Air quality assessment in 'Area C', the new Milan city center traffic restriction zone. PM10, PM2.5 and Black Carbon results of the 2012 wintertime campaign at urban residential sites

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Background

Particulate matter (PM) is a heterogeneous mixture of suspended particles with different physicochemical properties depending on meteorological conditions and emission sources Current air quality standards for PM use the mass concentration of PM10 and PM2.5 as a metric, on the basis of epidemiological studies showing strong associations between ambient PM mass concentrations and several adverse health effects. However, due to heterogeneity of PM, it is likely that different PM component have different importance for toxicity standpoint (WHO, 2007).

Combustion-related particles are thought to be more harmful to health than PM that is not generated by combustion. In urban areas, road traffic is a major source of combustion PM and a well known health risk factor with a huge buden of disease (Kuenzli et al., 2000). A more recent assessment of traffic exposure concluded that there is sufficient evidence to support a causal relationship between exposure to traffic-related air pollution and exacerbation of asthma, and suggestive evidence of a causal relationship with onset of childhood asthma, nonasthma respiratory symptoms, impaired lung function, total and cardiovascular mortality, and cardiovascular morbidity (Health Effects Institute, 2010).

Although many factors contribute to the high particulate matter (PM) levels in Milan, a city located in the Po Valley, Italy, which is one of the most polluted EU areas, road traffic is an important pollution source, and different traffic restriction interventions have been implemented in the recent years to improve air quality in the city center. However, so far the evidence of PM reduction has been scanty (Kelly et al., 2009). By January 16th 2012 the Milan Municipality implemented new private traffic restriction scheme called 'Area C', which prohibits the circulation in the city center of diesel cars Euro 0, 1, 2, and 3, while a ticket is required for Euro 4-6, and for gasoline fuelled cars Euro 1-6 (Fig. 1).

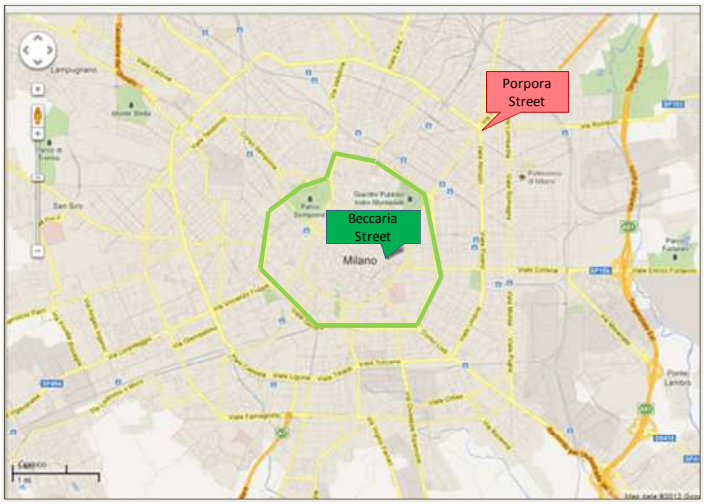

Figure 1: Map of Area C surrounding Milan city center and locations of the two urban residential sites

Only electric and hybrid cars, and those fuelled with GPL and methane are allowed to enter Area C for free. Area C is operating on workdays from 07:30 am to 07.30 pm. This Limited

Traffic Zone (LTZ) was introduced in observance to the results of a public referendum indicating that the vast majority (79%) of Milan citizens wanted to potentiate public transports and to limit traffic-related pollution.

The Milan Municipality is currently carrying out an air quality monitoring project to assess the effects of Area C by using black carbon (BC) measurement, which is being proposed as a new metric of particulate pollution more suitable for the assessment of traffic sources than PM10 and PM2.5 (Brukmann et al., 2011; HEI, 2010; Invernizzi et al., 2011; Reche et al., 2011; UNECE-CLRTAP, 2010; Westerdahl et al., 2009; Zhu et al., 2000). The project will cover air quality and traffic characteristics measurements in winter, summer and fall, with fixed monitoring sites at urban residential locations and studies of personal exposure to traffic proximity or in pedestrian zones. In the present report we show the results of the wintertime campaign.

Aims

To compare BC, PM10 and PM2.5 concentrations inside and outside the traffic restriction zone at two urban residential sites in the wintertime, and to correlate them with traffic volumes, in order to obtain an evaluation on environmental and health potential effects of the Area C LTZ measure.

Methods

Two urban residential sites were chosen, one in the city center inside Area C (Beccaria Street), the other 3 km far away, placed outside the traffic restriction zone (Porpora Street) (see Figure 1). Both sites are situated in a large square on which different important streets meet and are open to pollutants dispersion by wind. The monitors were placed on the terrace of two 3rd floor flats, and left operating from Feb 6th to Feb 26th 2012.

