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Monitoring the quality of air in the port of Naples

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ABSTRACT: Recently the assessment of the impact of atmospheric emissions of cruise ships in ports on the air quality of urban areas has received a large interest. This is due both to the entity of these emissions and to the proximity of ship mooring points to the center of the towns. In fact, cruise ships need a large amount of electric energy to feed hull and hotel services when they stay at berth. This energy is produced by auxiliary engines. In order to study the air quality in the port of Naples (Italy) and the correlation between air quality and ship cruise emissions, two monitoring campaigns were carried out during 2012. Concentration of the main pollutants was monitored continuously for 15 days in April and 15 days in November. Simultaneously, the presence of ships in port was registered in order to evaluate the emission rate of atmospheric pollutants coming from the exhausts of the ship engines. Spatial distribution of pollutants was measured by passive samplers. Area selected represents sites close to the busiest berths. In this paper the main results of the first campaign will be presented together with an analysis of the spatial distribution of pollutants, and of the correlation between their concentrations in air with ship activities in port.

1 INTRODUCTION: THE PORT OF NAPLES (40°51'19" N–14°15'36" E)

Naples is the main harbour of southern Italy; both traffic of goods and passengers can benefit from more than 11 km of banks with 75 mooring points, 3 km road infrastructures and about 2 km of rails connected with the national railway network.

It is one of the main ports of departure and destination for cruises in the Mediterranean.

In order to give an idea of marine activities involved in this harbour, in Table 1 last available data are reported about cargo and passengers traffic.

The port, that covers a total area of about 2.304.000 m^2, is fully hemmed in by residential areas (Musso, Piccioni, Van de Voorde 2013). The extent, the business developed in it, the closeness to one of the most densely inhabited zones in Italy, made it extremely reasonable and urgent to predict and measure the real impact of maritime activity on the life of people living and working in the surroundings.

On the other hand, first results don't reveal a very dangerous environment or, at the least, a noxious environment due exclusively to the operations of ships.

An instrumented van was positioned close to a dockside of the port of Naples named "Molo Beverello", normally destined to host cruise ships. Hourly average values of NO_2, SO_2, CO and PM10 were obtained by using reference analytical methods established by EC directives (PM10 was measured using equivalent method: nephelometry).

Table 1. Main data on traffic in the port of Naples.

Goods	Reference period	Unit	#
General cargo	2012	t	20.038.162
Containers	2008	TEU	481.521
Containers	1/2013	TEU	37.789
Cruise	2012	Pax	1.228.651
Local traffic	2007/2008	Pax	5.791.880
		Commercial vehicles	111.043
		Cars	189.930

2 ASSESSMENT OF AIR QUALITY IN THE PORT AREA

Before starting the full scale tests, a series of preliminary studies have been carried out to assess the possible impact of atmospheric emissions of maritime traffic in ports and its general dimensions (Caputo 2013; Balsamo & Quaranta 2005). Afterwards, two test campaigns were carried out; the first one lasted from March, 28th to April, 9th.

Passive samplers (Radiello®) were positioned in various sites in order to measure the period average concentration of NO_2, SO_2 and BTEX (Fig. 1).

Together with atmospheric pollutants, meteorological parameters (wind intensity and direction, rain, pressure, humidity and temperature) were measured by using sensor type "Davis" at the mobile lab. The results of first air monitoring campaign are reported in Table 2.

Figure 1. Location of passive samplers in the port area of Naples (F2 is the position of mobile lab, F1 is the position of instruments close to it).

Table 2. Results of first monitoring campaign by passive samplers and continuous analysers (*Benzene, Toluene, Ethyl Benzene and Xylenes).

Pollutant	Average [µg/m³]	Min [µg/m³]	Max [µg/m³]	Confidence interval [µg/m³]
BTEX (*)	13,14	9,4	17,67	11,29–15,56
Benzene	1,42	0,78	1,73	1,16–1,68
Toluene	5,73	2,68	9,6	4,33–7,13
Ethylbenzene	1,18	0,97	1,41	1,06–1,30
m+p-xylene	3,83	2,34	5,96	3,13–5,54
o-xylene	1,21	0,78	1,52	1,01–1,40
NO_2	44,14	24,72	74,29	31,69–56,58
SO_2	2,93	0,28	8,61	1,46–4,40
NO_2 (analyser)	48,41	10.49	156.49	
SO_2 (analyser)	6.41	5.34	26.61	
PM_{10} (analyser)	27.18	0.57	95.51	

Measured concentration levels are significantly below EC limit values (Directive 2008/50/EC) reported in Table 3.

