

Air pollution with ultrafine particles from shipping in Italian port cities



Upwind ferries



Downwind ferries

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Background

This measuring report is part of the EU LIFE project: LIFE4MEDECA with the purpose to designate a Mediterranean Sea Emission Control Area (ECA) to reduce health and climate damaging emissions of air pollution from ships. The purpose of air quality screening measurements in port cities is to visualise ship pollution for populations in the Mediterranean and thereby create awareness about air pollution from shipping and engage the public in discussions on a Mediterranean Sea ECA.

According to the European Environmental Agency air pollution causes about 65,000 deaths in Italy every year i.e., in 2020 and 2021 air pollution caused the same mortality as COVID-19. Air pollution with SO_x, NO_x and particles from shipping in the Mediterranean Sea is an important pollution source that contributes significantly to morbidity, mortality and to acid rain thereby damaging cultural heritage, crops and nature in the Mediterranean. Furthermore, CO₂ and black carbon from ships contribute significantly to climate change. An ECA for SO_x and NO_x in the Mediterranean Sea will minimize regional air pollution from ships. This will benefit all Mediterranean societies and protect populations in the Mediterranean from ship pollution to the same extent as the Northern European ECA does, where a sulphur ECA was implemented back in 2007 followed by a NO_x ECA in 2021.

The air quality screenings in port cities were mainly focused on cruise ships and ferries. Cruise ships are large floating hotels with very high energy demands thereby emitting as much NO_x and particles per second at berth as thousands of cars. Ferries significantly influence local air quality because of frequent arrivals/departures and overnight stays idle running at berth. Most cruise ships and ferries at berth burn bunker oil containing 100 times more sulphur than road diesel and are often at berth close to densely populated city centres. Hence, onshore wind will thereby expose whole communities to heavy air pollution with exhaust particles from ferries and cruise ships.

Freshly emitted exhaust particles from ships mainly consist of ultrafine particles (PM_{0.1}) with a diameter below 0.1 micrometre (100 nanometres). Due to their size, these particles can enter the finest parts of the lungs and continue into the bloodstream. Ultrafine particles have a high content of soot and polycyclic aromatic hydrocarbons (PAH's) classified as level 1 carcinogens by the World Health Organization. Particle pollution increases the risk of cancer, blood clots, brain haemorrhages, cardiovascular diseases, bronchitis, asthma, etc. Ultrafine particles emitted from ships at open sea will aggregate to toxic fine particles (PM_{2.5}) before reaching land and should be monitored together with SO₂ and NO_x. However, in port cities air quality monitoring should as well include ultrafine particles emitted directly from ships at berth thereby polluting local city areas.

Air pollution from ships in ports can be eliminated by switching to shore power and electric ships. Larger cruise companies are retrofitting cruise ships to meet expected requirements for shore power in cities concerned about public health. However, this requires investment in shore power systems in ports allowing cruise ships to connect. This investment will (in contrast to traditional infrastructure projects) be paid back by connection fees and electricity sales to ships (resulting in an insignificant price increase for passengers). Pollution from international shipping in the Mediterranean Sea, that uses even more polluting fuels than ships at berth, can be reduced by establishing an ECA through international collaboration and public involvement. The EU Commission therefore initiated project *LIFE4MEDECA* bringing together nations around the Mediterranean Sea - and compiling experience from the Northern European ECA - to designate a Mediterranean Sea ECA.

Purpose

One of the purposes of project *LIFE4MEDECA* is to perform screening measurements of air pollution from cruise ships and ferries in Italian port cities to create awareness about air pollution from shipping and engage the public in discussions on the implementation of a Mediterranean Sea ECA.

Measurements

Ultrafine exhaust particles from cruise ships were measured in 2021 in the following port cities:

Civitavecchia on September 30th, October 1st, October 6th.

Savona on October 3rd.

Genoa on October 4th.

Livorno on October 5th.

Piombino on October 6th.

Furthermore, for comparison air pollution from traffic was measured in central Rome (*Esquilino*) during rush hour (around 16.00 on Thursday October 7th with dense traffic).

Ultrafine particles were measured with P-Trak's (Model 8525 Ultrafine Particle Counter) from TSI calibrated and cross-calibrated prior to measurements and control calibrated after the measurements. Calibration showed that the equipment worked well throughout measurements. The measurement frequency was once per second, however, minute average values are used in tables and graphs to reduce fluctuations and peak concentrations thereby better reflecting average air quality levels.

