

ENVIRONMENTAL IMPACT OF CRUISE TRAFFIC WITHIN PALMA DE MALLORCA

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EXECUTIVE SUMMARY

- **University Rovira i Virgili (URV) researchers have developed a predictive machine learning algorithm to accurately and precisely isolate the impact of cruise ship activity on the pollution levels in metropolitan areas.** This innovative methodology has been applied to a study of the impact of cruise ships in Palma de Mallorca.
- **70 cruise ships would need to dock in Palma de Mallorca simultaneously to lift mean NO₂ concentrations to levels deemed “Poor” by the European Environment Agency (EEA).** Similar results were found for other air pollutants, suggesting that cruise activity alone is not capable of producing unhealthy air quality in these destinations, which is supported by other recent studies that have found residential activity and other local factors to be greater determinants of air quality.
- **Recently implemented restrictions limiting to 3 simultaneous ships docked in port have produced virtually no impact on observed emissions at the monitoring station at Foners.** The restriction would only apply to, on average, 238 hours out of a typical pre-restriction year.
- **Future development of environmentally friendly technologies, such as the transition to cleaner fuels, increased Onshore Power Supply (OPS) availability, and energy efficient ship designs, are expected to further mitigate the impact of cruise ships on the local environment.**

INTRODUCTION

The energy intensive operations of cruise ships, which encompass hoteling and transportation, are often scrutinized as a major contributor to local air pollution, particularly in port cities. Key focus is on the production of nitrogen dioxide (NO₂), sulfur dioxide (SO₂), particulate matter (PM), and carbon monoxide (CO), due to their harmful effects on human health. Recent environmental developments have heightened the recognition of the need to curtail air emissions, and the cruise industry's position in the tourism and maritime shipping sectors afford it a prominent role in the environmental movement.

Cruise ships operate as floating cities, providing passengers with hotel, catering, and entertainment services. These non-transportation activities have substantial energy requirements, which continue while docked. Such energy intensive operations raise the potential for subsequent air emissions to impact local areas. Since cruise ships share space with a variety of ships at port, separating their environmental impact from other marine vessels as well as other emission contributors in the cities, such as flights and automobiles, is vital in order to quantify the realized impact of cruise ships on the local air quality.

Researchers at the University Rovira i Virgili (URV) in Tarragona, Spain have pioneered a predictive machine learning model to disentangle the air pollution impact of cruise ships from other urban effects, overcoming some of the inherent error in traditional approaches due to difficulties in precisely reconstructing a natural hydrodynamic field and pollutant characterizations. This innovation allows for each pollutant source's direct impact on the local air quality to be isolated, including cruise ships, eliminating extraneous concurrent factors. This report will delve into the results of these recent studies, the environmental impact of cruise ships in Palma de Mallorca, and advancements of the cruise industry in furthering its environmental goals.

NEW CRUISE IMPACT STUDIES

The novel machine learning methodology laid out in Fabregat et al. (2022) was utilized in separate studies examining the air quality in Palma de Mallorca¹ This location was selected due to data availability and the level of cruise ship traffic its port receives. While this study incorporated pollution readings from multiple monitoring stations throughout the city, not all stations are designed to track the same pollutants. Thus, the geographic coverage within Palma de Mallorca is not uniform for all pollutants. However, the results of the study found that while cruise ships do contribute to the levels of most air pollutants, it is often negligible and not a determining factor in pushing pollution to unhealthy levels.

Each additional cruise ship registered an increase of 3.4% in the mean concentration of NO₂ based on the average measurement across all Palma de Mallorca's monitoring stations. The monitoring station closest to the cruise terminal (Foners), where the cruise emissions are at their highest level, recorded an increase of 1.3 µg m³ (4.5%) above its mean NO₂ recording per additional cruise ship.

Researchers pioneer novel methodology isolating the impact of cruise ships on air quality in Palma de Mallorca.

