Assessing the Environmental Impact of Maritime Transport for the Port of Mytilene with a Focus on the Emission Accounting of the Port of Arrival

KELMALIS A.[1,*], LEKKAS D.F.[2] and VAKALIS S.[1]

[1] Energy Management Laboratory, Department of Environment, University of the Aegean, 81100 Mytilene, Greece
[2] Waste Management Laboratory, Department of Environment, University of the Aegean, 81100 Mytilene, Greece

*corresponding author:
e-mail: kelmalis@env.aegean.gr

Abstract Global accounting of the environmental impact from maritime transport is an ongoing conversation. This study introduces the idea that emissions from open-sea cruising can accounted as stock at the port of arrival. An example is presented for the case of Mytilene (for a single month) where the in-port and open sea emissions are calculated and presented. In this specific analysis, during a single calendar month, 518 individual routes were identified with 42.47% being passenger ships and 33.98% being Ro-Ro/ passenger ships. The routes with the higher impact have been identified to be the ones with the highest combination of Deadweight Tonnage and frequency of arrival. Characteristically 117 of the total routes can be attributed to vessels with Deadweight Tonnage over 3000 tons. In the later part of the work, the study discusses two important aspects that should be under consideration in the overall maritime transport analysis. Firstly, the in-port emissions with a focus on sulphur oxides and secondly the integrated accounting of shipping emissions.

Keywords: Emissions, Accounting, Maritime Policy, Marine fuels, Methodology

1. Introduction

The Greek economy is inextricably linked to tourism and shipping. Greece's leading position in the EU (and worldwide) in relation to coastal shipping, imposes the need to monitor and control the exhaust emissions of passenger coastal shipping ships. In this regard, the assessment of the carbon footprint of commercial coastal shipping in Greece has so far been based primarily on data from domestic sales of marine fuel (Tzannatos, 2005). Inland passenger shipping in Greece is developed through a complex network of connections between mainland and island destinations, as well as between island and mainland ports. The destinations are located on a coastline of about 15,000 km, which ranks Greece second in Europe and eleventh in the world (EUROSTAT, 2009)

Maritime transport and overall shipping practices is a sector with a continuously increasing energy demand due to the continuous growth in the sectors of global trade, transportation, and leisure activities. Environmental pollution is particularly exacerbated by the exhaust gases from internal combustion engines that are used in the shipping vessels. The engines combust primarily heavy fuel oil, which results in the significant production of nitrogen oxides and sulphur oxides. In accordance with the IMO 2020, seagoing vessels should reduce sulphur oxide emissions by 85% and down to a limit of 0.5% sulphur content, and in SECAs (Sulfur Emission Control Areas) 0.1% (IMO, 2020). Marine diesel oil is gradually being used from 2020 but older ships are still using heavy fuel oil.

During the last 20 years, the domestic passenger shipping industry in Greece has been the subject of various studies, referring to its importance for national cohesion, balanced development and social welfare (Chlomoudis et al., 2011). Greece is required to take action in order to fully comply with the IMO regulations on the reduction of emissions of SO_x and NO_x, as it shows by the percentage of pollution control systems, e.g., scrubbers, installed on registered ships (46 %). This percentage is quite low, in comparison to other European countries, such as Norway. IMO's new regulation on the matter of nitrogen oxides emissions (IMO, 2020), introduced the usage of innovative technologies (catalytic filters), and groundbreaking practices for vessel fuels, such as gas exhaust recirculation. For the case of sulphur oxides, scrubbers are the main technological option.

This paper focuses on the maritime practices in Lesvos island, since it combines international sea routes/lines connecting Lesvos island to (mainly) Ayvalik, and domestic routes. This makes Lesvos one of the few Greek islands with this type of parameters that can be investigated. Up to date, there is a research gap towards the assessment of emissions from the maritime transport on Lesvos island and the comparative effect on the overall maritime sector in Greece and globally. This research provides a blueprint for addressing the environmental impact on a global level by taking into account individual destinations. Also, the issue of in-port emissions of vessels is investigated. In this context, the present study aims to analyze the environmental impact of shipping practices for the port of Mytilene.