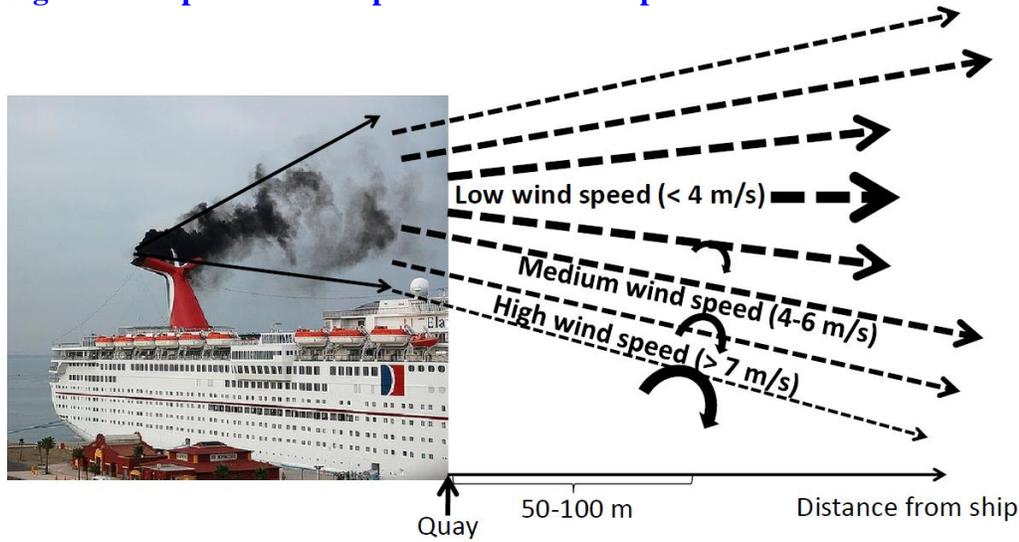
Local wind speed/direction, humidity and temperature were measured with a WindMate 350 and compared to the official local weather forecasts.

The pollution plume

Air pollution from cruise ships and ferries is emitted from smoke stacks many meters above ground level. The exhaust is very warm and moves upwards until it is cooled down to the temperature of the surrounding air. In calm weather, the pollution will spread in all directions by dispersion. At windy conditions, the pollution plume moves in the direction of the wind and expands perpendicular to the wind direction. Expansion happens quickly at high wind speeds (> 7 m/s, due to high turbulence) and the diluted periphery of the pollution plume reaches ground level a few hundred meters from the ship. Expansion happens slowly at low wind speeds (wind speed < 4 m/s) and the concentrated pollution plume thereby reaches the ground level several kilometres from the ship. Ships are therefore able to pollute central city areas quite a distance from their location (Figure 1).

As it is very difficult to localise the pollution plume several kilometres inside cities where many other pollution sources, like traffic, also contributes to air pollution, the best measuring conditions are onshore high wind speeds. This allows measurements close to ships where the diluted periphery of the plume can be localised and is unaffected by other pollution sources. If possible, measurements must be performed both upwind the ship (sea background being unaffected by pollution from the ship) and downwind the ship (air being polluted by ship emissions). Measurements with no ships can replace upwind measurements. Measurements during offshore wind require a boat.

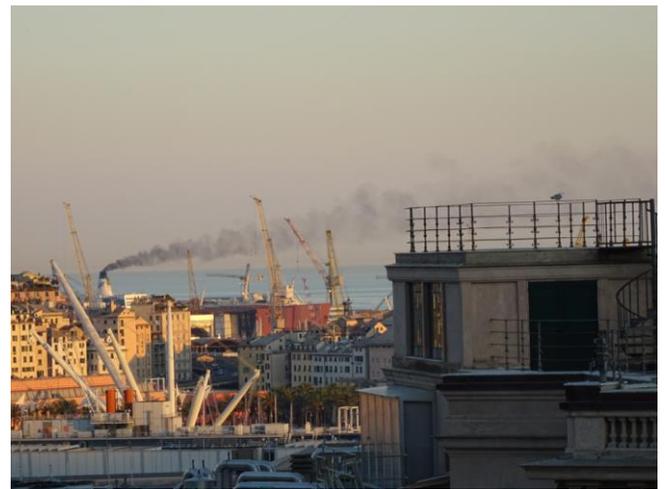
Figure 1: Dispersion of air pollution from a ship.



The pollution will spread in all directions by dispersion when there is no wind and mainly pollute the port area. (Photo from Genoa 2016)



Low wind speeds will give a dense pollution plume that can reach ground level several kilometres from the ship. (Photo from Genoa 2016)



Results

Humidity and temperature were within the validity range of the measurement equipment at all times. Unfortunately, offshore wind made it impossible to measure pollution in Civitavecchia on September 30th and in Savona. Very fluctuating wind speed made it difficult in Genoa. In Civitavecchia (October 6th), Livorno and Piombino, successful air quality screening measurements were conducted.

