AN INTEGRATED APPROACH BETWEEN DISPERSION MODELS AND AIR QUALITY DATA FOR AIR POLLUTION EXPOSURE ASSESSMENT PURPOSES

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Abstract: The extent of the exposure to chemicals in absence of continuous measurements of their concentration in air and direct measures of personal exposure is crucial for epidemiological studies. Dispersion models can be a useful tool to reproduce spatio-temporal distribution of contaminants emitted by a specific source. However they cannot easily be applied in short-term epidemiological studies because they need very precise information on daily emission scenarios which are not generally available.
The aim of this work is to identify the potential appropriate variables for exposure scenarios assessment in short term epidemiological studies by integrating air pollution concentration data, emission data and model simulations. The methodology is applied to the industrial area of Brindisi (Italy). Results suggest evaluating population exposure to air pollution by taking into account the wind (direction and speed) as a potential health effects modifier, the interurban variability that the wind regimes create and daily/weekly temporal variability.

Key words: *urban and industrial pollution; wind direction; air pollution exposure, sulphur dioxide, spatial distribution of pollutants.*

INTRODUCTION

The health effects of air pollution have been studied intensely in recent years. Exposure to pollutants such as nitrogen dioxides (NO_2), sulfur dioxides (SO_2), ozone and particulate matter (PM) has been associated with increased mortality and hospital admissions due to health outcomes such as respiratory and cardiovascular diseases (Pope and Dockery 2006). These effects have been found in both short-term and long-term studies. (Brunekreef and Holgate 2002; Dominici et al. 2006; Medina-Ramón et al. 2006). Studies typically focus on the risk associated with single pollutants, and do not take into account the mixture of pollutants usually found in the atmosphere. In presence of large industrial sources in urban areas, these issues become more relevant due to the complex mixture of substances released, which depend on process input, material, and type of process. These chemicals, whose atmospheric concentrations are usually measured only in hot spot campaigns, add to the background and urban pollution, making the air pollution pattern quite complex and, consequently, population exposure quite difficult to assess.

Therefore, in epidemiological studies the key question concerns the extent of the exposure to various chemicals in absence of continuous measurements of their concentration in the air and direct measures of exposure. In such a case the exposure is commonly evaluated by three indirect methods: use of the distance from the source as proxy for exposure, dispersion modelling and air monitoring. Dispersion models, including information on meteorology, emission and topography can be a useful tool to predict mean ground level concentration around sources and to identify, on average, areas of maximum and minimum population exposure as well as to contaminants which are emitted in air but not measured at ground. Nevertheless, dispersion models might not be applied in short-term epidemiological studies since very precise information on daily emission scenarios are not generally available, in particular for high complex industrial areas. In these latter studies air-monitoring data from urban monitoring networks and proximity models are typically used as surrogates for population exposure assessment.

The aim of this study is to identify the potential appropriate variables for exposure scenarios assessment in short term epidemiological studies by integrating air pollution concentration data, emission data and model simulations. The methodology has been applied as a case study, to the industrial area of Brindisi which is one of the most industrialized regions in southern Italy with some critical epidemiological situations (Martuzzi et al. 2002; Belli et al. 2004; Gianicolo et al. 2008; Serinelli et al. 2010; Gianicolo et al. 2013)

AREA OF STUDY

The town of Brindisi (90,000 inhabitants) is located on the east coast of the Salento Peninsula in the southeastern corner of Italy (Figure 1). The area is one of the most industrialized regions in southern

Italy, with several polluting emission activities including two power plants, a petrochemical plant and several pharmaceutical, metallurgical, manufacturing and cement industries. Two other large industrial emissions sources near the town may affect the area: a big coal power plant (one of the largest in Europe) 12 km away to the SE and one of the largest European steel producers, which is 65 km away in the W-SW direction. Some other activities with high environmental impact are more integrated within the urban area and have to do with the presence of the harbor that supports both industrial and tourist activities, the airport in the northern part of the city and the highway on the western side.