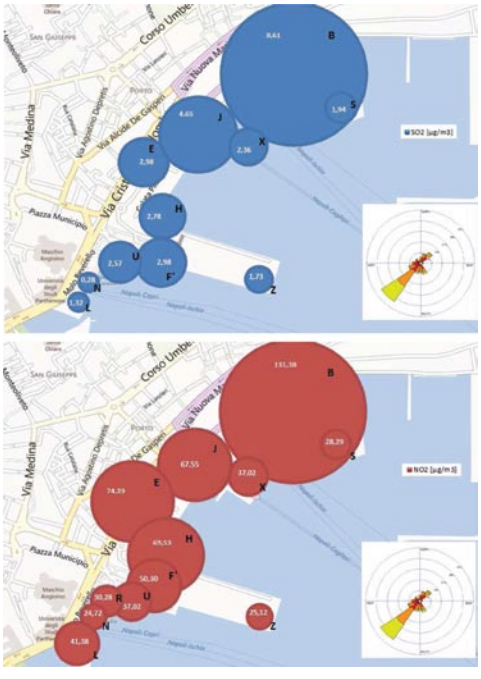
Passive samplers are indicated with a letter from B to Z in Figures 1–3.

In Figures 2 and 3 the spatial distributions of NO_2 and SO_2 are reported.

In both figures, in the bottom right angle the wind rose for the same period of the monitoring campaign is reported. During the first campaign the prevailing wind direction was from SW to NE. This is typical of spring time in Naples. It can be observed that both NO_2 and SO_2 show a certain correlation between air concentration level and downwind distance (the concentration increases with downwind distance). This is an indication of

Table 3. EC Limit values for ambient air.

Pollutant	Average type	Limit
NO_2	1 hour	200 µg/m³
	1 year	40 µg/m³
SO_2	1 hour	350 µg/m³
	1 year	125 µg/m³
PM10	1 day	50 µg/m³
	1 year	40 µg/m³



Figures 2 and 3. Spatial distributions of NO_2 and SO_2.

the contribution of NO_2 and SO_2 sources present in the port area to air quality.

3 ASSESSMENT OF SHIP EMISSIONS

It is generally a hard task to assess a reliable value to the ship emission rates of pollutants in the atmosphere.

This is due to two different aspects of operations of ships when in port. First of all, the real power rated by engines is unknown and its determination is possible (with difficulty) only after each working period, since the load profile on auxiliaries is generally variable and fairly unpredictable. On the other side, the real requirement of power for electric services onboard depends on the state of the ship, on the number of persons on board, on the operative choices which makes the determination of the electric load needed even harder.

Since a direct determination of the emissions from engines was not possible, the assessment of NOx emissions was made by using a method that the authors consider reliable: since to obtain the IAPP certification the ship has to cope with the MARPOL Annex VI directives and the related setting of engines involves some decay of their performance, it was supposed that any engine could emit the maximum allowable rate of NOx according to the Regulation 13 (Chapter III) of the MARPOL Annex VI.

So, since generally cruise ships have engines running @ 600 rpm and using a reasonable value of the load factor (0.64 drawn out from California Air Resources Board 2005), the power rate from each engine of the ships in port during the campaigns was predicted by using a database of ships similar to those really present in port. The related level of NOx emissions was then predicted (by following the method described in Battistelli, Coppola, Fantauzzi, Quaranta 2011 & 2012) and, then, compared with the concentration of nitrogen oxides measured in the atmosphere.

Since limits of contents of nitrogen oxides in air are given in terms of NO_2 (and already given in Table 3) while their maximum emission from engines is in NOx (but expressed as NO_2 equivalent), in diagrams these compounds are reported and, in case of NO_2, compared with its maximum limit in the air.

A similar routine is impossible with SO_2 whose limitation is not achieved by the engine setting but by containing the overall concentration of sulfur in the fuel.

On the other hand, today's ships must use low-sulfured fuels when in ECA ports (Naples is one of them); this considerably reduces the emissions of SO_2 and, consequentially, its concentration in the air (results will confirm this).

Consequently, the diagram representing SO_2 emissions, reports only the measured concentration of this component in the air.

4 CORRELATION OF AMBIENT AIR CONCENTRATION WITH EMISSION RATES

Diagrams in Figures 4 and 5 report the comparison between NOx emissions from ships with

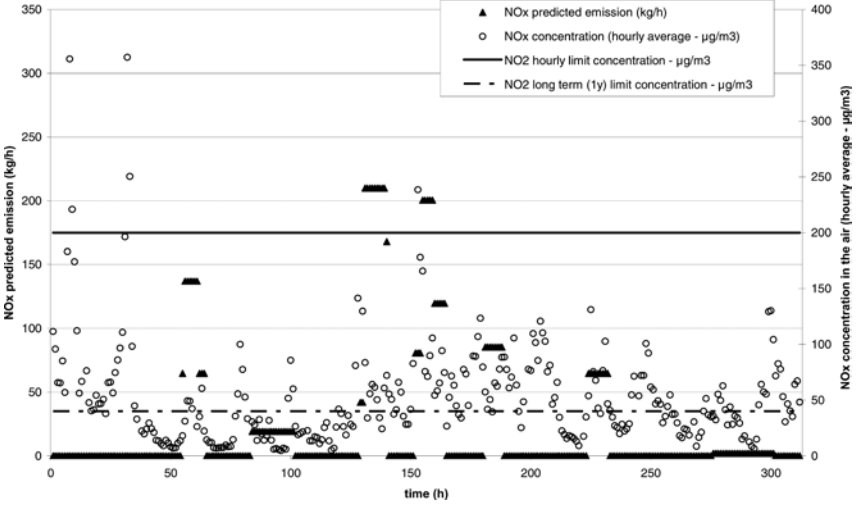


Figure 4. Comparison between NOx predicted emission and ambient air concentration of NO_2.

