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Assessment of the impact of ship emissions on the air quality in Naples

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ABSTRACT: The paper report the results of a monitoring campaign of SO_2, NO_2 and Benzene carried out in the port of Naples and inside the nearby urban canopy from 20th January to 8th March 2016. The activity is a continuation of a previous monitoring campaign realized by the authors in 2012. About 40 passive samplers were placed and average concentration in the period for the three pollutants was evaluated. Concentration levels observed are lower than limit values established by European directives both for SO_2 and NO_2. Benzene in some place of measure exceeded the limit value (5 g/m^3) that is fixed, however, as annual average. Results have been interpreted by an interpolation algorithm using the software SURFER® obtaining contour maps that show significant differences among the three pollutants. In fact, maximum levels of SO_2 occur inside the harbour area, those of NO_2 inside the urban area while Benzene maximum average concentrations in the period occur at the boundary between port and urban canopy. This result has been interpreted on the basis of the occurrences of wind direction and speed measured in the same observation period.

1 INTRODUCTION

In a previous paper [Prati et al. 2015] the authors reported results of a monitoring campaign of SO_2, NO_2, PM10 and BTEX carried out in 2016 inside the area of the port of Naples in spring (14 days) and Fall (19 days) sessions. About 15 passive Radiello® samplers were located inside the port area. Time-averaged concentrations in the period were: SO_2 (8.5 g/m^3), NO_2 (41.1 g/m^3), PM10 (29.8 g/m^3) and Benzene (1.0 g/m^3). Results indicated that pollution levels were lower than limit values established by European legislation. In that paper the authors tried also to assess the impact of ship emissions through the interpretation of spatial distribution of pollutants monitored and wind direction and speed observed in the same period of the monitoring campaign. It was observed that a certain correlation exist between ship emissions and concentration measured at pedestrian level especially for SO_2. Moreover it was observed for the other pollutants a good correlation between data of monitoring stations located in the urban canopy of Naples.

One of main limitations of the previous study was the absence of data for SO_2 inside the urban canopy. In this study the area monitored inside the port of Naples is quite larger with respect to that studied previously [Prati et al. 2015] covering about all the port area. And still more important, SO_2 has been measured also in the urban canopy in several points. However, the results of present campaign are limited to the wind conditions occurring during the campaign. The wind was blowing mainly from N-NE. This is a typical condition during winter season and in summer but only during night time and with low wind speed.

The aim of the present paper is to verify the air quality in the port of Naples by means of a new monitoring campaign and evaluate the impact of ship emissions on air pollution in Naples by using data collected both inside and outside the port area.

2 THE TRAFFIC OF CRUISE SHIPS IN THE PORT OF NAPLES: PRELIMINARY ESTIMATE OF THE EMISSIONS FROM CRUISE SHIPS

The values of concentration of noxious substances logged in the campaign under description here were measured with passive samplers; thus analyses give the average concentration in the period due to overall amount of pollutant matter released during the entire observing time.

Therefore, it could be useful to evaluate the "pollutant capability" of the most important category of vessels in harbor, i.e. the cruise ships. Their significant contribution to the overall air pollution in ports is due to the need of electric energy when the ship is moored to supply both hull and hotel services.

Thus, in order to provide reference values of the emission of NOx, the method normally used is to re-late it to the value of the power generated by the engines onboard [Battistelli et al. 2011 and 2012]. Since it is impossible to know these values with accuracy, authors used a prediction algorithm capable of giving an approximate value of this parameter, starting from a significant value characteristic of the ship. A good correlation has been assessed by using the overall length of the ship as in-dependent variable for the evaluation of the mean power delivered by generators onboard during berth-ing. With the help of the "mooring plan" (i.e. the list of the ships moored in the Port of Naples during the period of observation), it has been possible to reconstruct the presences of each cruise ship. And by knowing their propulsion plants, it has been possible to estimate the power release in port by applying a statistical tool based on a data base of similar ships when the power generated at berth is known for each of them and for each period of the observed time.

