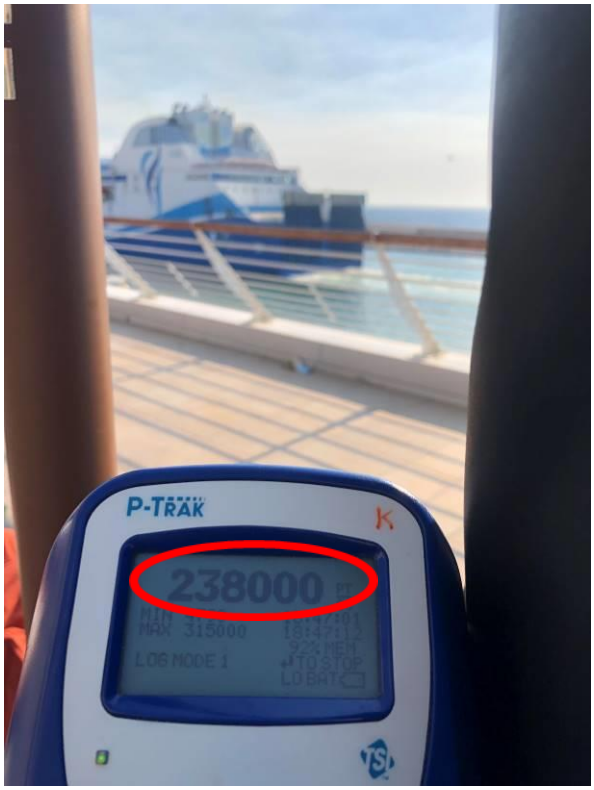
Air pollution with ultrafine particles from shipping in Marseille

Clean air (no ferry)



Ferry passing

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Background

These measurements are 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 shipping. 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 50,000 deaths in France every year i.e. in 2020 and 2021 air pollution caused same mortality as COVID-19. Air pollution with SOx, NOx and particles from shipping in the Mediterranean Sea is an important pollution source contributing 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 same extent as the Northern European ECA, where a sulphur ECA was implemented back in 2007 followed by a NOx ECA in 2021.

This air quality screening in Marseille was focused on ferries since the cruise port was restricted area. However, cruise ships will contribute significantly to air pollution in Marseille since 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 inside the heart of Marseille. Most ships at berth in EU burn bunker oil containing 100 times more sulphur than road diesel. Onshore wind can thereby expose whole city communities to heavy air pollution with exhaust.

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 freshly emitted from ships in the port thereby polluting local city areas.

Air pollution from ships in ports can be eliminated by switching to shore power and electric ferries. 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 ships in Mediterranean ports to create awareness about air pollution from shipping and engage the public in implementing a full Mediterranean Sea ECA to reduce SO_2, NOx and particle pollution and thereby significantly improve public health and the environment in the Mediterranean.