2. Materials and Methods

2.1. Utilized data and analysis of the case study

This study focused on the environmental impact of the main commercial shipping routes that arrived at the port of Mytilene in a single calendar month. The month of analysis was June 2019 because the scope was to assess the full operation of the port during normal summer period (pre-COVID). Firstly, these routes were logged, and the company Marine Traffic S.A. assisted this effort by providing detailed information about the number of arrivals per ship, the Deadweight Tonnage (DWT), the draught, the distance that was travelled and the type of ships. From publicly available data, this study identified the utilized engines of each shipping vessel. It has to be noted that for all cases, the shipping vessels utilized heavy fuel oil. In parallel, this study implemented an independent research about the average fuel consumption per nautical mile.

By using this information, and in combination with the data and the routes that were provided by Marine Traffic S.A and from publicly available data, this study calculated the total fuel consumption for the ships of interest. The study used standardized emission factors as published by the technical report "Air Pollutant Emission Inventory Guidebook" of the European Environment Agency (EMEP/EEA, 2016) and the Entec report in order to calculate the total emissions of CO_2, SO_2, NO_x, PM and HC for the national and international shipping routes of interest, as described in the following paragraph. Table 1 presents the emission factors in the basis of g/ kWh as published by the EMEP/EEA report.

Table 1. Emissions of Mediterranean shipping vessels in g/ kWh (EMEP/EEA, 2016)

	Main Engine		Aux. Engine
g/ kWh	**Cruise**	**Manouvering**	**All activities**
NO_x	12	10.6	13.9
SO_2	4.1	4.5	4.3
CO_2	645	710	690
HC	0.5	1.5	0.4
PM	0.9	1.5	0.3

This study focused on the emissions of the primary routes that are implemented by Passenger, Ro-Ro Cargo and Ro-Ro/ Passenger vessel and arrive regularly at the port of Mytilene on a scheduled constant basis. These routes represent more than 85% of the total arrivals and more than 90% of the total Deadweight Tonnage. The data that were obtained from this data collection campaign were used as presented in section "2.2. Methods of analysis". In order to fully respect the anonymity of each ship operator and each corresponding company, the specific values of the shipping vessels are not reported.

2.2. Methods of analysis

The main scope of this study is to introduce a new methodology for assessing and accounting the emissions of cruising routes along with the in-port emissions. Thus, the analysis is being done on a dual level. Firstly, the in-port emissions are accounted by applying a standardized methodology that is presented here. On a second level, this study introduces the idea of "Emissions Accounting at Port of Arrival" or else the *EAPA method* where the emissions from open-sea cruising of a given shipping vessel are accounted as stock at the port of arrival. This is a methodology that can assist the national but also (primarily) the international accounting of emissions from maritime transport, because there is a research gap in accounting the emissions from international routes.

The load percentage and the times of operation for the main and the auxiliary engines are presented in Table 2, as published by the EMEP/EEA report. These values, as presented in the Table, are utilized for converting the nominal power of engines for each ship into the adjusted values that correspond to each action, i.e., cruising, maneuvering and hoteling. The fuel that is considered for this analysis is heavy fuel oil. In order to provide numerical references but also ensure the anonymity of the shipping vessels, it can be reported that the passenger ships have an average main engine power of 7668 KW, the Ro-Ro Cargo ships have an average main engine power of 11600 KW, and the small (short sea) passenger ships have an average main engine power of 1300 KW. The output power of the auxiliary engines was calculated to be between 27% and 39% of the output power of the main engines for each case. The values in respect to power output and hours of operation are adjusted for each action and in accordance with Table 2.

