Air Pollution from Ships in the Mediterranean Sea

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What is the problem?

- Sulfur content of fuel for marine sea ships can be about 500 times as high as on shore (cars, trucks)
- From 2020 sulfur content is limited to 0.5 %,
- in ECA and EU harbors: S- max 0.1 %

- Toxic emissions:
  1. Particulate Matter (PM) and
  2. Black Carbon (BC)
  3. Sulfur Dioxides (SO_2)
  4. Poly Aromatic Hydrocarbons (PAH)
  5. Heavy Metal Oxides
  6. Nitrogen Oxides (NO_x)

What Are the Health Effects of NO_2?

Nitrogen dioxide causes a range of harmful effects on the lungs, including:

- Increased inflammation of the airways;
- Worsened cough and wheezing;
- Reduced lung function;
- Increased asthma attacks; and
- Greater likelihood of emergency department and hospital admissions.[1]

New research warns that NO_2 is likely to be a cause of asthma in children.[2]

A large new study found evidence that people with lung cancer faced greater risk from NO_2, Looking beyond the lungs, newer research has linked NO_2, ozone, and other outdoor air pollutants. to cardiovascular harm, lower birth weight in newborns and increased risk of premature death.[4]

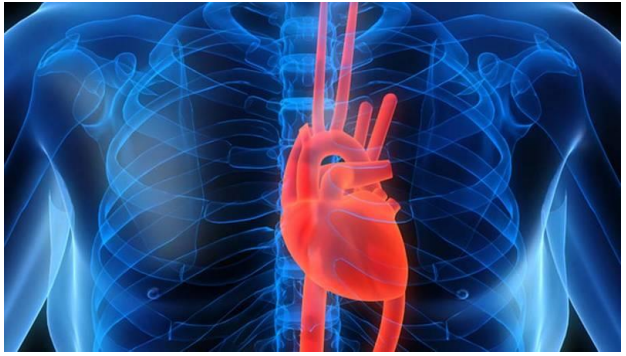
https://www.lung.org/clean-air/outdoors/what-makes-air-unhealthy/nitrogen-dioxide

Environmental Impact of NO_x

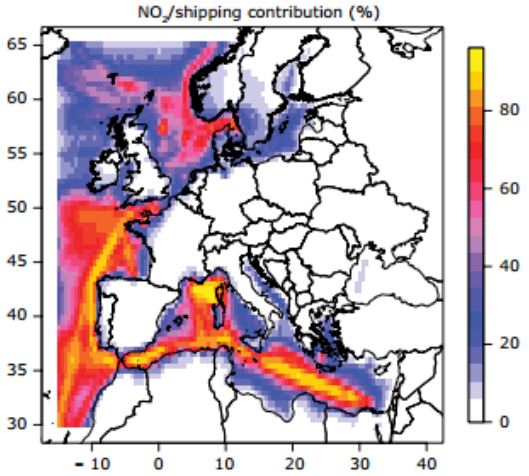
NOx molecules react with volatile organic compounds (VOC) and form under sunlight and higher temperature ground-level (or tropospheric) ozone (O_3).
Ozone at the ground level is a serious pollutant. Ozone in addition to the health impact, damage plants and materials like cotton.
NOX contribute to acid rain and nutrification of soil. It also
Additionally NOx deposion into water provides algaes with attitional nutrients and leads to algal blooms.

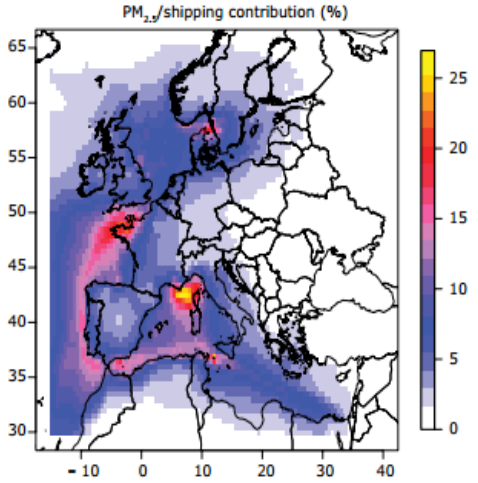
Problem: BlackCarbon(1)