PM10 and PM2.5 concentrations were measured with two real time optical counters (Aerocet, MetOne, USA), while black carbon concentrations were measured with two aethalometers (Magee Instruments, USA). The instruments have been precalibrated with urban ambient air before operating. Traffic flow volumes and composition was obtained by inductive loop detectors and video camera techniques.

Results

BC and PM concentration data were obtained with a high time resolution and processed as 24 h average concentrations (Fig. 2).

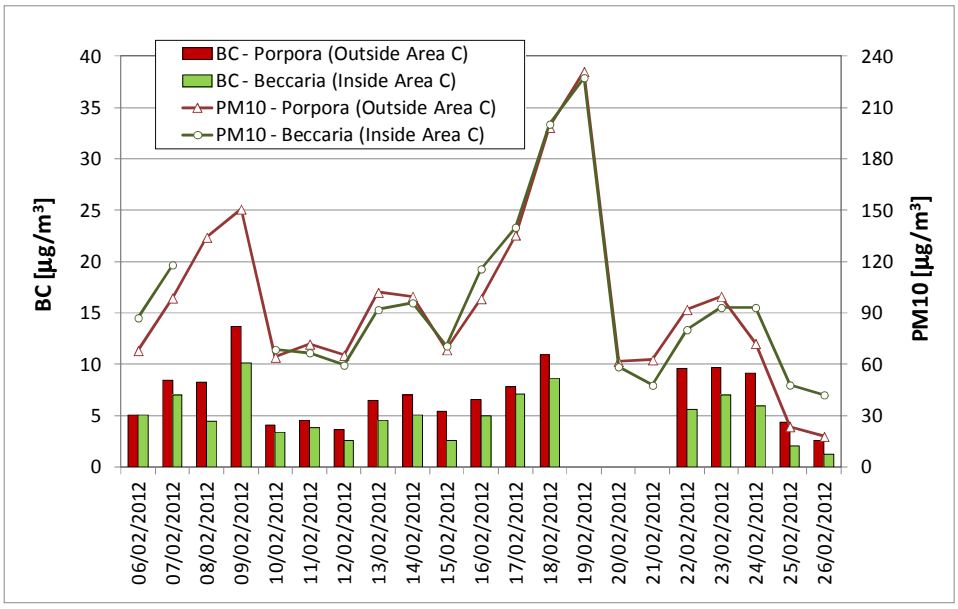

Figure 2: Daily mean BC and PM10 concentrations

During working days - with restriction in force - inside and outside Area C 24h mean (SD) BC concentrations were 5.6 (1.9) µg/m^3 and 7.8 (2.5) µg/m^3 respectively (p<0.0001), which represents an absolute difference of 2.2 µg/m^3 (or -28%) in the traffic restriction zone as compared to the outside area (Fig. 3).

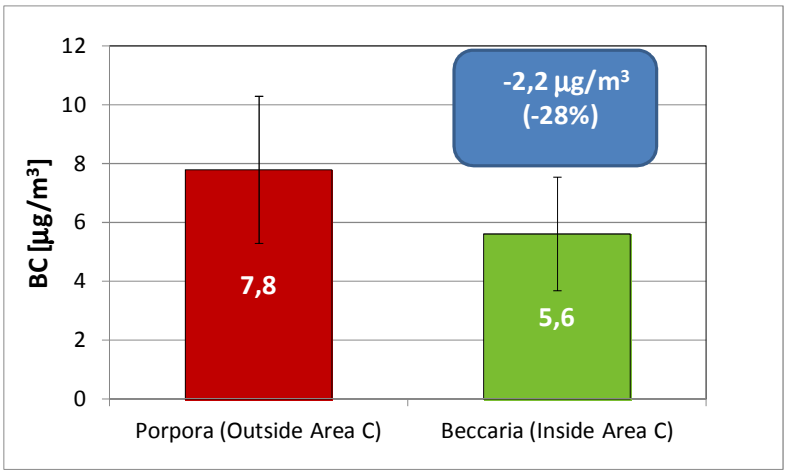

Figure 3: Mean black carbon concentration inside and outside Area C LTZ, during working days (measure being in force)

A non significant difference was observed for PM10 concentrations: 89.4 (25.4) µg/m^3 and 91.1 (27.3) µg/m^3, respectively inside and outside; similarly, PM2.5 concentrations did not differ significantly, 48.6 (17.4) µg/m^3 and 53.6 (18,0) µg/m^3, respectively (Fig. 4).