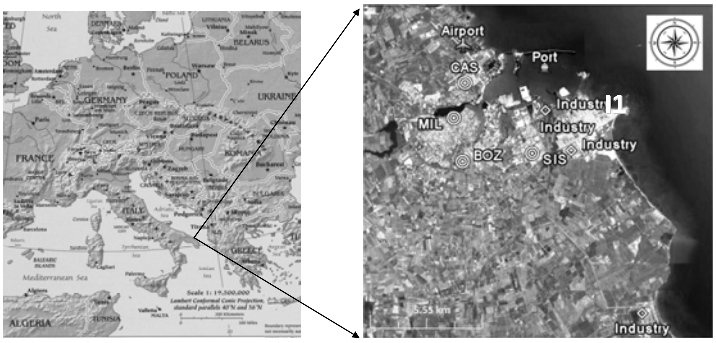

Figure 1. The area of the study

Emission data (Tab.1) evidences how the industrial and energy sectors account for the largest share of emissions, making the emission scenarios of the cities very different from the typical urban environment, where transportation is often the main sector as regards NO_2/NOx and PM emissions. SO2 emission data are attributed mostly to industrial/energy sector and secondly maritime transportations and can be considered a good proxy of the industrial activity. In addition to the emissions of traditional pollutants, such industrial activities are responsible for emissions of substances associated in literature to health effects and whose concentrations in air are not measured routinely: heavy metals, polycyclic aromatic hydrocarbons (PAHs), benzo(a)pyrene, organic solvents, polychlorinated biphenyls (PCBs) and dioxin etc., whose concentrations in air are not measured routinely.

Table 1 Emission data for NOx, SO_2 and TSP. Year 2005. Source: ARPA PUGLIA

Pollutant	Emission (Mg/year)	Industrial/ energy (%)	road transport (%)	Other mobile source(%)	Other (%)
SO2	20191	85.9	0.1	3.7	0.1
NOX	19400	81.0	2.9	10.6	0.4
TSP	1421	85.2	3.5	7.9	0.3

METHODOLOGY

Different series of data were used: air concentration data, emission data and dispersion simulations. Analysis presented here is focused on the year 2006 and on the SO_2 data which represents a good proxy for the industrial sector (Mangia et al., 2011, Cervino et al., 2012).

We analysed concentration data simultaneously measured at 4 urban/industrial monitoring stations. The main characteristics of the stations, managed by the ARPA Puglia (Regional Environmental Protection Agency), are summarised in Table 2, while their positions are shown in Figure 1. Among different emission sources, in this case study we focus on the impact of the emissions from the coal power plant I1 which is located on the Eastern part of the city 2 km from the centre. Table 3 summarizes the emissions of the power plant.

Table 2 Monitoring stations

Station	Acronym	Type	Type_of_area
Bozzano	BOZ	traffic/indus.	urban
Casale	CAS	background	urban
Sisri	SIS	industrial	suburban
Mille	MIL	traffic	urban

Table 3 Emission data coal power plant I1. Fonte http://prtr.ec.europa.eu/

	Emissions (Mg/year)
SO_2	2091.3
NOx	1281.5
PM_{10}	90.8

Emission data from the two groups of the plant was derived from continuous monitoring emission control system. Analysis of series evidences the existence of consistent periods of missing data indicating time windows in which the plant was not operative for long periods and shorter periods of stop-start up of one or both groups.

Together with emission and concentration data, the dispersion model CALMET/CALPUFF (Scire et al . 2000a, Scire et al. 2000b). The dispersion model was a 60kmx60km area with horizontal resolution data of 500m CALMET was initialised with MM5 output obtained at a grid resolution of 4 km. This data, used as initial guess fields, was further adjusted by interpolation methods with surface observations from meteo stations available in the area (Mangia et al. 2011)

Being the plant located in eastern part of the city particular attention has been paid to the wind blowing from this sector

RESULTS

In order to evaluate the impact of different operating conditions of the power plant, we analysed the SO_2 concentration data for prevailing wind direction from Eastern sectors. The prevailing daily wind direction was assumed to be the direction that occurs most frequently during a day. Table 4 shows the mean and 90th percentile values of SO_2 data at the monitoring stations- 0 indicates long periods of missing emission data, 1 periods with continuous emission data and ss short periods of missing data.

Table 4. Mean and 90th percentile values of SO_2 at the monitoring stations. 0 indicates long periods of missing emission data, 1 periods with continuous emission data, ss short periods of missing data.

Station	Mean (ug/m3)			90 th perc (ug/m3)			
	0	1	Ss		0	1	ss
MIL	5.9	7.8	13.1	MIL	9.7	12.0	25.6
BOZ	1.4	1.8	3.6	BOZ	3.7	4.9	4.4
CAS	3.7	4.4	5.9	CAS	2.9	2.9	4.4
SIS	3.0	3.7	4.1	SIS	2.3	2.6	3.0

As expected, the data indicates a tendency of increasing of SO_2 concentrations (both on average and 90th percentiles) for all stations with an increasing factor ranging from 1.2 to 2.7 times the values compared to 0 condition.

To investigate the impact of the plant on the spatio/temporal SO_2 ground level concentration, the CALPUFF model was run for a period of ten days, June 13-21, 2006, which presented prevailing wind conditions from eastern sectors. Furthermore, during this period the worst SO_2 pollution case of 2006 was registered.

