Air pollution with ultrafine particles from shipping in Valletta

Upwind cruise ship

Downwind cruise ship

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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 250 deaths in Malta every year i.e., in 2020 and 2021 air pollution caused the same mortality as COVID-19. Air pollution with SOx, NOx 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, CO_2 and black carbon from ships contribute significantly to climate change. An ECA for SOx and NOx 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 NOx ECA in 2021.

The air quality screenings in port cities were mainly focused on cruise ships, ferries and smaller commercial ships. Cruise ships are large floating hotels with high energy demands thereby emitting as much NOx 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. Smaller commercial ships idle running at berth can cause significant local air pollution as well. Most ships at berth in EU burn bunker oil containing 100 times more sulphur than road diesel. Onshore wind can thereby expose whole communities to heavy air pollution with exhaust particles.

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 SO_2 and NOx. 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 Valletta to create awareness about air pollution from shipping and engage the public in discussions on the implementation of a Mediterranean Sea ECA.

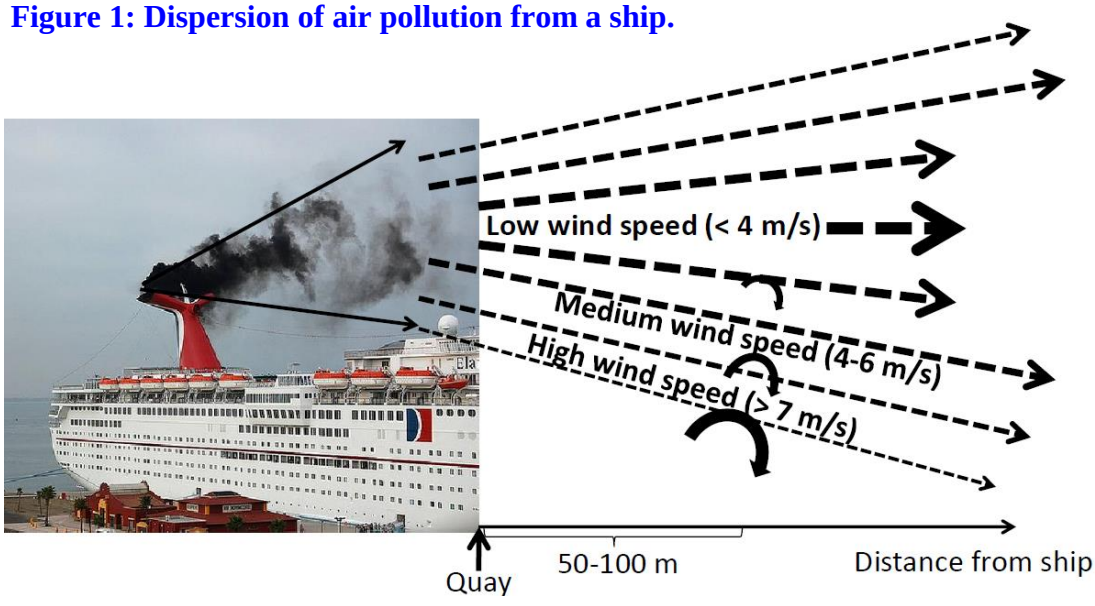
Measurements

Ultrafine exhaust particles from cruise ships and smaller commercial ships were measured in 2021 in Grand Harbour in Valletta (incl. Senglea & Vittoriosa) in week 42. Ultrafine particles were measured with P-Trak's (TSI: Model 8525 Ultrafine Particle Counter) 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).

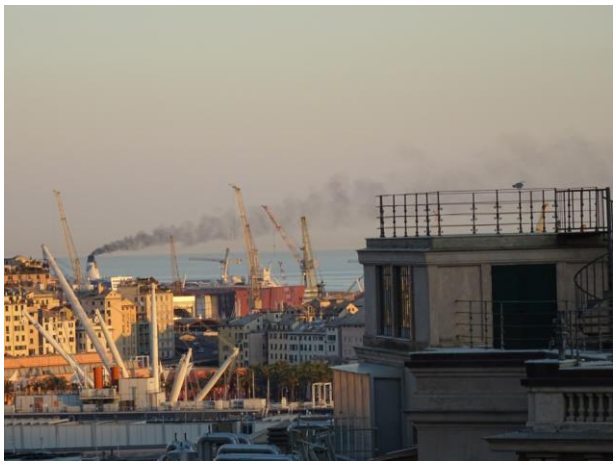
Figure 1: Dispersion of air pollution from a ship.