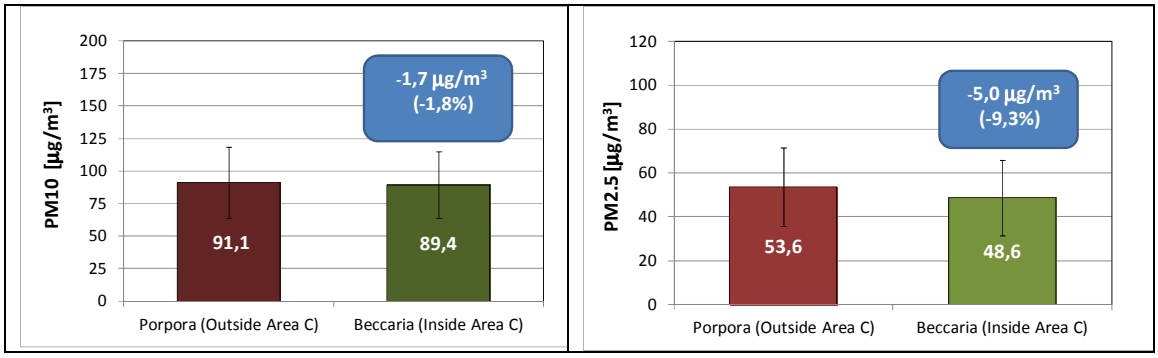

Figure 4: Mean PM10 and PM2.5 concentration inside and outside Area C LTZ, during working days (measure being in force)

Overall BC/PM10 and BC/PM2.5 ratios were 32% (p<0.001) and 25% (p=0.014) lower in the restriction zone as compared to the outside area (Fig. 5 - 8).

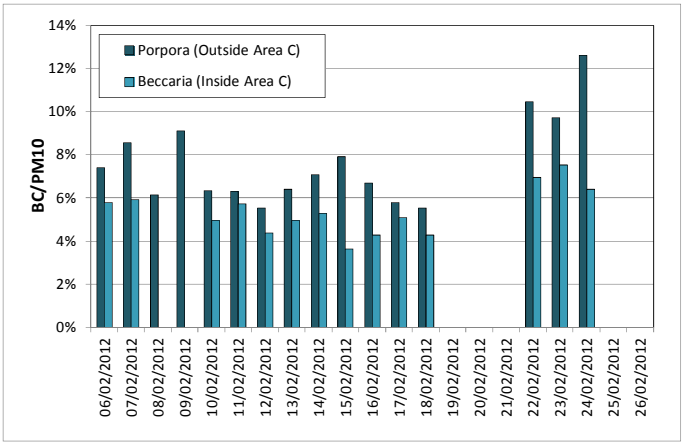

Figure 5: 24 h average BC/PM10 ratio inside and outside Area C LTZ, during the whole campaign

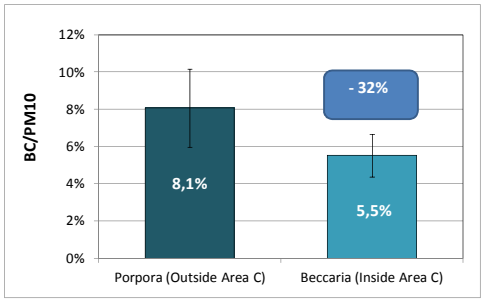

Figure 6: Working days overall BC/PM10 ratios inside and outside Area C LTZ (measure being in force)

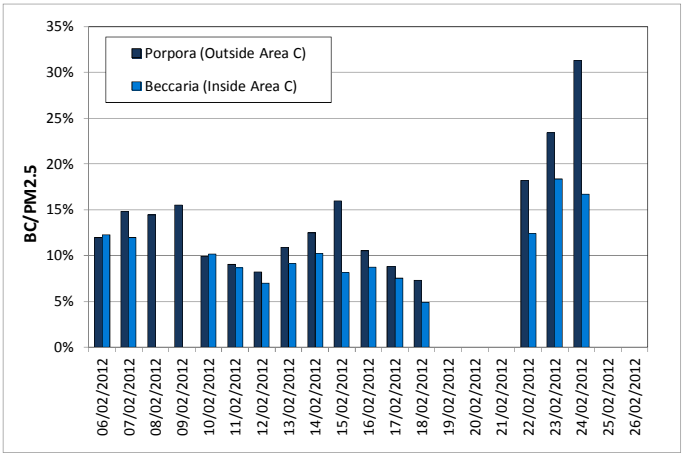

Figure 7: 24 h average BC/PM2.5 ratio inside and outside Area C LTZ, during the whole campaign