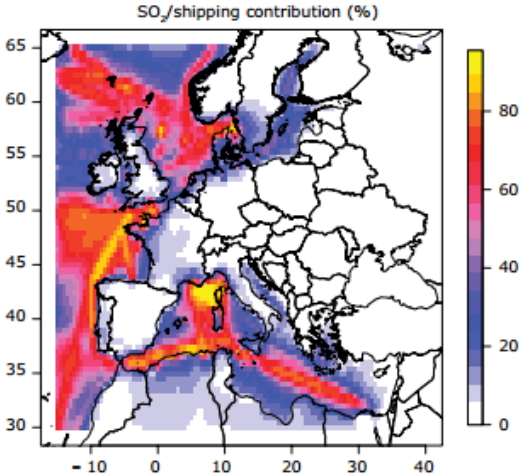
- results from the incomplete burning of fossil fuels and biomass
- component of PM
- shortens life expectancy
- causes respiratory and cardiovascular diseases
- can cause lung-cancer

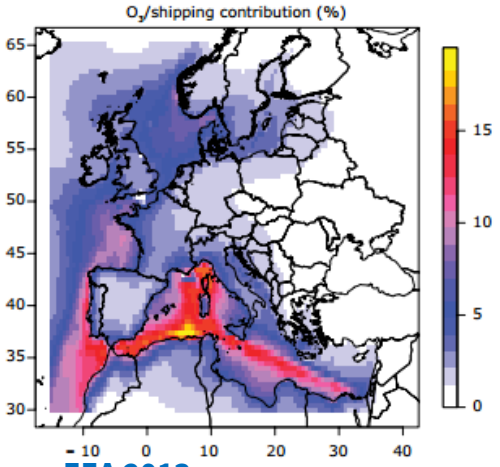


Maps of Contribution of Shipping Emissions in % to the Annual mean of NO2, SO2, PM2.5 and Av. of the Summer daily max O3