Figure 2 shows the modelled daily average concentration for June 17 and 20 2006 while Figure 3 shows the comparison between SO_2 predictions and measured data at the four stations. The figures evidence how SO_2 is related to local emissions within the time span tested in this work. There is a tendency of the model to overestimate the impact of the plant, which is only one of the different sources in the area. Some discrepancies between measurements and predictions may due to the poor resolution of the model. However, the model realistically reproduces the SO_2 variability at monitoring sites when they are downwind the plant, in particular most the peak values. While for NO_2 and PM_{10} values (not shown here) the scenario is more complex and variability seemed to depend upon more complex local sources and background dynamics. Furthermore, SO_2 values (modeled and measured) showed both a short time-scale strong variability (Fig.3) if hourly averages are considered and spatial variability inside the town (Fig.2), whose relevance for population exposure is still to be investigated, but should not be neglected.

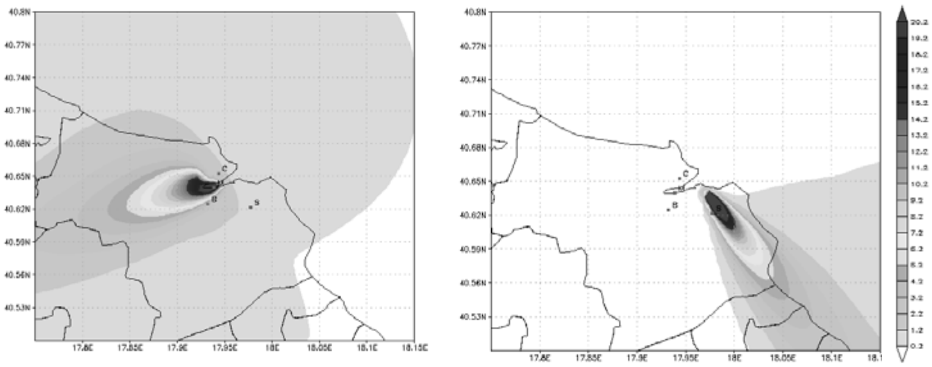

Figure 2. Simulated daily ground level SO_2 concentration ($\mu g\ m^{-3}$) for June 17, 2006 (a) June 20, 2006 (b)

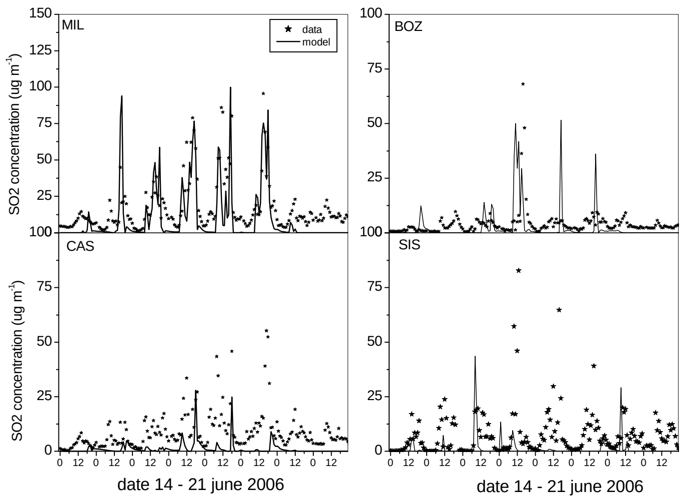

Figure 3. Temporal variation of SO_2 ($\mu g\ m^{-3}$) data at the four stations.

CONCLUSIONS

Studies about health effect of air pollution are very often based on an exposure estimation of standard pollutants (SO_2, NO_2, PM_{10}), averaged over months or weeks (esp. for long terms effects) until obtaining daily averages to infer short-term adverse outcomes. Nevertheless, heavy sources of air pollution near populated areas lead that exposure may change significantly at short time, on a spatial level and by contaminant mixture. A detailed knowledge of intensity and variation of exposure may be addressed by integrating modelled data of pollution at ground level together with measurements from monitoring sites. Concentration data, emission data and dispersion simulation, may help to individualise which monitoring sites may be most influenced by the impact of a specific source and which wind regime negatively influences such an impact. In our case study, analysis confirms that influence of the industrial site may be primarily identified with the series of SO_2 data, which, although below the national air quality standards, could be used as proxy of exposure to the more complex mixture of contaminants emitted from the specific source. Moreover, results suggest a surveillance of population exposure to air pollution by taking into account the wind (direction and speed) as a potential health effect modifier (Gianicolo et al . 2013) , the interurban variability that the wind regimes imply, and daily/weekly temporal variability which could be expressed, for example, by 90^{th} percentile of concentration in the examined period.

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