Environmental Research 111 (2011) 1321–1327

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Human health risk in relation to air quality in two municipalities in an industrialized area of Northern Italy

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ARTICLE INFO

Article history:
Received 26 May 2010
Received in revised form
8 June 2011
Accepted 23 June 2011
Available online 20 July 2011

Keywords:
AirQ software
Particulate matter
Ozone
Nitrogen dioxide
Mortality

ABSTRACT

Air quality is one of the major environmental issues related to human health, and people and authorities are increasingly aware and concerned about it, asking to be involved in decisions whose fallout can have consequences on their health. The objectives of the present study were to provide quantitative data on the impact of air pollution on the health of people living in two small municipalities in a highly industrialized, densely populated area of Northern Italy. We applied the approach proposed by the World Health Organization (WHO) using the AirQ 2.2.3 software developed by the WHO European Centre for Environment and Health, Bilthoven Division. Daily concentrations of ozone, nitrogen dioxide, and particulate matter of aerodynamic diameter $\leq 10\,\mu m$ (PM_{10}) and $\leq 2.5\,\mu m$ ($PM_{2.5}$) were used to assess human exposure and health effects in terms of attributable proportion of the health outcome, annual number of excess cases of mortality for all causes, and cardiovascular and respiratory diseases. Long-term effects were estimated for $PM_{2.5}$ as years of life lost.

Considering short-term effects, $PM_{2.5}$ had the highest health impact on the 24,000 inhabitants of the two small towns, causing an excess of total mortality of 8 out of 177 in a year. Ozone and nitrogen dioxide each caused about three excess cases of total mortality. Results on long-term effects showed, respectively, 433, 180, and 72 years of life lost for mortality for all causes, cardiopulmonary diseases and lung cancer, in a year.

These results are consistent with other reports of the impact of air quality on human health and the AirQ software seems an effective and easy tool, helpful in decision-making.

1. Introduction

The acute effects of air pollution on human health were amply proven in the 20th century, when severe air pollution in Europe (Meuse Valley and London) and in the United States (Donora, Pa) caused deaths and disease in hundreds of thousands of people (Ciocco and Thompson, 1961; Logan, 1956; Nemery et al., 2001). Much lower concentrations of air pollutants, however, also have adverse effects on human health (Bell et al., 2006; Downs et al., 2007; Gauderman et al., 2007; Jerrett et al., 2008; Kunzli et al., 2005, 2000; Miller et al., 2007; Pope et al., 2002) and air quality standards may not be protective enough for the most sensitive groups (USEPA, 1996). In addition, even though pollution due to combustion fuels has fallen dramatically in recent years, emerging pollutants such as ozone (O_3) and nitrogen oxides, and changes in the composition and size distribution of particulate matter, have become important in the health effects of air pollution (Brunekreef and Holgate, 2002). In the last two decades epidemiological studies have shown that outdoor air pollution is a cause of morbidity (cardiovascular and respiratory symptoms, decrease in lung function, chronic bronchitis, etc.) and mortality. The biological mechanisms by which these pollutants affect human health are not all clarified but probably involve their potent oxidant action, both directly against the cellular components of the airways, and through activation of intracellular oxidant pathways.

Abbreviations: AP, attributable proportion; APHEA, air pollution and health: a European approach; ARPA, Regional Agency for Environmental Protection; CI, confidence interval; ICD-9-CM, International Classification of Diseases, 9th Revision, Clinical Modification; NO_2, nitrogen dioxide; O_3, ozone; PM, particulate matter; $PM_{2.5}$, particulate matter of aerodynamic diameter $\leq 2.5\,\mu m$; PM_{10}, particulate matter of aerodynamic diameter $\leq 10\,\mu m$; RR, relative risk; USEPA, United States Environmental Protection Agency; WHO, World Health Organization

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doi:10.1016/j.envres.2011.06.012

We assessed the health impact of air quality on the residents of Mazzano and Rezzato, two small towns in the Po Valley – the *Pianura Padana* – in the Lombardy region (Fig. 1). This is the most industrialized area in Italy, with heavy traffic and high population density. In addition it is enclosed by mountains on three sides and the wind speeds are usually low (very often <1 m/s) making for very frequent thermal inversions, trapping air pollutants in the lower layers of the atmosphere. These concomitant conditions make this valley one of the worst areas in the world for atmospheric pollution, with a large number of days exceeding air quality standards during the year, and some very strong pollution episodes (de Meij et al., 2009). As an example, in 2007 in almost the whole of the Lombardy region, the guidelines for daily and annual averages of PM_{10} were never met (Giudici et al., 2008).