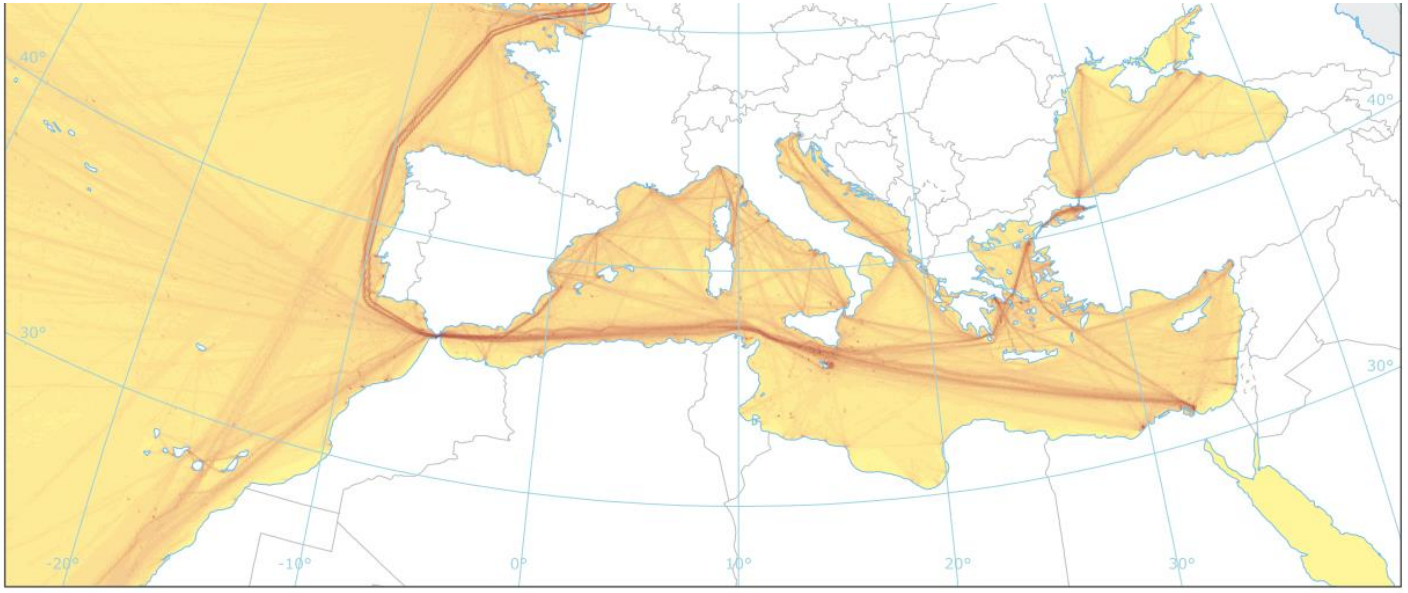




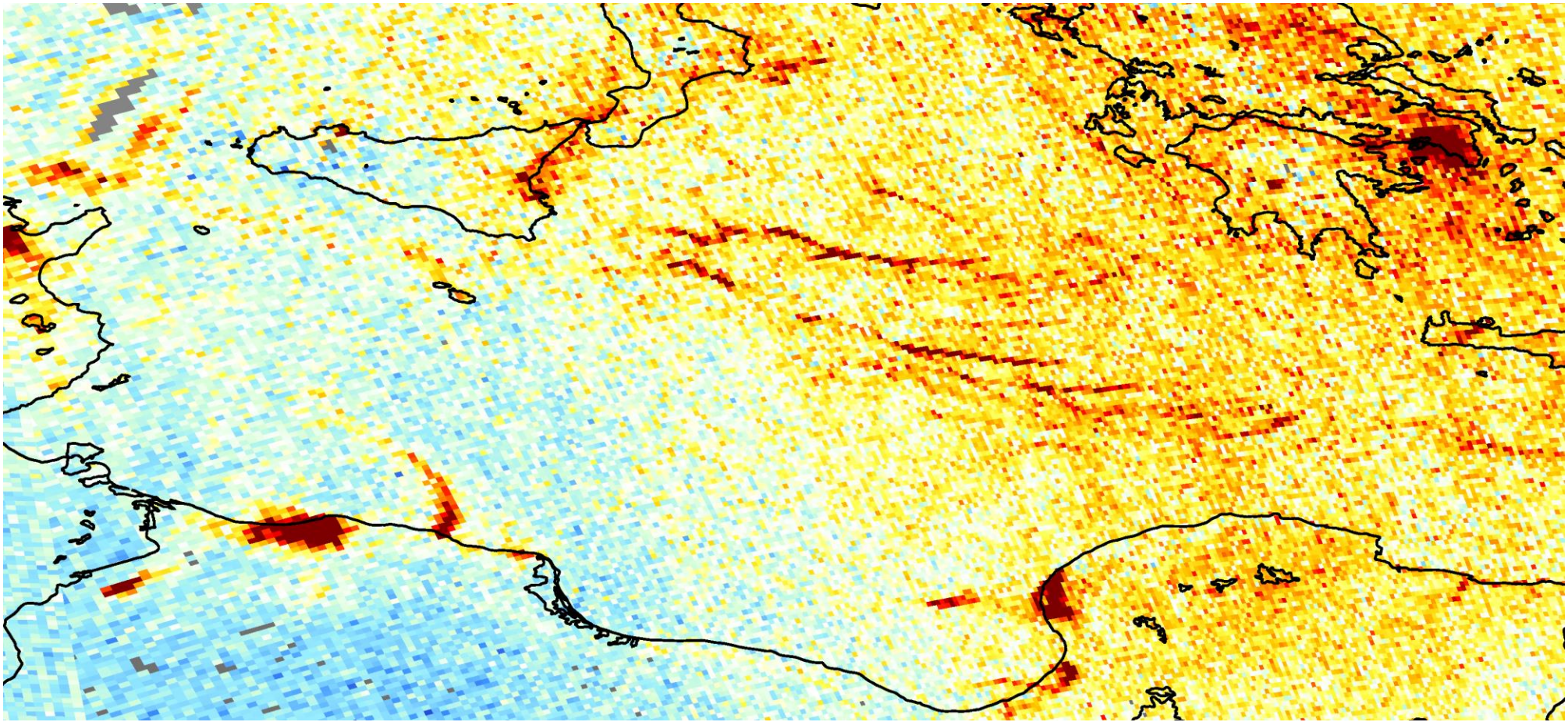


Source: EEA 2013

NOx Emissions from Shipping in the Mediterean Sea



Source: STEAM (2021).