Table 2. Percentage of engines operation (ME: Main Engine, AE: Auxiliary Engine)

	% load ME	**% time ME operation**	**% load AE**
Cruise	80	100	30
Maneuvering	20	100	50
Hoteling	20	5	40

In respect to the time that is needed for each action to be performed, these parameters are presented in Table 3. The study analyzed data during summer (month: June 2019) and thus, the reduced hoteling-idling times were accounted for. It is reported that during winter season these times are between 14-15 hours for the cases of Passenger ships and Ro-Ro Cargo ships. But during the summer these times are cut to approximately 6 hours and at the same time the frequency of the arrivals increases significantly. Contrary to the case of hoteling-idling, the necessary time for maneuvering remains the same on a year-round basis. These two parameters, i.e., hoteling-idling times and maneuvering times are utilized for the calculation of the in-port emissions. But, as mentioned before, one of the scopes of this study is to assess the emissions during cruising. The idea of the "Emissions Accounting at Port of Arrival" method *(EAPA method)* is that the emissions from open-sea cruising of a given shipping vessel are accounted as stock at the port of arrival. Therefore, the cruising times from the previous port to the port of arrival (in this case Mytilene) are also taken into account. These values are collectively presented in Table 3 and in conjunction with the factors from Tables 1 and 2, are utilized for the calculation of the in-port and open sea emissions.

Table 3. Parameters for cruising and in-port ship activity

Ship type	Cruise (km/h)	Manoeuvring (h)	Hotelling (h)
Ro-Ro Cargo	27	1	6
Passenger	39	0.8	6
Passenger (short sea)	25	0.6	2

3. Results and Analysis

Figure 1 presents the percentage of the arrivals sorted by type for the port of Mytilene in June 2019. Passenger ships hold the biggest percentage of total of arrivals with 42.4%, while Ro-Ro/ Passenger vessels account for the 33.9 % of the total arrivals. Ro-Ro Cargo ships account for approximately 3.5% of the total arrivals. These three types of ships have regular arriving schedules and -at the same time- account for the vast majority of the arrivals (~80%). There are other ships that can be accounted and primarily these ships cover vital supplying services like the delivery of fuel oil and cement for the island. It should be stated that Figure 1 does not include military shipping vessels or other non-scheduled shipping practices that could account for a different value of total arrivals.

Figure 2 presents the arrivals at the port of Mytilene sorted by the Deadweight tonnage (DWT). Passenger ships that have a DWT of 6148 have 36 arrivals in the month of June and represent a significant fraction of the total arrivals. On the other side of the spectrum -in respect to the Deadweight tonnage- smaller passenger ships that primarily implement short sea international routes have a range between 50 and 180 DWT and account for 151 arrivals in June 2019. These short sea passenger ships primarily perform the international route Mytilene-Ayvalik. Other Passenger ships of high (comparatively) DWT also account for a high number of arrivals, with Passenger ships of 3348 DWT accounting for 28 arrivals and Passenger ships of 7622 DWT accounting for 31 arrivals in June 2019.

The number of arrivals, along with the type of engines of the ships were utilized for the calculation of the in-port emissions and the emissions during open sea cruising. Figure 3 presents the in-port emissions of the shipping vessels of primary consideration. Figure 4 presents the emissions of the shipping vessels form the previous port to the port of arrival, i.e., the port of Mytilene. Characteristically, the nominal power of the engine was adjusted by using the data form Tables 1-3 in order to calculate the emissions. It is the case that the main engines are not used extensively during hoteling since they are operational only 5% of the time. Several studies, like the one by Tzannatos (2010) accounted for the use of main engines for 0% of the time during hoteling, and this could be a valid argument. Nonetheless, this study utilized the values provided by the EMEP/EEA report but recognizes that there is merit to the alternative argument as well.