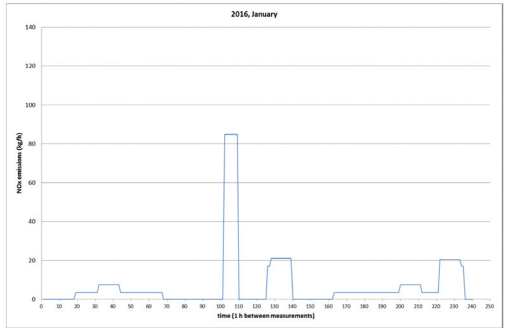
Finally, from the power release in port, the evaluation of the emissions of NOx has been made possible by applying the emission factors suggested by the EMEP-EEA air pollutant emission inventory guide-book 2016 (Table 3.9 and 3.10). The Tier 3 methodology is based on information for individual ships and emission factors are provided for different engine types/fuel combinations and vessel trip phases (cruising, hotelling, manoeuvring) in g/kWh.

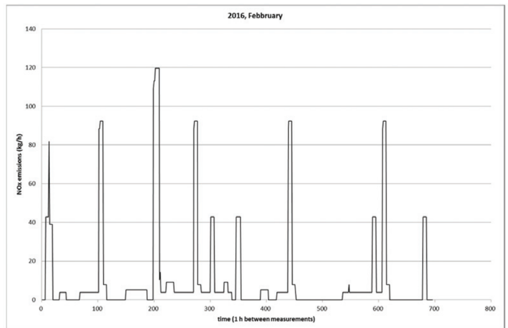
This led to the determination of the hourly mean emission of NOx for the whole period of observation; in Figs. 1 to 3 these results are reported with reference to January, February and March, 2016

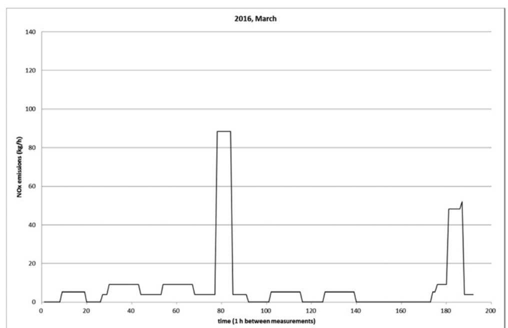
Further elaboration with the aim of connecting the emissions form ships to the concentration of noxious in the air is quite useless since the evaluation of the pollutants with passive samplers is global and it cannot follow the time-dependence of emissions.

However, with this method it is possible to supply some figures representing the mean value of the emissions of NOx in kg/h; in the whole period of observation (49 days) the mean emission of NOx from cruise ships (day and night) has been of about 9.5 kg/h. This emission caused the pollution measured that will be presented later on.

A different situation regards the SOx emissions which are not related to the operating conditions of the engines but to the content of S in the fuel burned in ports. In the port of Naples cruise ships use normally 0.1% sulphured fuels and this allows







Figures 1, 2 and 3. Hourly emissions of NOx evaluated using EF.

to lower the rate of SOx in the exhausts dramatically [Prati et al. 2015].

3 ASSESSMENT OF AIR QUALITY IN THE PORT AREA AND IN THE URBAN CANOPY

Air quality in the harbour of Naples and inside the nearby urban area was measured from 20th January to 8th March 2016. Thirty-six passive samplers located inside the port area (numbered from 1 to 35 plus X in the maps) and five in the urban canopy (from A to E) to measure the concentration of SO_2, NP NO_2 and Benzene. Ten additional sam-

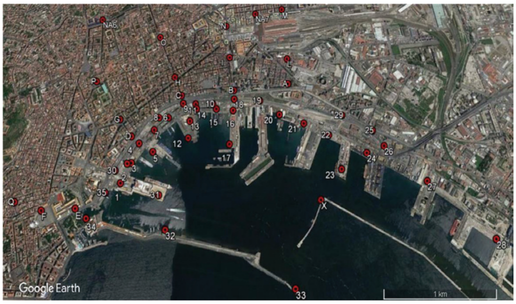


Figure 4. Location of passive samplers.