1.3 µg/m³

Maximum increase in NO₂ level above mean concentration per additional cruise ship

As measured at Palma de Mallorca's Foners monitoring station

¹ Fabregat et al., 2022

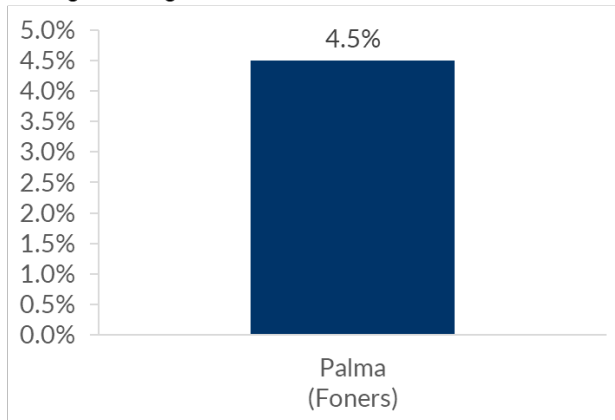
0.15%

Largest expected increase in mean CO levels at a monitoring station per additional cruise ship

Across all monitoring stations in a range of port cities

Marginal impact of cruise ships on NO₂

Average % change in concentration from mean

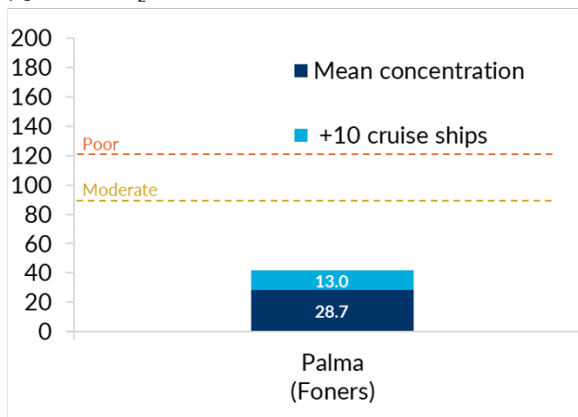


Source: Fabregat et al. (2022)

The mean NO₂ concentration in Palma de Mallorca (28.7 µg m³) is well within what the European Environment Agency (EEA) deems as “Good” as per its Air Quality Index (AQI). An additional 10 cruise ships would push it into low “Fair” territory (AQI bands are “Good”, “Fair”, “Moderate”, “Poor”, “Very Poor”, “Extremely poor”). At the Foners station – the port station with the greatest percentage increase in NO₂ levels per additional cruise vessel – 70 simultaneously docked ships would be needed to push the mean NO₂ value to an AQI reading of “Poor” (the level at which it is advised for “sensitive populations” to consider limiting outdoor activities). Such a volume of cruise ships is well beyond Palma de Mallorca’s current cruise port capacity.

Impact of cruise ships on NO₂

µg m⁻³ of NO₂

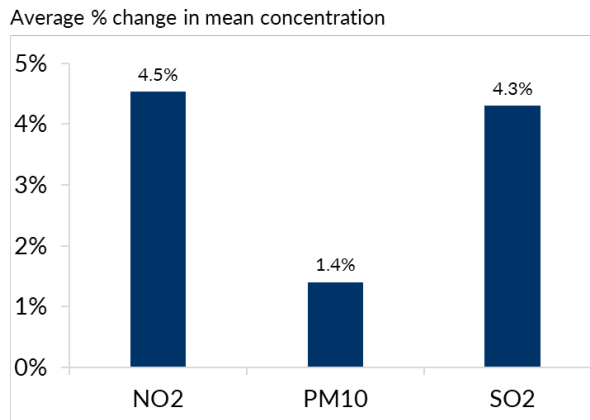


Source: Fabregat et al. (2022), EEA

Similarly, the predicted impact of cruise ships in this study on SO₂ and PM₁₀ fails to be a significant enough factor on its own to result in unhealthy Air Quality Index readings. In Palma de Mallorca, 118 simultaneously docked cruise ships would be needed to reach a mean PM₁₀ reading that the EEA classifies as “Poor”. The predicted impact of an additional cruise ship on the SO₂ readings in Palma de Mallorca indicates an impossibly large number of simultaneously docked cruise ships (10,000+) would be necessary to lead to the air quality deteriorating to a level deemed “Poor” by EEA’s Air Quality Index.