https://www.esa.int/ESA_Multimedia/Images/2020/11/Nitrogen_dioxide_emissions_over_the_Mediterranean

EU Air Quality Directive 2008/50/EC

Pollutant	*Concentration*	*Averaging period*	*Legal nature*	*Permitted exceedences each year*
Fine particles (PM2.5)	25 µg/m3***	1 year	Target value entered into force 1.1.2010 Limit value enters into force 1.1.2015	n/a
Nitrogen dioxide (NO2)	200 µg/m3	1 hour	Limit value entered into force 1.1.2010	18
	40 µg/m3	1 year	Limit value entered into force 1.1.2010*	n/a
PM10	50 µg/m3	24 hours	Limit value entered into force 1.1.2005**	35
	40 µg/m3	1 year	Limit value entered into force 1.1.2005**	n/a

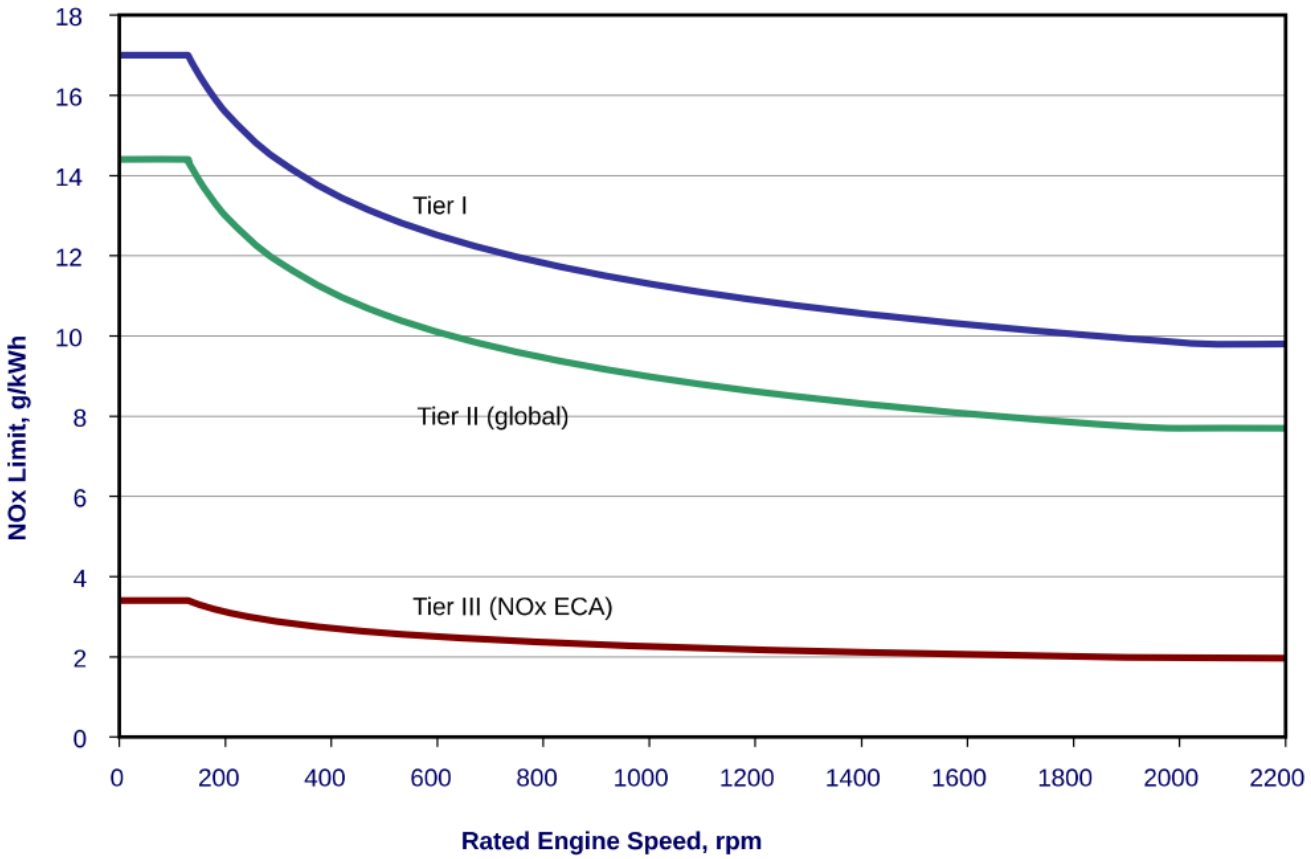
WHO Air Quality Guidelines

World Health Organization

Recommended 2021 AQG levels compared to 2005 air quality guidelines

Pollutant	Averaging Time	2005 AQGs	2021 AQGs
$PM_{2.5}$, $\mu g/m^3$	Annual	10	5