Table 1. Data of passive samplers: spatial average, maximum and standard deviation; measured in porta area and urban canopy.

Pollutant	Average [g/m^3]	Max [g/m^3]	Dev STD [g/m^3]
NO_2 port	11.24	20.01	3.77
NO_2 urban	13.24	15.32	2.71
SO_2 port	3.06	19.09	4.11
SO_2 urban	1.36	3.05	0.72
Benzene port	3.48	5.7	0.75
Benzene urban	5.42	7	1.33

Figure 5. NO_x, SO_x and Benzene contour maps.

plers (indicated form F to Q in the maps), measuring SO_2 only, were placed in the urban canopy to overcome the absence of SO_2 analyzers in the air quality monitoring stations of urban network.

Data by three monitoring stations of the air quality network of the Regional authority were also acquired and used to complete the data base. Location of passive samplers is reported in Fig. 4.

Pollutants were captured using the Analyst® passive sampler developed by CNR Institute of Atmospheric Pollution. Samplers were then analyzed using standard methods. Average concentrations in the period were then obtained for each of three pollutants.

Wind direction and speed were measured in a monitoring station inside the port. Prevailing direction was from N-NE (average direction 22.5°) with about 35% of whole observations. Wind speed was mainly and equally divided in three categories:

0.5–2 m/s; 2–4 m/s; 4–6 m/s.

Results of analysis of passive samplers are reported in Table 1.

Results reported in Table 1 confirm those measured in the previous monitoring campaign [Prati et al. 2015]. The comparison with limit values, indicates that all pollutants are below the limit values apart from Benzene in the urban area. It must be remembered, however, that limit values are defined in a one solar year observation time. It can be observed that only SO_2 shows both as average than as maximum higher values in the porta area with respect to data collected in the urban canopy.

Data collected during the monitoring campaign, together with data from air quality monitoring stations, have been used to create contour maps reported in Fig. 5.

Contour maps reported in Fig. 5 show that maximum of SO_2 average concentration in the period occur inside the area of the port probably due the emissions of ships maneuvering in the port and of ships at berth in docks located in the north-east part of the port corresponding to commercial area. On the contrary maximum of NO_2 concentration occur in the urban canopy.

This evidence associated with the observation that prevailing wind direction was from N-NE leads to the conclusion that contribution of ship emissions to NO_2 levels is less relevant with respect to contribution from other sources. Maps of Benzene are intermediate between SO_2 and NO_2 maps and maximum values occur at the edge between port and urban canopy.

4 CONCLUSIONS

Results reported confirm that of a previous monitoring campaign [Prati et al. 2015]: the air quality inside the port of Naples is not critical. Present results cover a larger part of the port with respect to the previous campaign. This, however, does not mean that the impact of emissions from ships on air quality in the urban canopy of Naples is not significant. Ship emissions, due to the height of the sources, can impact at pedestrian level far from the port area. To have an insight on this aspect we have interpolated data from the port area and the urban canopy obtaining contour maps. Maps show that impact of ship emissions is relevant on SO_2 concentration levels, while other sources play a main role in determining NO_2 concentration. A similar conclusion was reached in a previous campaign [Prati et al. 2015] using a different method.

It must be remarked that there is a limited number of studies on global shipping emissions which contain estimations on the in-port emissions, that is ship emissions in ports. Generally there are relatively inexact data or assumptions on the time that ships spent in a port, as discussed by [Merk O. 2014]. A fairly recent approach is to use Automatic Identification System (AIS) data to refine the maritime data [Tichavska et al. 2015], which enable the positioning of ship emissions with a high spatial resolution (typically a few tens of metres) [Huanga et al. 2017].

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