Overall, cruise ships were not found to have a discernible impact on the mean level of CO, on average. For the other pollutants examined (NO₂, SO₂, and PM₁₀), the average percentage increase at the Foners monitoring station of an additional cruise ship vessel was 4.3% for SO₂, while increases in NO₂ and PM₁₀ on the same basis were 4.5% and 1.4%, respectively.

Marginal impact of cruise ships at the closest station to the Port (Foners)



As measured at Palma de Mallorca's Foners station
Source: Fabregat et al. (2022)

Compared to other modes of transportation modeled the average SO₂ contribution of one additional cruise ship was found to be within the margin of error as one additional ferry, flight, other marine vessel, and 100 cars. In a study concerning Palma de Mallorca, a standard ferry is found to have a greater expected PM₁₀ contribution than a cruise ship at all monitoring stations. At some stations in Palma, 100 cars are also found to have a similar or greater impact on PM₁₀ levels than a cruise ship, including at the Foners station in central Palma de Mallorca where 49 cars travelling along Gabriel Roca Avenue had the equivalent impact of one cruise ship. However, a cruise ship not only transports significantly more passengers than a ferry or flight or 100 cars but also provides accommodation, dining services, and entertainment to all its passengers.

The Palma City Council approved a plan in 2021 to limit the number of cruise ships visiting the port to a maximum of three per day. Part of the goal for this measure was to reduce the cruise industry's impact on the City of Palma's air pollution. In analyzing the net effect of such a measure, this limitation would have only applied to 2.7% of the time between 2017 and 2021, corresponding to an average of 238 hours per year. Given the expected impact of cruise ships found in the study, this limitation would only represent a 0.12% reduction in the annual NO₂ concentration and a 0.05% reduction in the annual PM₁₀ concentration across the monitoring stations in Palma, on average. At the Foners monitoring station, the closest station in downtown Palma de Mallorca to the port, instances where the limitation would go into effect – when there were more than three cruise ships that visited Palma de Mallorca – would lead to a 4.6% and 2.0% reduction in NO₂ and PM₁₀, respectively. However, the expected NO₂ and PM₁₀ levels when more than three cruise ships did dock in the Port of Palma were already considered “Good” by the EEA's Air Quality Index. So, while this measure would slightly reduce the NO₂ and PM₁₀ levels in central Palma, it is not expected to improve the AQI rating of the area during these times, with regards to NO₂, PM₁₀, SO₂, and CO.

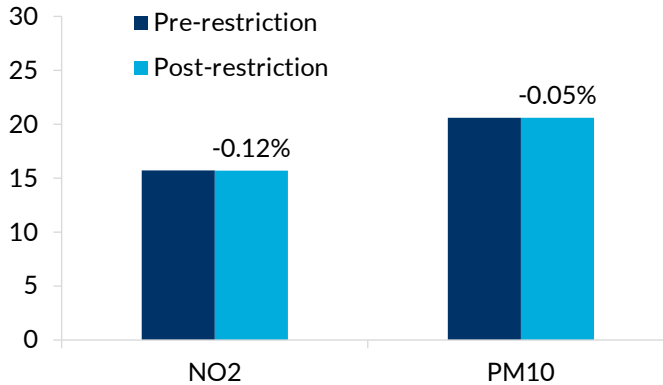
2.6%

Share of NO_x linked to maritime in Bordeaux.

57% comes from road activity.