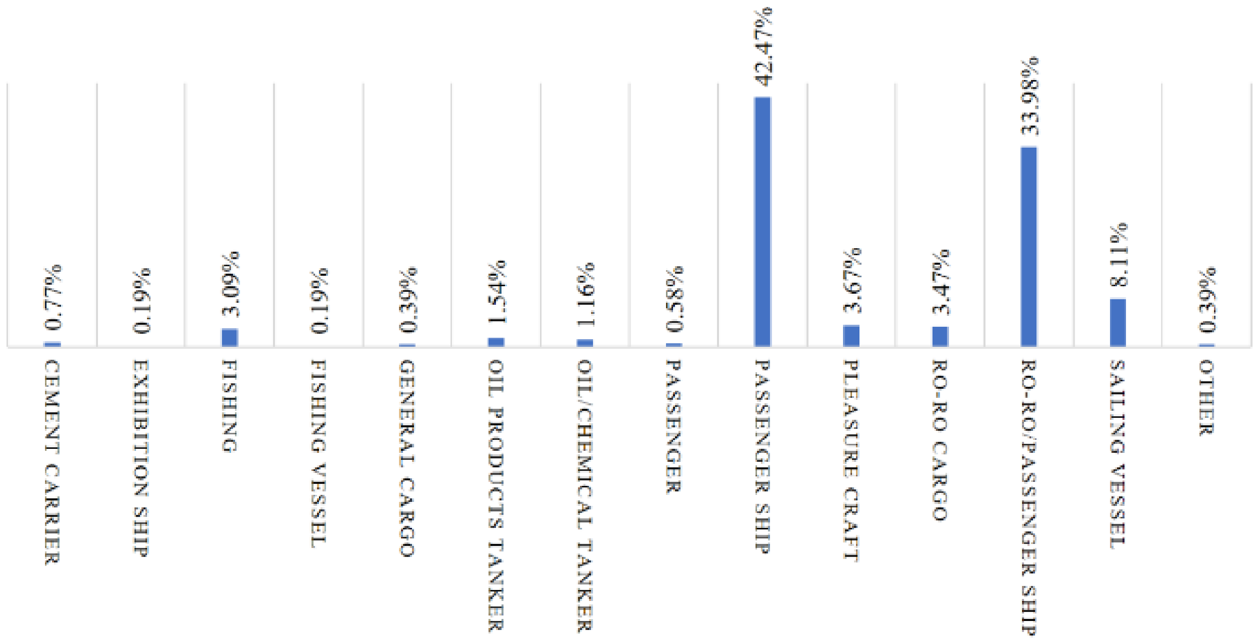

Figure 1. Percentage of arrivals at the port of Mytilene in June 2019 - sorted by type

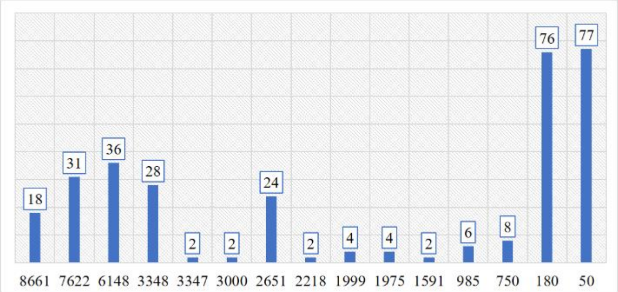

Figure 2. Arrivals at the port of Mytilene sorted by DWT

Figure 3 shows the in-port emissions from the primary (scheduled) routes at the port of Mytilene during June 2019. Figure 3 does not depict the carbon dioxide emissions that are calculated to be 26.4 tons for the main engines and 10.9 tons for the auxiliary engines. The main pollutants are the nitrogen oxides, as they are a main compound of the exhaust gases from internal combustion engines.

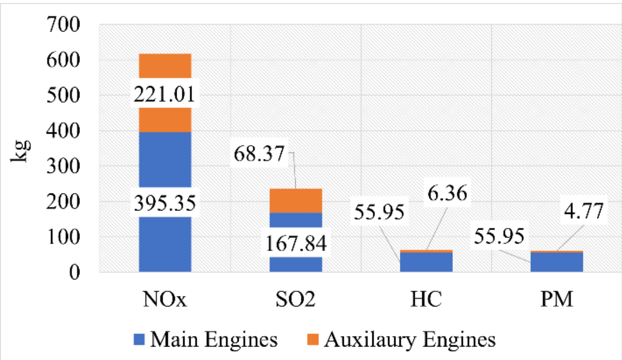

Figure 3. In-port emissions from primary (scheduled) routes at the port of Mytilene during June 2019.

