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Air pollution exposure, cause-specific deaths and hospitalizations in a highly polluted Italian region

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ABSTRACT

Background: The Lombardy region in northern Italy ranks among the most air polluted areas of Europe. Previous studies showed air pollution short-term effects on all-cause mortality. We examine here the effects of particulate matter with aerodynamic diameter ≤ 10 μm (PM_{10}) and nitrogen dioxide (NO_2) exposure on deaths and hospitalizations from specific causes, including cardiac, cerebrovascular and respiratory diseases.

Methods: We considered air pollution, mortality and hospitalization data for a non-opportunistic sample of 18 highly polluted and most densely populated areas of the region in the years 2003–2006. We obtained area-specific effect estimates for PM_{10} and NO_2 from a Poisson regression model on the daily number of total deaths or cause-specific hospitalizations and then combined them in a Bayesian random-effects meta-analysis. For cause-specific mortality, we applied a case-crossover analysis. Age- and season-specific analyses were also performed. Effect estimates were expressed as percent variation in mortality or hospitalizations associated with a 10 $\mu g/m^3$ increase in PM_{10} or NO_2 concentration.

Results: Natural mortality was positively associated with both pollutants (0.30%, 90% Credibility Interval [CrI]: −0.31; 0.78 for PM_{10}; 0.70%, 90%CrI: 0.10; 1.27 for NO_2). Cardiovascular deaths showed a higher percent variation in association with NO_2 (1.12%, 90% Confidence Interval [CI]: 0.14; 2.11), while the percent variation for respiratory mortality was highest in association with PM_{10} (1.64%, 90%CI: 0.35; 2.93). The effect of both pollutants was more evident in the summer season. Air pollution was also associated to hospitalizations, the highest variations being 0.77% (90%CrI: 0.22; 1.43) for PM_{10} and respiratory diseases, and 1.70% (90%CrI: 0.39; 2.84) for NO_2 and cerebrovascular diseases. The effect of PM_{10} on respiratory hospital admissions appeared to increase with age. For both pollutants, effects on cerebrovascular hospitalizations were more evident in subjects aged less than 75 years.

Conclusions: Our study provided a sound characterization of air pollution exposure and its potential effects on human health in the most polluted, and also most populated and productive, Italian region, further documenting the need for effective public health policies.

1. Introduction

Northern Italy ranks among the top most polluted areas of Europe (EEA, 2014). The Lombardy region is the geographic and economic epicenter of this area, with more than 10 million residents and the highest gross domestic product per inhabitant of the country (RSY, 2015). Most of its major cities are located in the basin of the Po River, which crosses the entire region. The basin is bordered on three sides by mountains which render air mass exchange very low. Wind speed measured in the Po River plain is among the lowest in Europe, causing frequent phenomena of thermal inversion and trapping of smog and pollution close to the ground. In addition, Lombardy counts many industrial facilities as well as small and medium enterprises for which road transport is an essential component for economic viability (non-industrial combustion plants and road transport represent more than 60% of particulate matter emission sources in the region, Supplementary Table 1). Overall, its unfavorable geographical context, climate

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characteristics, land use and emission sources create a high level of air pollution.

The short-term health effects of exposure to air pollution are well established. Many studies documented, in Europe as well as elsewhere, an association between ground levels of both particulate and gaseous pollutants and health outcomes, measured as deaths and/or hospitalizations (Analitis et al., 2006; Ballester et al., 2006; Biggeri et al., 2004; Samoli et al., 2006; Samoli et al., 2008; Samoli et al., 2013; Stafoggia et al., 2013; WHO, 2013). The 2010 Global Burden of Disease study found that outdoor air pollution in the form of fine particles is the ninth-leading cause of premature death and ill health (IHME, 2015) and ranks first among the environmental risk factors for health (Hanninen et al., 2014). Many health outcomes have been investigated. Respiratory and especially cardiovascular effects (in terms of both mortality and hospital admissions) are supported by the stronger evidence of association with air pollution exposure (Anderson et al., 2012; Mannucci et al., 2015).

Previous studies on particulate matter exposure and all-cause mortality have already addressed the magnitude of the effects of air pollution exposure on human health in Lombardy (Baccini et al., 2011), accounting also for between-city commuting (Baccini et al., 2015). These studies documented a clear effect of PM_{10} exposure on all-cause mortality, with a maximum observed for the capital city of Milan.

In this study we expanded the set of investigated causes and air pollutants considered. We selected the most polluted and densely populated areas of Lombardy, whose exposure to particulate matter with aerodynamic diameter $\leq 10\ \mu m$ (PM_{10}) and nitrogen dioxide (NO_2) is measured by a network of air quality monitoring stations, and examined air pollution short-term effects on all-cause and cause-specific deaths and hospital admissions.