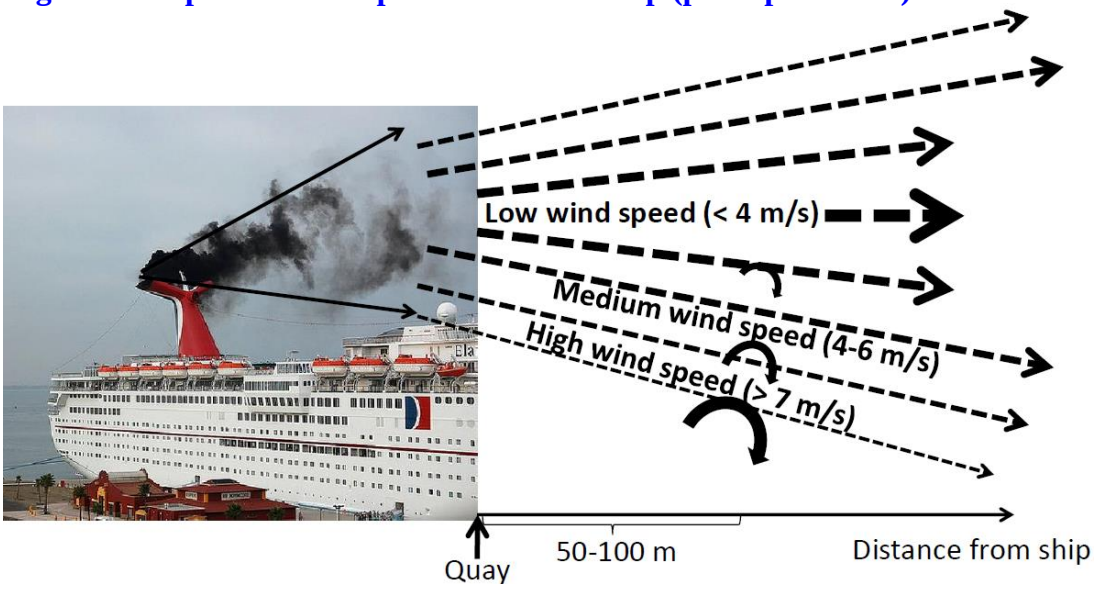
Measurements

Ultrafine exhaust particles from cruise ships and ferries were measured in July (week 27/28) in 2022 in Marseille port. Ultrafine particles were measured with P-Trak's (TSI: Model 8525 Ultrafine Particle Counter) cross-calibrated prior to measurements and control calibrated after measurements. Calibration showed that the equipment worked well throughout measurements. The measurement frequency was once per second. Local wind speed/direction, humidity and temperature were taken from local weather forecasts.

The pollution plume

Air pollution from large ships 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).

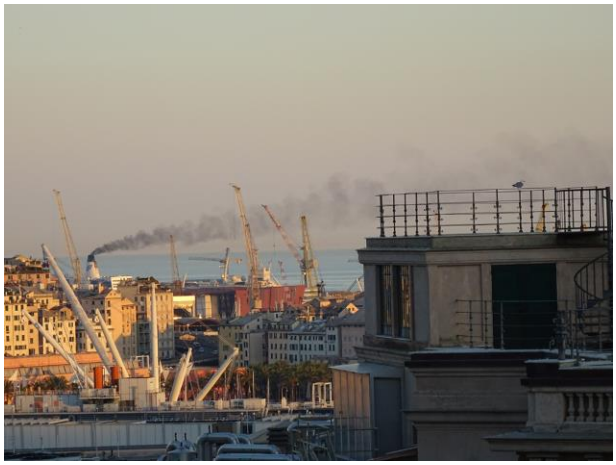
Figure 1: Dispersion of air pollution from a ship (principle sketch).



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 high wind speeds towards a convenient measuring position (typically on land or on a bridge/jetty). 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 ultrafine particles from local ships) and downwind the ship (air being polluted by ultrafine particles from local ship emissions). Measurements with no ships can replace upwind measurements. Measurements during offshore wind typically 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, low wind speeds (many quiet days with less than 4 m/s) and only few days with partly onshore wind combined with restricted port areas (no access) made measurements challenging as explained in figure 1. Results of the successful measurements are summarized in table 1.

Table 1: Particle pollution in Marseille port (July 2022)

		Date	**Particle pollution** (particles per cm^3)		**Wind** (direction : speed)
			Average	**Max.**	
Background	**No local ship pollution**	July 10th	3,150	5,900	S : 3 m/s
Ship pollution	**40 m from small tour boat**	July 9th	28,600	80,000	SW : 3-4 m/s
	350 m from ferry sailing by	July 12th	53,350	236,000	S : 2-3 m/s
	350 m from ferry sailing by	July 12th	76,350	181,000	S : 2 m/s
	200 m from ferry sailing by	July 15th	51,150	126,000	SV : 4-5 m/s
	200 m from ferry sailing by	July 15th	100,550	315,000	SV : 4-5 m/s

From Table 1 is seen that air unaffected by local ship pollution in Marseille (sea background) in average contains around 3,150 particles per cm^3. In comparison, polluted air hundreds of meters downwind ferries was measured to contain 51,150-100,550 particles per cm^3 in average and have maximum peak values above 300,000 particles per cm^3. During higher wind speeds and onshore wind the pollution levels would be much higher (as explained in figure 1).

In comparison, the average particle concentration alongside large streets in EU capitals is usually 15-20,000 particles per cm^3 in the rush hours. All new road vehicles have very efficient particulate filters reducing the particle concentration in the exhaust pipe to below 2,000 particles per cm^3. But there are still no filter requirements or sufficient shore power for ships sailing and idle running in Marseille.

The World Health Organization has discussed a limit value of maximally 10,000 particles per cm^3. However, a limit value for ultrafine exhaust particles has not yet been decided. The recommendation is to inhale as little ultrafine exhaust particles as possible since there seems to be no safe limit for this kind of air pollution (like tobacco smoking - the only safe thing is not to smoke at all).