Effect of Palma City Council restrictions

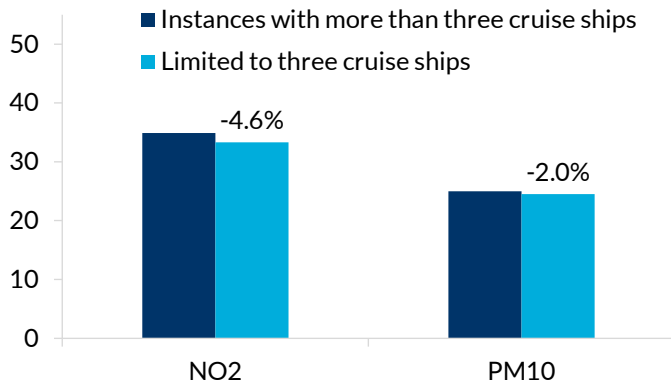
Average annual concentrations, $\mu\text{g m}^{-3}$



Source: Fabregat et al. (2022), Tourism Economics

Effect of Palma City Council restrictions

Concentrations at Foners station, $\mu\text{g m}^{-3}$



Source: Fabregat et al. (2022), Tourism Economics

85%

Fewer NO_x emissions from LNG

And virtually zero sulfur emissions

The new approach to isolating the impact of cruise ships on pollutant levels in metropolitan areas developed by the URV researchers allows for predictive inferences due to changes in cruise activity, proving a valuable tool for estimating the impact of policy, such as the Palma City Council's limitation on the number of cruise ships. The present but relatively small impact of cruise ship activity on the air quality of port cities found in the URV examination of Palma de Mallorca² substantiate the findings of prior studies, such as Murena et al. (2018) which found that NO₂ levels still registered as healthy, on average, according to the EEA's AQI, during peak cruise periods, and Eurofins and Olfasense's joint 2018 study which found that harmful levels of NO₂ at the Port of Kiel (Germany) were not attributable to cruise emissions.^{3,4}

Several studies have found that local activity, rather than cruise activity, to be the driving factor in poor air quality. Atmo Nouvelle-Aquitaine – a regional air observatory certified by the Ministère de la Transition Écologique – found the main factors influencing air quality in Bordeaux were nearby road traffic, residential activity, and

² Fabregat, et al., 2022

³ Murena et al., 2018

⁴ AQMesh, 2018

the rail sector.⁵ Congruently, in a 2019 air quality impact assessment in Juneau (Alaska), the Alaska Department of Environmental Conservation (ADEC) found that notable effects on PM_{2.5} levels from cruise ships dissipated within two hours. Instead, wildfires and local activity – such as construction, grilling, and bonfires – had more pronounced impacts on air quality and visibility.⁶

Future implementations of the URV researchers' model are intended to incorporate adequate data on electricity consumption to account for residential emissions, as well as industrial and agricultural sources. The advancements in environmentally friendly technologies for the cruise industry and the pace of implementation is expected to lead to further mitigating the impact of cruise ships on the air quality of the port cities they visit.

TECHNOLOGICAL PROGRESS

The cruise industry continues to demonstrate a commitment to the development and application of environmentally responsible technologies, policies, and practices. Cruise lines remain at the forefront of investing in and adopting responsible environmental practices and innovative technologies, which benefit the entire maritime industry. Key approaches being utilized to improve the environmental performance of cruise ships include implementing more sustainable specifications for new-build ships, retrofitting ships in operation to replace and improve technologies, and investing in a variety of onboard and portside green technologies, as well as cleaner fuel sources.

Presently, Liquefied Natural Gas (LNG) is the primary alternative fuel source being utilized due to its strong environmental performance, growing land-based infrastructure, and established technological viability. Burning LNG produces virtually zero sulfur emissions, 85% fewer nitrogen oxide emissions, 95-100% fewer particulate emissions, and the industry estimates up to 20% fewer greenhouse gas (GHG) emissions than heavy fuel oils. Cruise ships on order or under construction that rely on LNG propulsion comprise 52% of new passenger capacity.⁷ With the objective of further reducing carbon intensity, current research initiatives are exploring the long-term viability of biofuels, ammonia, hydrogen, other alternative fuels, fuel cells, and battery power on cruise vessels.