2. Materials and methods

2.1. Data

We considered air pollution, mortality and hospital admission data for the period 2003–2006 for 18 areas: 16 cities with more than 50,000 inhabitants, 1 small town, Sondrio (yet the largest in the Alpine administrative province), and all of the municipalities within the agricultural district of Lodi, collapsed into a single epidemiologic time series (Fig. 1). The air quality monitoring network of the Lombardy Regional Environmental Protection Agency (ARPA) provided the daily time series of PM_{10} and NO_2 measurements, temperature, and relative humidity values. The monitoring network provided the background levels of PM_{10} and NO_2. For each area separately we considered the stations not influenced by traffic and located within the municipality boundaries. We then imputed the missing daily values at one of these monitors using concentrations measured by the remaining monitors in the same area, and we obtained a daily time series of pollutant levels for each area by averaging data over the available monitors. A detailed description of the exposure assessment procedure can be found in Biggeri et al. (2005). Death certificates were retrieved from the regional mortality register. We considered mortality from all natural causes, excluding external causes (International Classification of Diseases, Ninth Revision, ICD-9 codes below 800), and we distinguished between cardiovascular mortality (ICD-9 390–459) and respiratory mortality (ICD-9 460–519). For each area, we focused on daily numbers of cause-specific deaths occurring in the

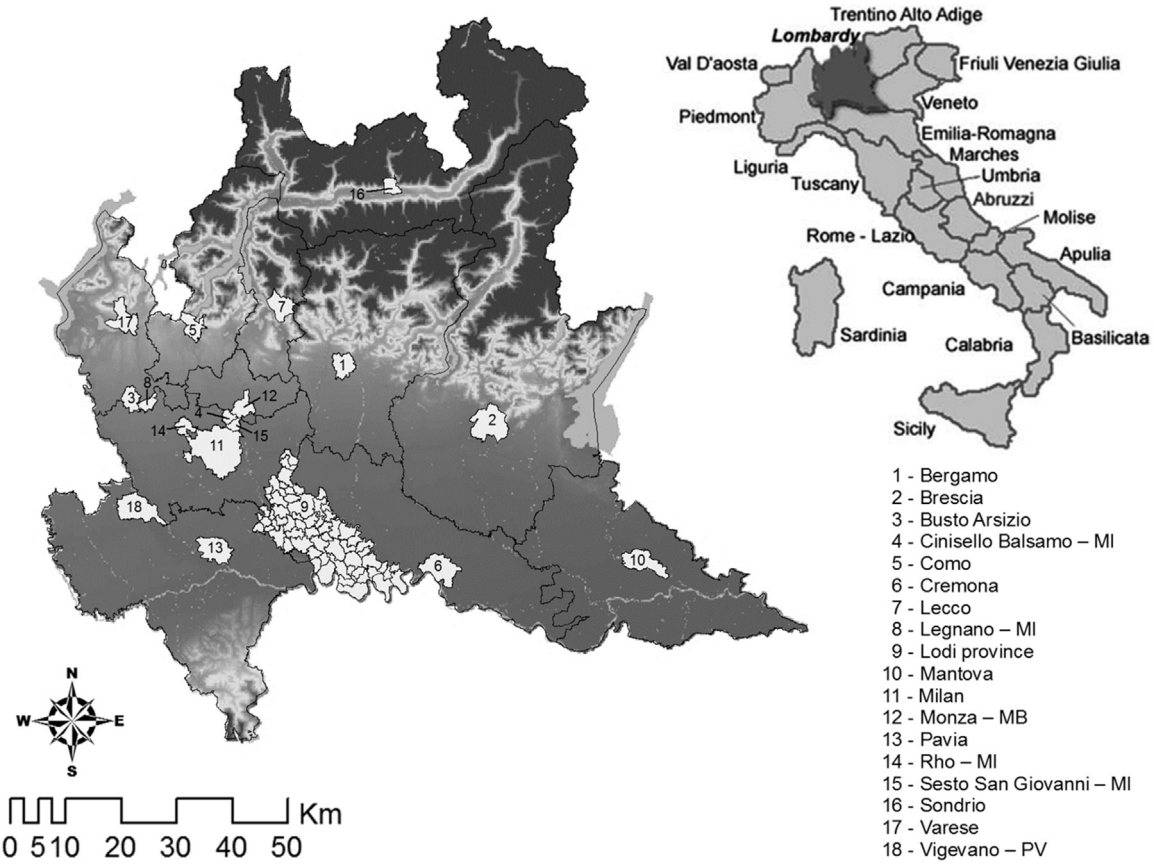

Fig. 1. The Lombardy region of Italy. The study areas included in the analysis of short-term effects of particulate matter $\leq 10\ \mu m$ in diameter (PM_{10}) and nitrogen dioxide (NO_2) are highlighted in white.