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.

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 and fluctuating wind speed made it impossible to measure some days. Results of the measurements are summarized in table 1.

Table 1: Particle pollution in Valletta

		Date	Ship	Particle pollution (average particles per cm^3)	Wind (direction : speed)
City background	**Valletta**	Oct. 16th	No ship	2,650	W : 7 m/s
	Fort St. Angelo	Oct. 19th	No ship	1,850	E : 6 m/s
	Mdina	Oct. 23th	No ship	2,700	No data
Ship pollution	**Senglea** (west wall)	Oct. 16th	Commercial	103,100	W : 7 m/s
	Senglea (west wall)	Oct. 17th	Commercial	35,800	W : 3 m/s
	Valletta (east wall)	Oct. 19th	Commercial	129,000	E : 6 m/s
	Valletta (east wall)	Oct. 24th	Downwind Cruise	82,300	S-SW : 5-6 m/s
	Valletta (east wall)	Oct. 24th	Upwind Cruise	2,650	S : 4 m/s

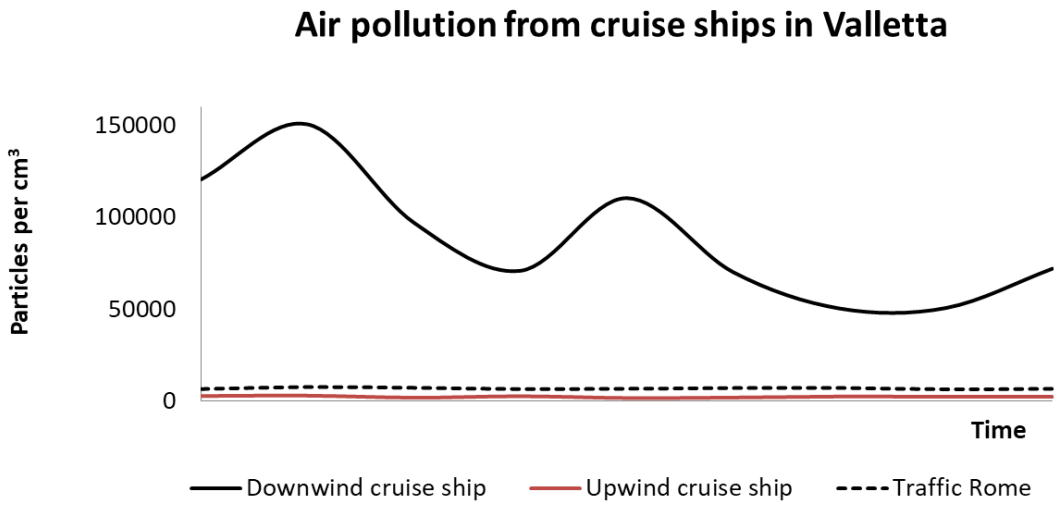
From Table 1 is seen that air unaffected by local ship pollution in Malta (city background) in average contains around 1,850-2,700 particles per cm^3. In comparison, polluted air downwind cruise ships and commercial ships was measured to contain 35,800-129,000 particles per cm^3. This clearly illustrates the intense air pollution from ships. On a calm day with less wind (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 cm^3; but there are still no filter requirements for ships.

Movies from similar measurements in Italian ports:
Piombino, upwind ferry: 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 Malta thereby cause the same serious air pollution as documented in many other port cities and expose the local population to carcinogenic and toxic air pollution.

Figure 2 shows graphs of measurements upwind and downwind a cruise ship in Valletta on October 24th. Measuring conditions were not optimal (too low wind speed c.f. Figure 1 and not optimal wind direction). 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 Valletta



The figure illustrates the influence of the wind on spreading the pollution plume from the ship. The highest levels are measured under highest wind speeds (wind gusts) blowing a more concentrated part of the pollution plume from the cruise ship down to measuring height at the wall (as explained in Figure 1). The extremely high pollution level from the cruise ship becomes clear when comparing to the upwind air quality levels (unaffected by local ship pollution) and traffic in the central Rome.

Conclusion

Emissions from large ships in Valletta cause the same intense air pollution as observed in other port cities. The pollution plumes can pollute whole city areas several kilometres downwind large ships. This pollution increases the risk of morbidity and mortality in Valletta. The solution is to build shore power systems for ferries and cruise ships to avoid ship 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 Valletta:

- 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 Malta, 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.

Further reading

Cleaner shipping: https://rgo.dk/wp-content/uploads/GTD_Cleaner_shipping_2021_Final.pdf