	24-hour[a]	25	15
PM_{10}, $\mu g/m^3$	Annual	20	15
	24-hour[a]	50	45
O_3, $\mu g/m^3$	Peak season[b]	-	60
	8-hour[a]	100	100
NO_2, $\mu g/m^3$	Annual	40	10
	24-hour[a]	-	25
SO_2, $\mu g/m^3$	24-hour[a]	20	40
CO, mg/m^3	24-hour[a]	-	4

Marpol Annex VI NO_x Emission Limits



Emission Limits HDV EU Euro VI:

0,4g/kWh Nox

0,01 g/kWh particles

$8{,}0*10^{11}$ particle number

Sea ships: No limits for particles

https://dieselnet.com/standards/inter/imo.php

NO_2 Measurement with Passive Sampler

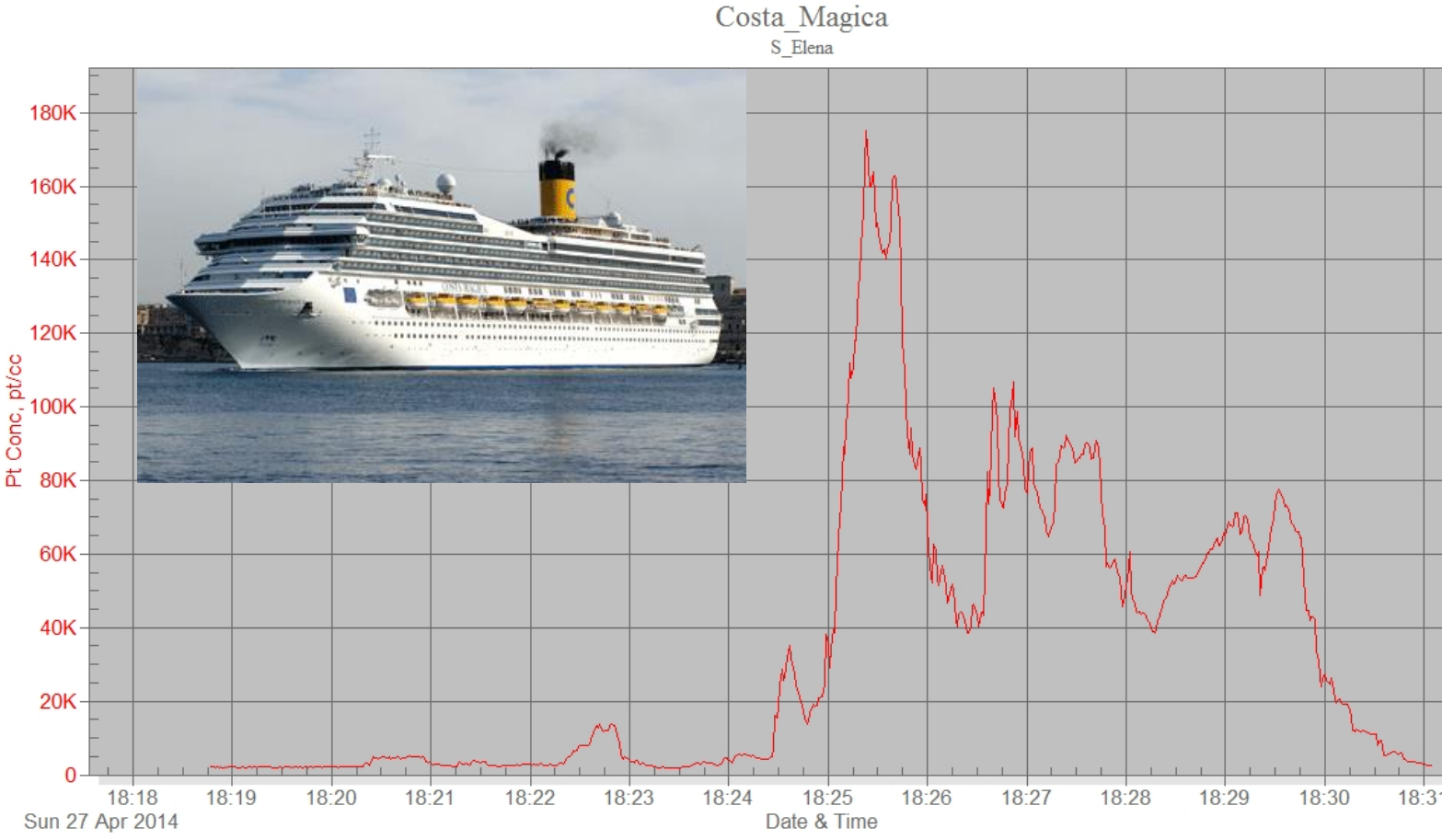
1	Location	focus	Date On	Date Off	µg/m^3 *
2	Molo Beverello, 80133 Naples	marine traffic	09.06.2018	10.07.2018	93,04
3	Calata Porta di Massa, 80133 Naples	marine traffic	09.06.2018	10.07.2018	81,29
4	Varco Immacolatella Vecchia, Naples	marine traffic	09.06.2018	10.07.2018	80,73
5	Varco Immacolatella Vecchia, Naples	marine traffic	09.06.2018	10.07.2018	74,99
6	Molo Beverello, 80133 Naples	marine traffic	09.06.2018	10.07.2018	53,37
7	Isola nova del Tronchetto, 14, 30135 Venezia	marine traffic	11.06.2018	06.07.2018	50,45
8	Via Rupi XXIX Settembre 3, 60125 Ancona	marine traffic	08.06.2018	08.07.2018	49,13
9	Msida roundabout, Msida	traffic	08.06.2018	06.07.2018	45,98
10	Trieste - Passeggio, Santiandrea	marine traffic	20.07.2018	18.08.2018	43,62
11	Calata Porta di Massa, 80133 Naples	marine traffic	09.06.2018	10.07.2018	43,04
12	8 Quai des Docks, 06300 Nice	marine traffic	08.06.2018	06.07.2018	42,65
13	Isola nova del Tronchetto, 14, 30135 Venezia	marine traffic	11.06.2018	06.07.2018	41,58
14	8 Quai des Docks, 06300 Nice	marine traffic	08.06.2018	06.07.2018	39,93
15	Piazza Caduti per la Libert 12, 19100 La Spezia	monitoring station (5m)	07.06.2018	06.07.2018	38,98