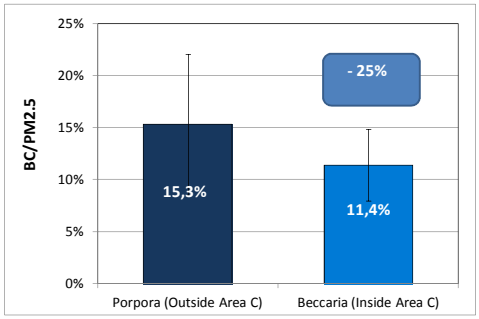

Figure 8: Working days overall BC/PM2.5 ratio inside and outside Area C LTZ (measure being in force)

Figure 9 shows hourly data of BC concentrations, number of vehicles, boundary layer mixing height and heating power plants consumption profile in a typical working day. It's possible to observe the high influence of traffic on daily BC profile despite the contribution of meteorological dispersive conditions and heating power plants in winter season.

BC concentrations were highly correlated with traffic volume during the daytime traffic restriction hours, both inside and outside Area C. Pearson's correlation coefficient (R) is in fact 0.77 for 8-19 hour mean BC concentrations Inside Area C site *vs* passenger cars entering Area C and 0.90 for 8-19 hour mean BC concentrations Outside Area C site *vs* passenger cars entering the LTZ area. This latest data, seems to confirm the role of main attractor of the city center and the fact that a measure adopted for this central area can affect also the traffic volumes and the linked pollution outside it.

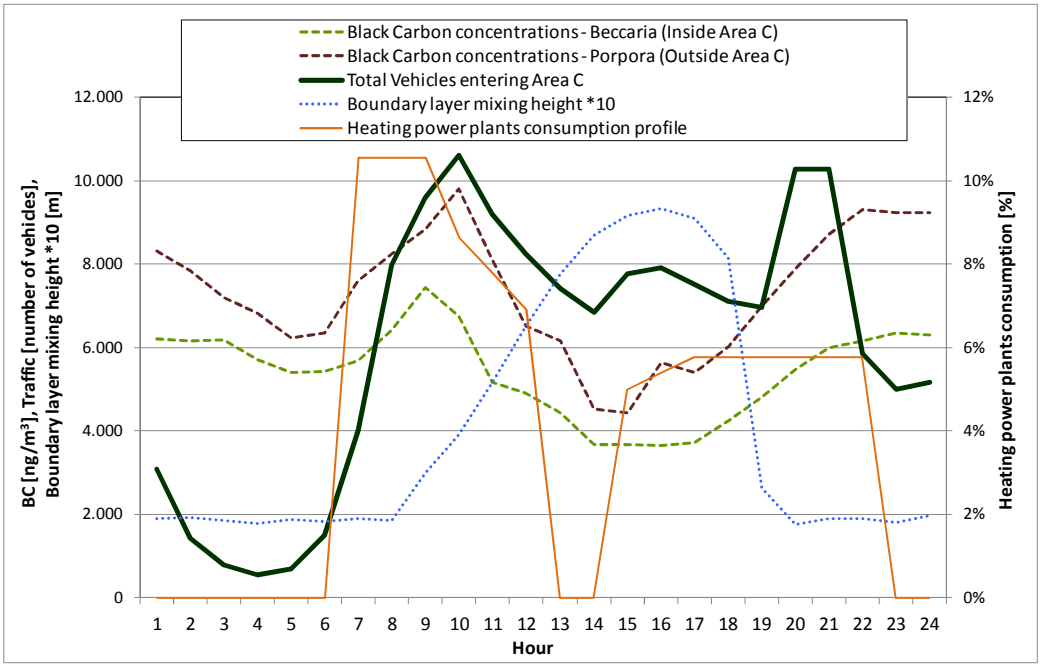

Figure 9: Hourly profile of BC concentrations inside and outside Area C LTZ, traffic density, boundary layer mixing height and heating power plants consumption in a typical working day

Conclusions

The wintertime air quality campaign showed a significant reduction in mean BC concentrations in the Area C traffic restriction zone as compared to the no restriction zone. On the contrary, no significant differences were observed in both PM10 and PM2.5 concentrations between the two different traffic intensity areas. The reduction of 2.2 μg/m^3 in the mean BC concentrations in Area C represents an improvement in air quality of more than two change unit by an epidemiological standpoint, with an expected relevant reduction in morbidity and mortality (Janssen et al., 2011). Such data are very encouraging regarding the Municipality programs of air quality control and mitigation. Black carbon confirmed its higher effectiveness in the assessment of traffic-related pollution as compared to PM, and in the monitoring of spatial and temporal variability of suspended particles concentrations in a metropolitan city. This work was funded by the City of Milan.

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