at maximum of 122 ton/km^2. The maxim emissions are not obtained only high traffic maritime straits (like Gibraltar or Dover straits) but also on inland waters transport, in urban areas on Rhine River in Germany and Netherlands.

CONCLUSION

The International Maritime Organization (IMO) conducted a study in 2018, which shows that the global concentration of water transport in global anthropogenic GHG emissions is around 3% in 2018 [10] by this fact there is a reduced contribution, so we can believe that maritime transport and inland water is an effective method for international transport of goods. Even if the contribution of CO_2 compared to others is low in the maritime transport sector, SO_2 and NOx emissions are relevant, with a 13% share for SO_2 and 15% for global NOx emissions, [10]. The data presented show us that naval transport, especially that on inland waters, forms a problematic source of local pollution, on land, but also in coastal areas.
Another research study that took place in France (2015-2016), [11] with direct emissions determinations on board several types of maritime and inland vessels, shows that a pusher tug emits up to 2 times more emissions. higher NOx, CO and particulate matter than Euro V trucks for 1 ton of goods transported. In this research, similar data were discovered, an example would be by using SHERPA for the GNFR6 sector (Road Transport), we noticed that emissions from road transport in Europe reached a maximum of 44 ton/km^2 compared to 122 ton/km^2 for water transport and SO_2 of 1.3 ton/km^2 compared to 14 ton/km^2 for water transport. And, the NMVOC emissions generated by road transport, 67 ton/km^2, are much higher than the 2.2 ton/km^2 found for water transport.

The European Union has focused on reducing or eliminating GHG emissions from all sectors in recent years, highlighting the energy and transport sectors. The aim of the study is to show that the SHERPA tool can ease the work of researchers and help EU decision-makers to introduce more correct strategies to reduce pollution and GHG in the geographical areas where these problems are encountered most often.

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