Science of the Total Environment 622–623 (2018) 547–555

Contents lists available at ScienceDirect

Science of the Total Environment

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

Impact on mortality of biomass combustion from wildfires in Spain: A regional analysis

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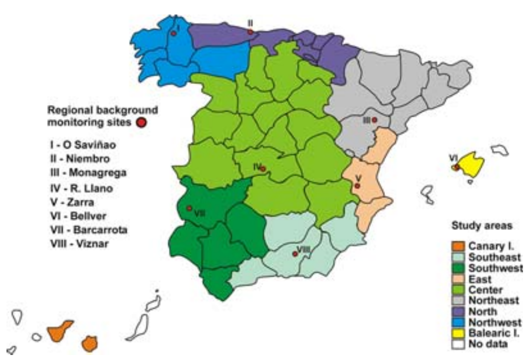
HIGHLIGHTS

- Daily mean PM concentrations were higher on DBA than on DNBA.
- PM_{10} was associated with higher daily mortality on DBA in regions where wildfires were most frequent.
- The increase in PM is linked to a significant IRR of mortality in Spain.
- Wildfires are likely to become increasingly frequent in the context of climate change makes this type of analysis necessary

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 2 November 2017
Received in revised form 27 November 2017
Accepted 27 November 2017
Available online xxxx

Editor: P. Kassomenos

Keywords:
Wildfire
Biomass combustion
Daily mortality
Particulate matter

ABSTRACT

Studies that analyse the impact on mortality of particulate matter (PM) produced by biomass combustion from wildfires mostly focus on a single city or on cities in different countries, with very few concentrating on one country as a whole. Accordingly, the aim of this paper was to analyse the impact that PM has on daily mortality in Spain on days with biomass combustion from wildfires.

To analyse natural PM advections the Ministry of Agriculture and Fishing, Food & Environment divides Spain into 9 geographical regions. One province representative of each region for was selected analysis purposes, with provincial daily natural-cause mortality across the period 2004–2009 as the dependent variable, and daily mean PM concentrations in the provincial capital as the independent variable. We controlled for the effect of other chemical pollutants (NO_2 and O_3), maximum daily temperature on heat-wave days, day of the week, trends, seasonalities and the autoregressive nature of the series, using generalised linear models with the Poisson regression link to calculate relative risks (RRs) and the increase in RR (IRR) of PM-related mortality. The analysis was performed for days with and without biomass advections (DBA and DNBA respectively), with a breakdown by year, summer, and the remainder of the year (i.e., excluding summer).

The results indicated that daily mean PM concentrations were higher on DBA than on DNBA, with statistically significant differences in most provinces. Furthermore, PM_{10} was associated with higher daily mortality on DBA in regions where wildfires were most frequent, but not in the remaining provinces. This translated as an IRR per 10 μg/m^3 of PM of 7.93 (2.36–13.81) in the North-west, 3.76 (1.36–6.22) in the Centre and 4.46 (2.99–5.94) in the South-west, values which in all cases were statistically higher than those obtained on DNBA.

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https://doi.org/10.1016/j.scitotenv.2017.11.321
0048-9697/

The increase in PM caused by biomass advections from wildfires is linked to a significant IRR of mortality in Spain. Hence, the fact that wildfires are likely to become increasingly frequent in the context of climate change makes this type of analysis particularly necessary.

1. Introduction

The main health impacts associated with particulate matter (PM) occur in densely populated urban areas (Ortiz et al., 2017) where the principal component is anthropic in nature (Querol et al., 2012), i.e., if one takes an urban area in southern Europe by way of example, 80% of such particulate and aerosol emissions will be seen to be linked to anthropogenic activities, while the remaining 20% continue to have a component of natural origin, stemming from advections of desert dust (Pey et al., 2013), sea spray (O'Dowd and de Leeuw, 2007), volcanic emissions (Von Glasow et al., 2009), and aerosols from wildfires (Barbosa et al., 2009). This anthropic origin of PM in cities is in contrast to the pattern observed at a global level, where 98% of all emissions are of natural origin (Guieré and Querol, 2010), fundamentally consisting of aerosols of marine origin (84–85%) and dust of mineral origin (13%).

The natural origin of PM in urban areas is of great importance, since this pollution is in addition to that which already exists in cities. In Spain, this inflow of PM serves to increase annual mean emission levels to 4% (Viana et al., 2014), basically in particles having a diameter of under 10 micra (PM_{10}). Although such values might on average seem of little significance, these contributions nevertheless tend to come in episodic periods of short duration which usually result in notable exceedances of the thresholds stipulated by European directives (Official Journal of the European Union, 2008) and the air quality guideline values established by the World Health Organization for protection of health (WHO, 2006), essentially in terms of the wide margin whereby PM_{10} and $PM_{2.5}$ levels are surpassed (Dennekamp and Abramson, 2011; Finlay et al., 2012).