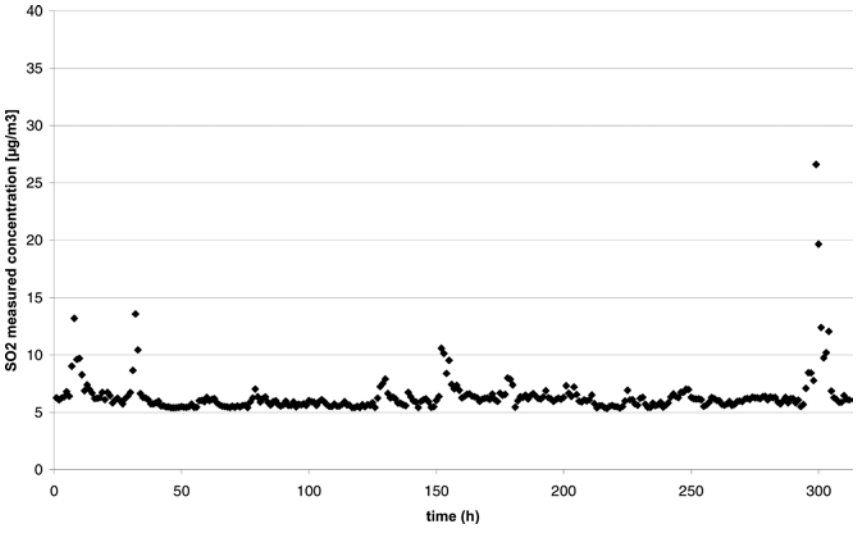


Figure 5. Ambient air concentration of SO_2.

concentration of NO_2 in the air and the concentration of SO_2 measured in the air.

From these diagrams the following conclusions can be drawn.

In general, the dependence of the noxious substance concentrations in the air emissions is evident; except for the first days (when no cruise ships were in port but level of NOx was significantly high), there is a clear relationship between emissions and pollution levels. On the other hand, in order to connect the effect on the air of the presence of ships more evidently, other variables must be investigated, in particular the presence of ships other than cruise ships in port.

The concentration of SO_2 in the atmosphere is always very low with some very rare peak that doesn't overcome 30 µg/m^3 (minimum EC limit is 125 µg/m^3 in 24 h): low sulfur fuels work well!

NOx may constitute a problem coming from the vessel traffic (Lonati, Cernuschi, Sidi 2010): indeed, their concentration in the air is meanly lower than the present hourly acceptable limit (200 µg/m^3) although some rare higher values (over 300 µg/m^3) have been detected. Year maximum allowable limit (40 µg/m^3) was often overcome but this can be considered acceptable while considering that in less busy periods, with less cruise ships at the berth, the level of NOx is much lower and the year-based emission figure will be predictably lower.

However, we will be definitively sure of this when we will extend the monitoring of the quality of the air in the port of Naples to other periods of the year in order to log more data about the potential pollution of this area.

5 CONCLUSIONS

Results show that ambient concentrations of some main air pollutants in the port of Naples are below the EU limit values. Even though some peaks overcome these limits. Some correlation between NO_2 and SO_2 ambient air concentrations measured in the port area with emissions from cruise ships exists. This has been proved both by an analysis of spatial distribution with respect to prevailing wind direction and from hourly diagram of emissions and concentrations.

Apart from these results, our work is an attempt to give figures about the abovementioned situation to keep under control the concentration in the ambient air of the main pollutants emitted by ship engines during their stay in ports, and to build an analytic tool able to supply an easy correlation between the emissions from ships and the level of pollution.

Both activities involve problems of knowledge of the real phenomena acting close to the berths where ships stay: the first one means exact information (and interpretation) of the influence of meteo parameters on the distribution in the atmosphere of the emissions from the engines of the ships. The second problem can be reasonably solved by gathering enough data on the ships at wharf, their polluting attitude, the electric load factors, and so on.

Although the proposed test method must be completed and improved, results of this first full scale test show some problems when many ships are contemporaneously berthed in a restricted area, close to each other, with a significant number

of their engines on to produce the electric energy needed for the services onboard.

Certainly, it would be very important to build regular systems to control the traffic of cruise ships (the most polluting when in port) by keeping in mind their pollutant capability.

In conclusion, this kind of investigation can be considered as preliminary for the study and application of remedies aimed at lowering the environmental impact of the operations of ships in ports. For example, the feed of electric energy to ships from terrestrial sources is now considered very interesting and it is applied in particular locations; in Battistelli, Coppola, Fantauzzi, Quaranta (2012) an outlook of this question and some real situations where cold ironing is applied with related problems and advantages.

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