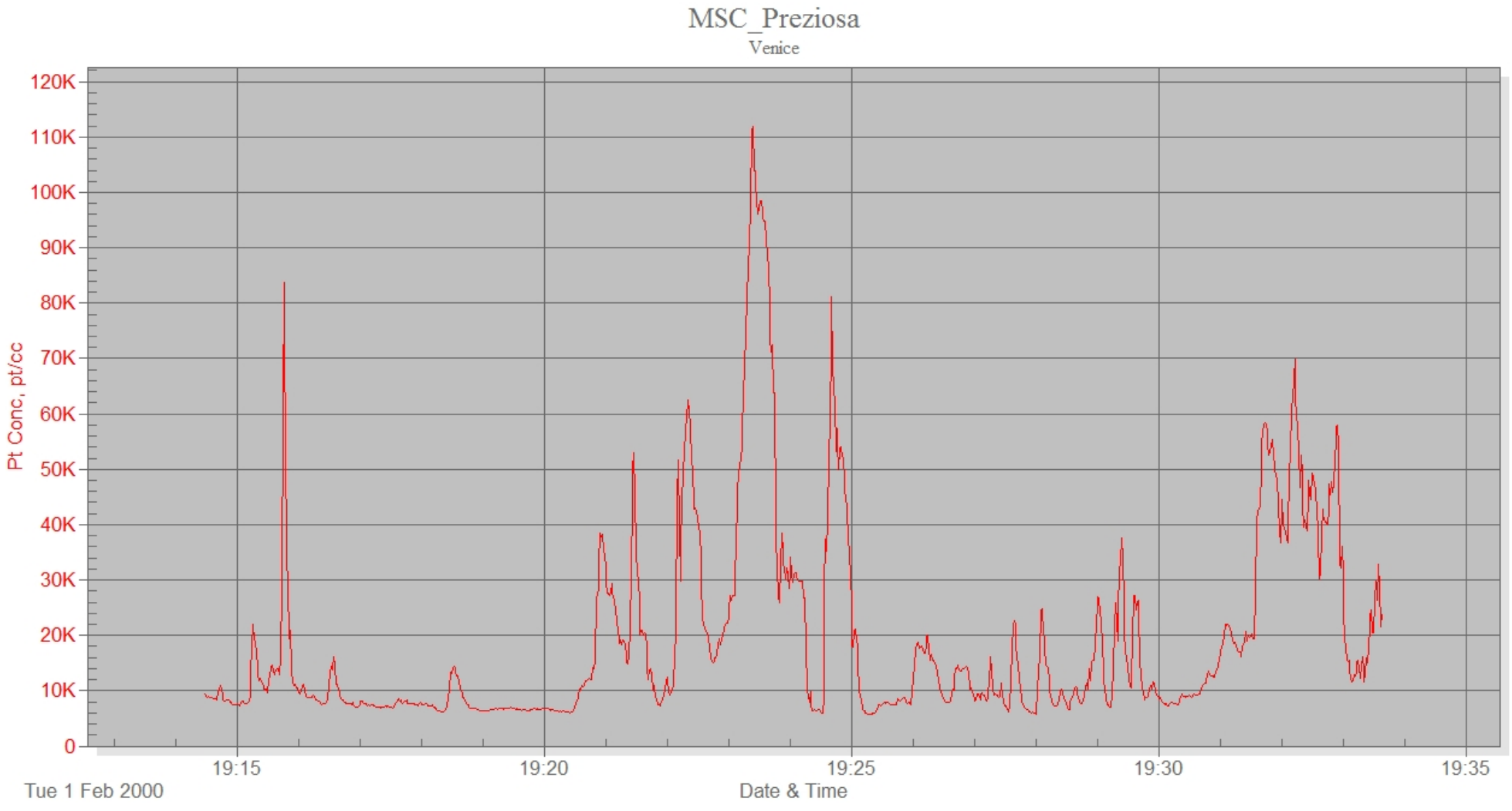
Particle Number Measurements

Measurements of Air Quality in Mediteranean Cities

- Measured ultrafine exhaust particles.
- Particles smaller than 100 nm consisting of soot (black carbon) coated with PAHs and heavy metals.
- Ultrafine particles are deposited in the finest parts of the lungs (alveoli) and transferred into the blood.
- Clean air in Europe contains 1,000-3,000 particles per cm^3.

Cruise ship emissions: Peanuts?

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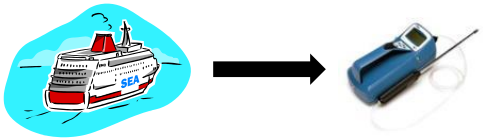