The contribution to PM levels by sources of natural origin in southern Europe is fundamentally due to Saharan dust intrusions and PM advections from wildfires. The health effects of Saharan dust have been widely studied in Spain, with its impact being analysed in terms both of daily mortality (Jiménez et al., 2010; Tobías et al., 2011; Pérez et al., 2012; Díaz et al., 2012; Díaz et al., 2017) and of hospital admissions (Reyes et al., 2014). Far fewer studies have, however, analysed the health impact of PM produced by biomass combustion from wildfires (Finlay et al., 2012). At an international level, these studies have generally focused on hospital admissions due to ensuing respiratory problems (Mirabelli et al., 2009; Ovadnevaite et al., 2006) or exacerbations of previous respiratory diseases (Lee et al., 2009; Martin et al., 2013). Recently, exposure to forest fire smoke has also been linked to cardiac diseases (Dennekamp et al., 2015; Weichenthal et al., 2017).

From the standpoint of this PM's impact on mortality, existing studies are few in number, local in scope, and somewhat inconclusive. While a Denver-based study reported no association between these events and increases in daily mortality (Vedal and Dutton, 2006), others such as that undertaken in Athens, showed that so-called medium-sized fires do indeed have an influence on increases in daily mortality (Analitis et al., 2012). Another study conducted in the city of Madrid, which analysed the impact had by PM advections from biomass combustion on daily all-cause, circulatory-cause and respiratory-cause mortality (Linares et al., 2015), reported the existence of a shift in the PM-related mortality pattern on days with as opposed to those without advection, characterised by an increase in the relative risk (RR) of PM_{10}-related mortality, essentially in the over-75 age group. Similar results were obtained in a study undertaken in 10 southern European cities (Faustini et al., 2015), which found that "smoke is associated with increased cardiovascular mortality in urban residents, and PM_{10} on smoky days has a larger effect on cardiovascular and respiratory mortality than on other days".

As stated above, though few in number, there are some studies which, at a city level, link the effect that locally occurring wildfires have on daily mortality in nearby towns, but there are no studies, such as the one reported here, which analyse this effect at the level of an entire country like Spain, with a high number of fires every year and a mean annual affected surface area of 133,000 ha between 2006 and 2015, according to the latest data available from the Spanish Ministry of Agriculture and Fishing, Food & Environment. In 2016 alone, there were 517 wildfires in Spain (MAPAMA, 2016). If one then adds the fact that the predicted meteorological conditions associated with climate change in Spain are likely to further favour the development of wildfires (Moreno et al., 2015), regional studies such as this must be seen as indispensable.

2. Material and methods

2.1. Determination of days with biomass advections (DBA) and days without biomass advections from wildfires (DNBA)

To determine DBA during the period 2004–2009, we used information supplied by the Ministry of Agriculture and Fishing, Food & Environment (*Ministerio de Agricultura y Pesca, Alimentación y Medio Ambiente/MAPAMA* http://www.mapama.gob.es/es/calidad-y-evaluacion-ambiental/temas/atmosfera-y-calidad-del-aire/calidad-del-aire/evaluacion-datos/fuentes-naturales/default.aspx), which divides Spain into the following 9 main areas: North; North-east; North-west; Centre; South-west; South-east; Levant; Balearic Isles; and Canary Islands (Fig. 1). These areas were selected with the aim to cover the main different climatic and geographic conditions in Spain. The existence of regional-background monitoring stations in each region has been an additional factor to select them. As it has been explained in the manuscript, the time series of PM registered in this type of stations have been used for the identification of contributions of biomass burning emissions in Spain (Querol et al., 2010). Biomass burning events occurring in each main area were identified, based on the output from the NAAPS (Navy Aerosol Analysis and Prediction System) Global Aerosol Model. The NAAPS is a global aerosol transport model maintained operationally by the U.S. Navy for predicting the distribution of tropospheric aerosols (https://www.nrlmry.navy.mil/aerosol/). The emissions, transport and sinks of smoke from biomass burning, among other aerosol sources, are simulated as forecast products, and are thereafter corrected from satellite Aerosol Optical Depth measurements (Reid et al., 2009). For model initialisation, smoke emissions are estimated on the basis of geostationary satellite and MODIS fire products. The MODIS products build on heritage algorithms for operational fire monitoring used with the GOES and AVHRR sensors, and provide information on the location of a fire, its emitted energy, the flaming and smouldering ratio, and an estimate of area burnt (Giglio et al., 2003). The resulting product is then fed into the NAAPS for transport and removal. NAAPS uses global meteorological analyses and forecast fields from the Navy's $0.5° \times 0.5°$ Operational Global Analysis and Prediction System (NOGAPS) on a $1° \times 1°$ global grid at 24 vertical levels reaching 100 hPa. Four times daily, the NOGAPS weather forecast model provides dynamic and surface fields to the NAAPS at 6-hour intervals for a six-day forecast period. Transport is calculated using a 5th-order Lagrange