However, since the same cruise ships - and same type of ferries - are at berth in most Italian port cities, air pollution levels from ships in Savona, Genoa and other Italian port cities can be presumed to be similar. Results of the measurements are summarized in table 1.

Table 1: Particle pollution in Italian port cities

		Date	Ship	Particle pollution (average particles per cm ³)	Wind (direction : speed)
Civitavecchia	City background	Oct. 1 st	---	1.600	W : 1-2 m/s
	With ship pollution	Oct. 6 th	Ferries	71.650	W : 8-9 m/s
Civitavecchia	City background	Oct. 1 st	---	2.250	W : 1-2 m/s
	With ship pollution	Oct. 6 th	Cruises	60.550	W : 8-9 m/s
Genoa	Sea background	Oct. 4 th	---	2.350	E : 6-10 m/s
	With ship pollution	Oct. 4 th	Cruise	82.400*	
Livorno	Sea background	Oct. 5 th	---	1.250	SW : 9-12 m/s
	With ship pollution	Oct. 5 th	Ferries	50.650	
Piombino	Sea background	Oct. 6 th	---	2.150	W : 6-8 m/s
	With ship pollution	Oct. 6 th	Ferries	45.550	
Rome city centre	Rush hour traffic	Oct. 7 th	Cars	7.100	4-5 m/s

--- : Background refers to a situation where no ship causes air pollution at the location of the measurement.

* Only a few measurements (240 measurements) since the local wind speed and direction were fluctuating.

From Table 1 is seen that air unaffected by local pollution sources in Italian port cities in average contains around 1.250-2.250 particles per cm³. In comparison, polluted air downwind cruise ships and ferries in average contains 45,000-80,000 particles per cm³ during rather strong winds where the pollution plume from the ships is quite diluted. Air pollution several hundred meters downwind ships thereby reaches much higher pollution levels than measured along streets in the central Rome. This clearly illustrates the intense air pollution from ships and that, on a calm day with much less dilution, ships are able to pollute whole city areas kilometres downwind the ships. In comparison, the number of particles measured directly in the exhaust of a new diesel car with particulate filter (requirement in EU since 2009) lies below 2,000 particles per cm³; but there are no filter requirements for ships.

Movies from measurements:

Piombino, sea background: https://www.dropbox.com/s/d7iaovj8z0r293v/IMG_2654.MOV?dl=0

Piombino, ferry pollution: https://www.dropbox.com/s/fybsan466ptxb8m/IMG_2634.MOV?dl=0

Traffic in central Rome: https://www.dropbox.com/s/7eexh2thsly5drd/IMG_2871.MOV?dl=0

Cruise ships and ferries in Italian ports thereby cause the same serious air pollution as documented in many other port cities and expose of the local population to carcinogenic and toxic air pollution.

Figure 2 shows graphs of measurements from October 1st and 6th for Civitavecchia and Figure 3 from October 5th for Livorno. Fluctuating concentrations downwind the ships are due to turbulence and wind gusts. To comparison are shown screening measurements from traffic in central Rome.

Figure 2: Measurements in Civitavecchia compared to traffic pollution in Rome city centre