The local authorities in these municipalities, with a view to planning further expansion of industrial activities in the area, asked us to make a quantitative assessment of the impact of air pollutants on human health for people living in this area. The pollutants selected were nitrogen dioxide (NO_2), O_3 and particulate matter because these had the highest concentrations in relation to air quality standards.

NO_2 is mainly derived from oxidation of nitrogen oxide by atmospheric oxidants such as O_3. The main sources are combustion (heating, industrial plants and vehicles) where NO_2 is formed after oxidation of atmospheric nitrogen. Tropospheric O_3 is a secondary pollutant arising from a very complex chain of reactions involving sunlight, nitrogen dioxide and hydrocarbons. The concentration of this compound generally follows different patterns from other related atmospheric pollutants, since it peaks during the summer and not in urban areas but in the suburbs. Finally, particulate matter differs from the other compounds since it is not a substance by itself but a complex mixture of different components condensed in a liquid or solid phase. We examined the fractions smaller than 10 μm (PM_{10}), and 2.5 μm ($PM_{2.5}$) in diameter. Generally the smaller particulate fraction arises from combustion and the coarser one from mechanical and re-suspension processes.

Fig. 1. Map of Italy showing the Po valley and the small towns of Mazzano and Rezzato.

2. Materials and methods

2.1. AirQ software

We adopted the approach proposed by the World Health Organization (WHO) using the Air Quality Health Impact Assessment (AirQ 2.2.3) software developed by the WHO European Centre for Environment Health, Bilthoven Division. This program is used to estimate the impact of exposure to specific atmospheric pollutants on the health of people living in a certain period and area. The assessment is based on the attributable proportion (AP), defined as the fraction of the health outcome in a certain population attributable to exposure to a given atmospheric pollutant, assuming a proven causal relation between exposure and health outcome and no major confounding effects in that association. The AP can be easily calculated by the following general formula (Krzyzanowski, 1997):

$$AP = \sum\{[RR(c)-1] \times P(c)\} / \sum[RR(c) \times P(c)] \quad (1)$$

where AP is the attributable proportion of the health outcome, RR is the relative risk for a given health outcome, in category "c" of exposure, obtained from the exposure–response functions derived from epidemiological studies and $P(c)$ is the proportion of the population in category "c" of exposure.

If the baseline frequency of the health outcome in the population under investigation is known, the rate attributable to the exposure can be calculated as

$$IE = I \times AP \quad (2)$$

where IE is the rate of the health outcome attributable to the exposure and I is the baseline frequency of the health outcome in the population under investigation.

Finally, knowing the size of the population, the number of cases attributable to the exposure can be estimated as follows:

$$NE = IE \times N \quad (3)$$

where NE is the number of cases attributed to the exposure and N is the size of the population investigated.

RR gives the increase in the probability of the adverse effect associated with a given change in the exposure levels, and comes from time-series studies where day-to-day changes in air pollutants over long periods were related to daily mortality, hospital admissions and other public health indicators. RR values used in the present assessment are shown in Table 1 and are mainly derived from the Air Pollution and Health: a European Approach study (APHEA), the largest multicity study related to the European population, using standardized protocols for the city level data analysis. The RR values used for PM_{10} were summary estimates derived from a quantitative meta-analysis of peer-reviewed studies focused on European investigations (Anderson et al., 2004), while for $PM_{2.5}$ the RR implemented in the software and proposed as summary estimate in the WHO Air Quality Guidelines for Europe (WHO, 2000a) was used. Finally, for O_3 and NO_2 the RR values came directly from published studies on short-term effects within the APHEA project (Gryparis et al., 2004; Samoli et al., 2006). The baseline rates of the health outcomes were based on statistics available on-line from the Brescia district local health authority.

The impacts of long-term effects of air pollution on health are based on cohort studies where populations with different levels of exposure were followed up over time, in order to cover long-term effects (Abbey et al., 1995; Brunekreef et al., 2009; Dockery et al., 1993; Krewski et al., 2009; Kunzli et al., 2000; Lipfert et al., 2000; Pope et al., 2002, 1995). These studies, which were systematically reviewed by Chen et al. (2008), are much more limited than the time-series studies since they are much more complex and demanding; however, they provide a more comprehensive estimate of the health effects of air pollution since they include deaths advanced by recent exposure and those due to chronic diseases caused by long-term exposure. In the present assessment, the long-term impact of $PM_{2.5}$ was computed by the AirQ software as the average reduction in lifespan measured in terms of years of life lost, due to mortality for all causes, cardiopulmonary, and lung cancer, from the community of the two municipalities of Mazzano and Rezzato. The RR values (Table 1) were from the study by Pope et al. (2002), who followed up a cohort of 552,138 persons aged over 30 years for 16 years. The software also requires the age structure of the population and age-specific mortality rates, which are available in the statistics available on-line (http://www.istat.it/).