Since its inception as a maritime fuel, LNG has provided substantial reductions in air emissions but has also entailed the risk of methane slip – producing an impactful greenhouse gas – occurring from gas leaking or from fuel that fails to burn during the combustion process. Engine manufacturers across the industry are pushing technology developments to upgrade existing engines to increase accessibility and speed up the transition to the latest innovations, including ones that correct for methane slip. For example, Wärtsilä, a Finnish-based leader in innovative marine technology manufacturing, has continuously honed its engines to reduce the risk of methane slip, with the latest engine generations achieving a 20% improvement over its predecessor.⁸ In addition to developing new low-carbon fuel options, enhancing

⁵ Atmo Nouvelle-Aquitaine, 2018

⁶ DEC – Alaska, 2021

⁷ Molon and Sacks, 2021

⁸ Wärtsilä, 2023

existing technologies offers the cruise industry opportunities for rapid gains in eco-friendliness to meet short- and medium-term goals.

Ships will also benefit from advancements and diversification in port energy supply. Onshore Power Supply (OPS) will enable ships to turn off engines while at port and use more efficient local power systems. Corbett and Comer (2013) estimated that the implementation of OPS in the Port of Charleston (USA) would reduce emissions using the same fuel mix for the electrical grid as in 2011, of which coal consisted of 48% of the fuel. Transitioning the electrical grid to less dependency on coal and greater reliance on clean fuels would result in even greater emissions reductions.⁹ Expanding the availability of high-wattage power sources at ports globally and utilizing municipal grids run on renewable energy will increase benefits.

CONCLUSION

The necessary tools to accurately measure and analyze cruise-related pollution are a recent technological innovation and further refinements could yield more insights. Due to the challenge of monitoring all direct pollution sources in order to distinguish the impact of cruise ships from alternative sources, proxies for other pollution-causing activities are commonly used. Gaseous diffusion makes measuring direct emissions a complex undertaking, thereby requiring expensive yet limited technology to isolate cruise-specific emissions. Varying equipment standards and geographical coverage of measuring stations used in the collection of data across studies present potential error in the accuracy and precision of readings and inequitable comparisons. Data collection consistency is also susceptible to fluctuations in local weather conditions.

Future research will shed light on the progress made by cruise ships. The ability of advanced machine learning techniques implemented in Fabregat et al. (2022) to extract the effect of cruise ships' emissions from overall port effects presents a valuable template that utilizes big data to accurately measure the environmental impact that can be replicated in additional locations. Their results for Palma de Mallorca indicate that pollution concentration levels are not highly influenced by cruise activity, but rather other localized factors, and when isolated from extraneous effects, cruise ship emissions do not significantly alter local air quality. The impact from cruise ships' presence alone does not appear to be significant enough to elevate AQI readings to unhealthy levels. Rather, some evidence suggests that emissions from other nearby activities, such as road traffic or residential activity, are more consequential to the local air quality.

Constructing panel data series through prolonged high-quality air quality monitoring can highlight changes in performance after new regulations and technologies have been introduced. Quantifying reductions brought about by the transition to cleaner fuels, increased OPS availability, and implementation of enhanced, energy efficient ship designs can inform policymakers and the public of the sources of environmental degradation, the expected returns on investment of these enhancements, and the areas of potential improvement in the goal of preserving local environments.

The continued improvement in data collection and analysis technology will allow for a better understanding of the effect of cruises on the air quality of ports. Coupled with increasing global sustainability reforms and more energy efficient technology, cruise ships will be able to lessen their environmental impact on the communities they visit

⁹ Corbett and Comer, 2013

even more so. While the cruise industry continues to strive towards reductions in emissions, the scientific literature indicates that the current impact of cruises on local air quality has been curbed through prior initiatives and is modest in nature.

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