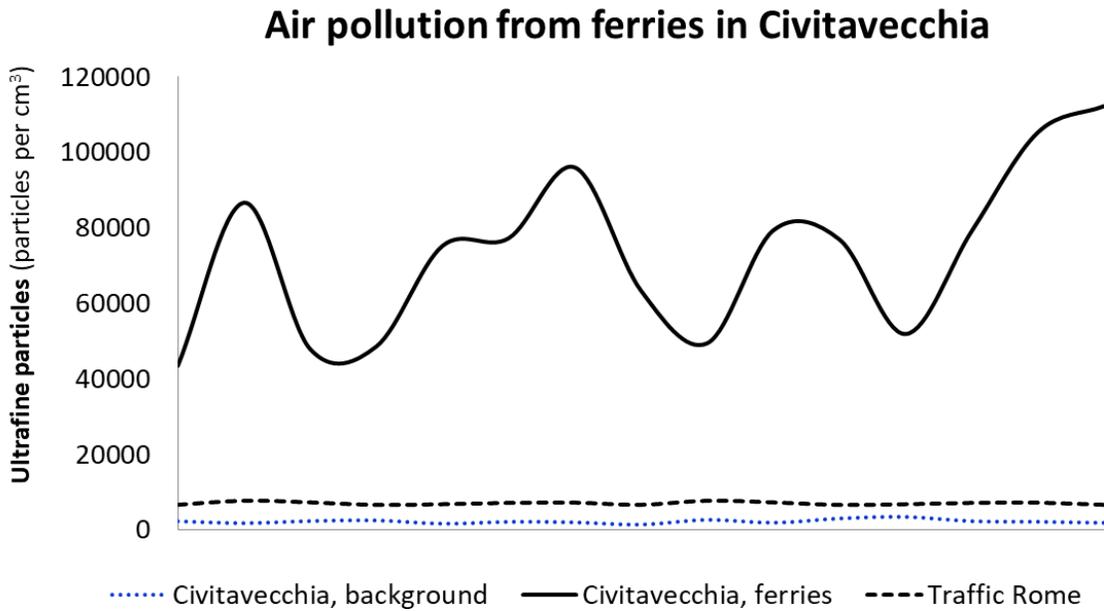
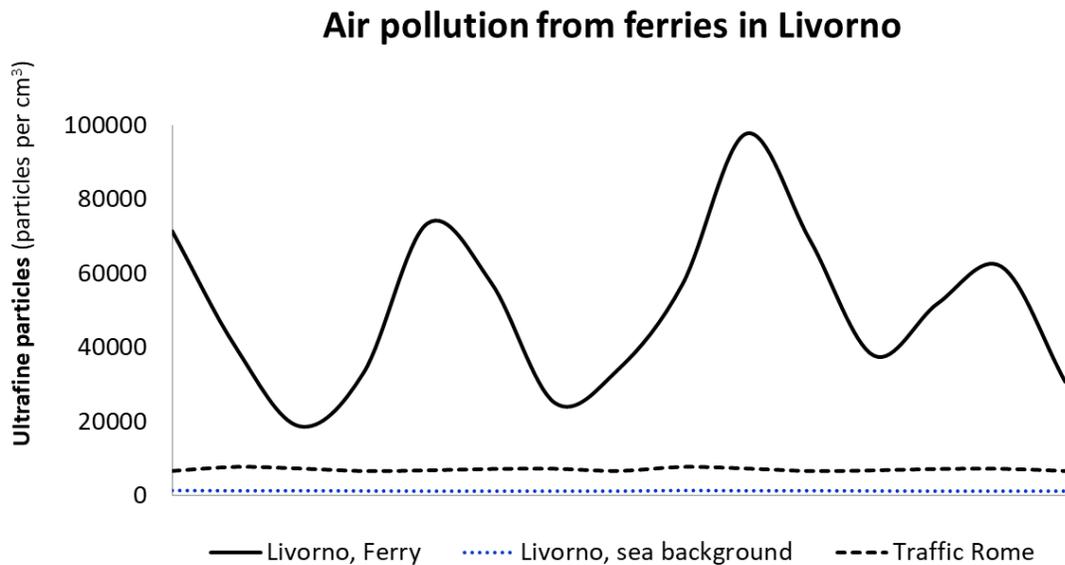


Figure 3: Measurements in Livorno compared to traffic pollution in Rome city centre



The figures clearly illustrate the influence of the wind on spreading the pollution plumes from ships. The highest pollution levels are measured under highest wind speeds blowing a more concentrated part of the pollution plume from the ferries down to measuring height at ground level (as explained in Figure 1). The extremely high pollution levels from the ferries become clear when comparing to the background air quality levels (unaffected by local ship pollution) and traffic sources in central Rome.

Conclusion

Emissions from large ships in Italian port cities cause the same intense air pollution as observed in other port cities. The pollution plumes can pollute city areas several kilometres from the ships. This pollution increases the risk of morbidity and mortality in Italian port cities. The solution is to build shore power systems for ferries and cruise ships to avoid ships exhaust. Furthermore, fully electric ferries (batteries) should be promoted. At sea, pollution from ships will be significantly reduced by introducing a Mediterranean Sea Emission Control Area (ECA) like the successful ECAs in Northern Europe and USA.

Recommendations

It is recommended that Italian port cities in cooperation:

- Decide to build shore power systems for ferries and cruise ships.
- Invest in fully electric ferries as in Northern Europe.
- Support designating a Mediterranean Sea Emission Control Area.
- Ban the use of heavy fuel oil and scrubber systems in territorial seas.

In addition to improving public health in Italy, these actions would improve public health in the whole Mediterranean region, reduce global warming, and reduce the risk of serious environmental damage in the Mediterranean Sea due to discharge of scrubber water as well as spills and illegal discharges of heavy fuel oil.