This clearly illustrates the intense air pollution from ships in Marseille. Ships are able to pollute whole city areas downwind. In addition, the measurements from ferries in Marseille were made from the roof port terrace (Les Terrasses du Port) with lots of people and their children relaxing just next to ferries (pictures). This is not an acceptable situation.

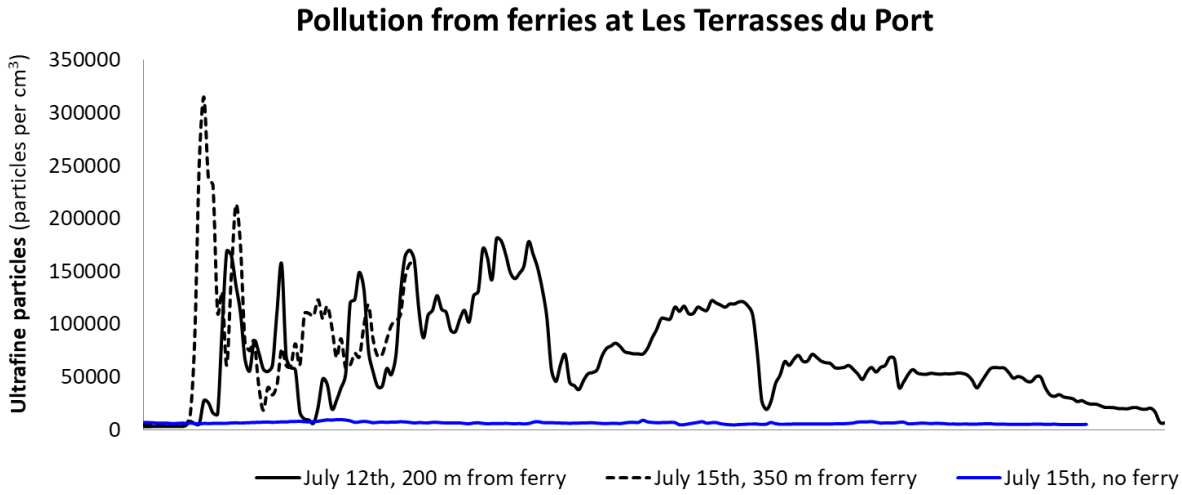
Movies and pictures from measurements in Marseille for free use:

https://www.dropbox.com/sh/uhejcvpc4hbxae9/AADs_KbrnkKwUFex2EsagbNYa?dl=0
Please acknowledge: EU LIFE4MedECA project when using the movies and pictures.

Cruise ships and ferries in Marseille 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 air pollution (second by second) at Marseille roof port terrace when ferries sail by. On July 15th the measuring equipment ran out of batteries (therefore measurements were interrupted).

Figure 2: Measurements downwind from ferries sailing by roof terrace (second measurements).



The figure illustrates the influence of the wind on spreading the pollution plume from the ferry. The highest levels are measured under highest wind speeds (wind gusts) blowing a more concentrated part of the pollution plume from the ferry down to measuring height. Under higher wind speeds and onshore wind pollution at the terrace would be much higher (as explained in Figure 1).

Conclusion

Emissions from large ships in Marseille 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 Marseille. People relaxing or working at the roof port terrace (Les Terrasses du Port) can be exposed to extremely high pollution levels from ferries. The solution is to build shore power systems for ferries, cruise ships and cargo ships to avoid ship exhaust. Furthermore, fully electric ferries (batteries) should be promoted. At sea, pollution from ships can be significantly reduced by introducing a Mediterranean Sea Emission Control Area (ECA).

Recommendations

It is recommended that Marseille:

- Build shore power systems for all ferries, cruise ships and cargo ships now.
- Start investing in fully electric ferries and tour boats as in Northern Europe.
- Support designating a Mediterranean Sea Emission Control Area as agreed at COP22.
- Ban the use of heavy fuel oil and scrubber systems in territorial seas incl. ports.
- Stop all investments in LNG since it is a very climate damaging fuel with no future.

In addition to improving public health in Marseille, 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 from discharge of scrubber water and heavy fuel oil spills.

Further reading

Cleaner shipping: https://rgo.dk/wp-content/uploads/GTD_Cleaner_shipping_2021_Final-2.pdf