Genoa with/without cruise ship: 6-10 m/s

With cruise ship

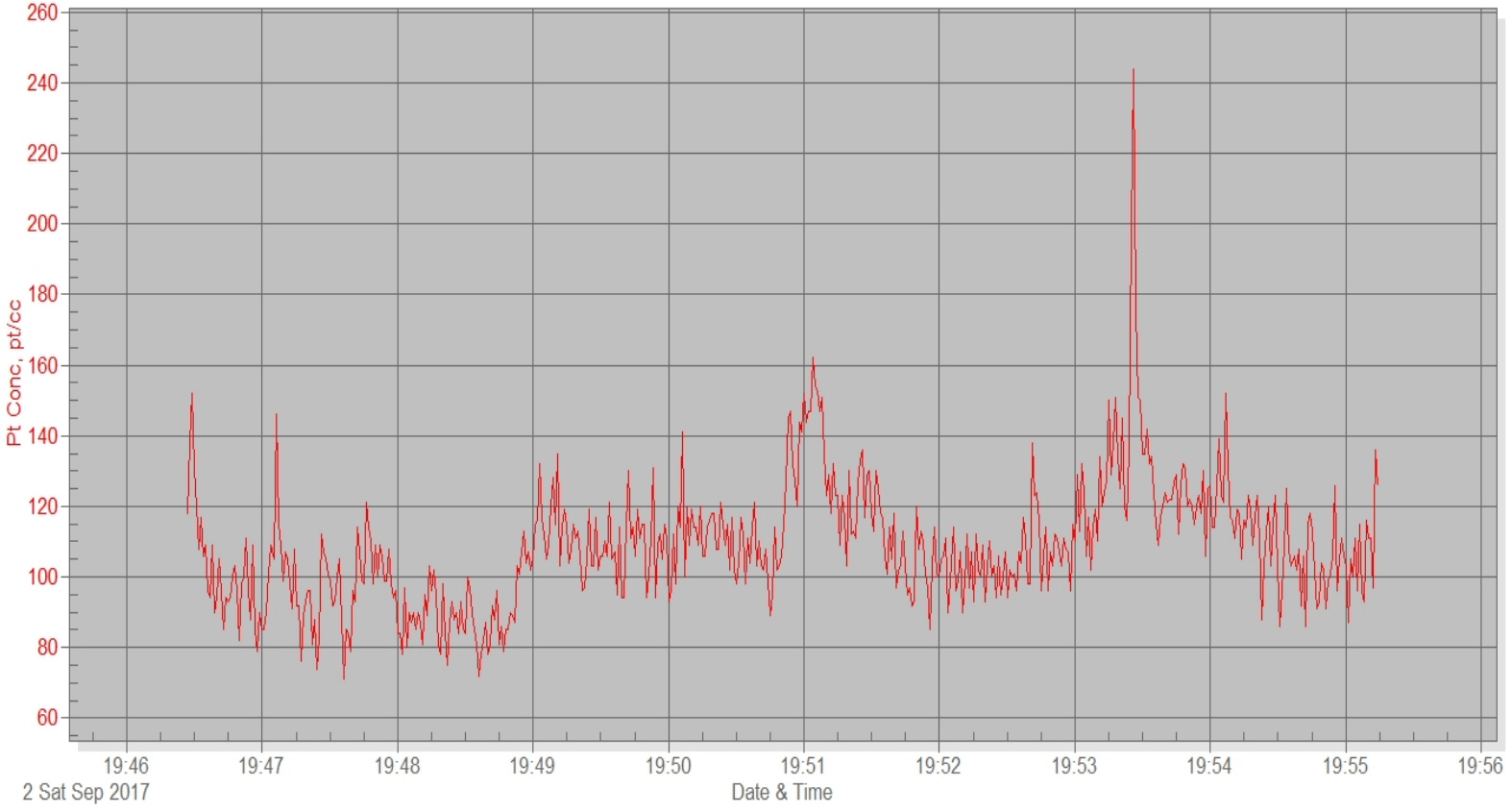
Without cruise ship

Results from measurements

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

Shipping cause significant pollution of Italian port cities.

Clean Air Spitsbergen



Particle Number Measurement at Ship Smoke Stack with Particle Filter

Particulate counter shows very low UFP concentration directly next to the smoke stack.
Foto:NABU/Diesener

Future SECA in the Mediterranean Sea

- An SECA is proposed by the contracting parties of the Barcelona Convention to the IMO for decision. It means from the 1st of January the maximum S- content in marine fuel will be 0.1 %
- The proposed area of application is identical to the geographic area described in Article 1.1 of the Barcelona Convention, which is hereinafter referred to as the Mediterranean Sea area. The waters of the proposed Med SOX ECA involve the twenty-two (22) Contracting Parties to the Barcelona Convention, namely Albania, Algeria, Bosnia and Herzegovina, Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Lebanon, Libya, Malta, Monaco, Montenegro, Morocco, Slovenia, Spain, the Syrian Arab Republic, Tunisia, Turkey, and the European Union.

Conclusion

The evidence of the air pollution level of NO, NO2, Ozone and particles show the urgent need to introduce not only a SECA, but also a NECA and a PECA in the Mediterranean Sea.
Analyses from research groups like IASSA and INERIS show that the benefit is much higher than the abatement cost

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