On a secondary level the sulphur dioxide emissions are sigificant and a factor of major condideration as the maritime transport industry moves towards the adoption of the IMO emission limits (IMO, 2020). HC and PM emissions are mainly attributed to the operation of the main engines although these engines operate at low load percentage and for only 5% of the total hoteling time. Finally, Figure 4 presents the emissions for the open sea cruising from the previous port (for each case) to the port of Mytilene which in the framework of this study is the port of reference. Also, for the case of Figure 4, carbon dioxide emissions are not depicted and are calculated to be 1687.4 tons for the main engines and 182.8 tons for the auxiliary engines. Nitrogen oxides again account for the majority of the open sea cruising emissions with 35.08 tons. The sulphur oxides from the operation of the main engines are also significant and calculated to be 10.73 tons. It should be noted that a limitation of the study is that the analysis is done on a basis of a single month and seasonal fluctuations should be accounted in a follow-up study.

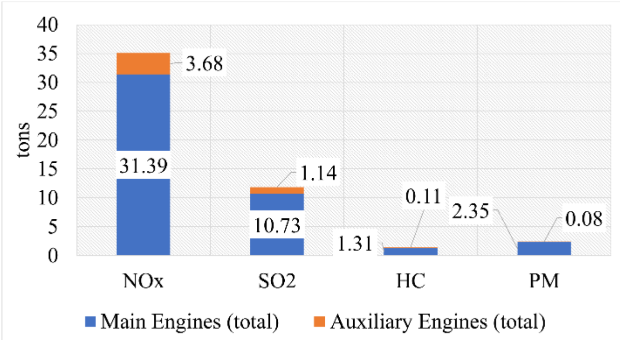

Figure 4. Open sea cruising emissions from primary (scheduled) routes at the port of Mytilene during June 2019.

4. Conclusions

This study introduced the idea of "Emissions Accounting at Port of Arrival" or else the *EAPA method* where the emissions from open-sea cruising of a given shipping vessel are accounted as stock at the port of arrival. As a reference this study calculated both the in-port emissions and the open sea cruising emissions for the primary shipping routes for the port of Mytilene during June 2019. This is a methodology that can assist the national but also (primarily) the international accounting of emissions from maritime transport. The main emissions were calculated to be nitrogen oxides, but a significant pollutant was also sulphur oxides. This can be a factor of major condideration as the maritime transport industry has transitioned to the adoption of the IMO emission limits.

References

Chlomoudis C., Kostagialas P., Papadimitriou S. and Tzannatos E., (2011), 'A European perspective on public service obligations for island transport services', *Maritime Economics and Logistics*, **13**:3, 342-354

EUROSTAT, (2009), 'Panorama of Transport', 2009 Edition. European Commission, ISSN 1831-3280. (Accessed on 15/04/2021)

IMO, (2020) Regulation for Sulphur Limits. Available at: https://www.imo.org/en/MediaCentre/HotTopics/Pages/Sulphur-2020.aspx (Accessed on 15/04/2021)

Tzannatos E., (2005). 'Technical reliability of the Greek coastal passenger fleet.' *Marine Policy*, **29**, 85-92.

Tzannatos E., (2010), 'Ship emissions and their externalities for the port of Piraeus – Greece', *Atmospheric Environment*, **44**, 400-407

EMEP/EEA, (2016). 'Air Pollutant Emission Inventory Guidebook. EEA'. Technical report No 21/2016.

Entec (2002), "Quantification of emissions from ships associated with ship movements between ports in the European Community, Report for European Commission", Entec UK Limited, Cheshire, England