Science of the Total Environment 473–474 (2014) 549–564

Contents lists available at ScienceDirect

Science of the Total Environment

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

The dark side of the tradition: The polluting effect of Epiphany folk fires in the eastern Po Valley (Italy)

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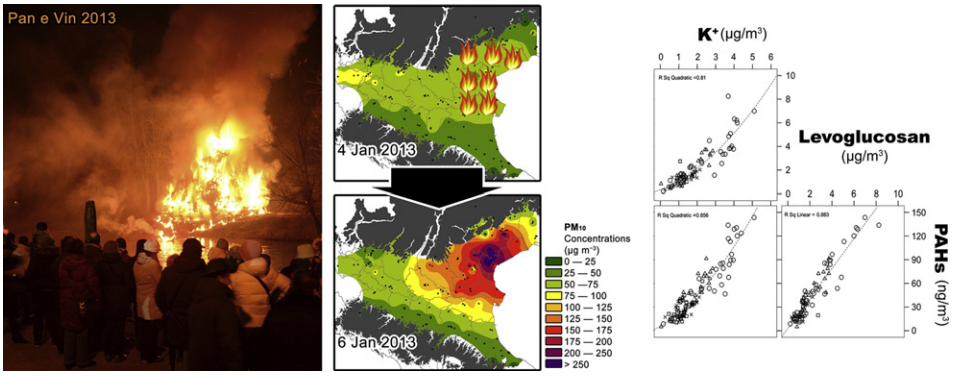
HIGHLIGHTS

- The effects of thousand folk fires on the air quality were monitored.
- The levels of TC, major inorganic ions, PAH, levoglucosan and K^+ were measured.
- The daily concentrations of $PM_{2.5}$ and PM_{10} exceeded 250 and 300 μg m^{-3}.
- The dispersion of the PM was traced in Veneto (Italy) and neighboring regions.
- This study provides experimental data on the biomass burning practice.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 24 June 2013
Received in revised form 16 December 2013
Accepted 16 December 2013
Available online 4 January 2014

Keywords:
Particulate matter
Biomass burning
Levoglucosan
Polycyclic aromatic hydrocarbons
Po Valley

ABSTRACT

In the Veneto Region (Po Valley, Northeastern Italy) on the eve of Epiphany, an important religious celebration, during the night between January 5th and 6th thousands of folk fires traditionally burn wooden material. The object of this study is to characterize the 2013 episode, by monitoring the effects on the air quality in the region's lowlands. The daily concentrations of $PM_{2.5}$ and PM_{10} exceeded 250 and 300 μg m^{-3}, respectively and the PM_{10} hourly values were above 600 μg m^{-3} in many sites. The levels of total carbon, major inorganic ions, polycyclic aromatic hydrocarbons and biomass burning tracers (levoglucosan and K^+) were measured in 84 samples of PM_{10} and 38 of $PM_{2.5}$ collected at 32 sites between January 4th and 7th. Total carbon ranged from 11 μg m^{-3} before the pollution episode to 131 μg m^{-3} a day afterwards, K^+ from 0.6 to 5.1 μg m^{-3}, benzo(*a*)pyrene from 2 to 23 ng m^{-3}, and levoglucosan from 0.5 to 8.3 μg m^{-3}. The dispersion of the particulate matter was traced by analyzing the levels of PM_{10} and $PM_{2.5}$ in 133 and 51 sites, respectively, in the Veneto and neighboring regions. In addition to biomass burning the formation of secondary inorganic aerosol was revealed to be a key factor on a multivariate statistical data processing. By providing direct information on the effects of an intense and widespread biomass burning episode in the Po Valley, this study also enables some general considerations on biomass burning practices.

1. Introduction

Biomass burning (BB) from natural and human-induced fires for deforestation, agricultural waste disposal and wood-fuel use for domestic heating, is largely recognized as a significant global source of gaseous

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http://dx.doi.org/10.1016/j.scitotenv.2013.12.077

and particulate matter (PM) emissions (e.g., Crutzen and Andreae, 1990; Andreae and Merlet, 2001; Mayol-Bracero et al., 2001; Simoneit, 2002; Radzi et al., 2004; Akagi et al., 2011; Zhang et al., 2013). Its impact on the atmospheric chemistry, regional air quality, human health, visibility and climate is currently being amply discussed (Reid et al., 2005; Gustafsson et al., 2009; Laumbach and Kipen, 2012; Keywood et al., 2011). In particular, both wildfires during intense episodes (Saarikoski et al., 2007; Pio et al., 2008; Alves et al., 2010; Portin et al., 2012) and domestic wood burning in winter (Szidat et al., 2007; Gelencsér et al., 2007; Caseiro et al., 2009; Piazzalunga et al., 2011; Reche et al., 2012) have been identified as major sources of PM at many European locations that deserve more attention from the scientific community.

Nevertheless, in the Po Valley, which is recognized as having very high levels of many air pollutants frequently breaching the European standards for air quality (EEA, 2013), data on BB are still incomplete, many questions are still unanswered and the debate on the use of wood for domestic heating is still in progress in northern Italy. Recent studies reported that wood combustion strongly contributes to the air pollution (van Drooge and Perez Ballesta, 2009; Piazzalunga et al., 2010, 2011; Belis et al., 2011; Perrone et al., 2012; Piazzalunga et al., 2013) and the use of wood (i.e. logs, briquettes, chips and pellets) is becoming a widely used renewable alternative to methane (Pignatelli et al., 2008; European Pellet Council, 2011; Pastorello et al., 2011). Studies on the effects of intense BB pollution episodes in the Po Valley are still lacking.

This study aims to experimentally characterize an intense air pollution episode caused by the simultaneous burning of more than a thousand folk fires in the eastern Po Valley, Veneto Region, in January 2013. The main goals are to quantify particulate pollution and characterize variations in the levels of some well-known BB tracers, such as levoglucosan, K^+ and certain polycyclic aromatic hydrocarbons (PAHs) during the period sampled. The concentration ratios between pairs of PM-bound compounds including BB tracers are used to investigate the PM composition before, during and after the event. Finally, the dispersion of the PM pollution in the surrounding regions is examined to assess the extent of the episode.

2. Study area and Epiphany fires

The concurrent presence of numerous emission sources and particular weather conditions that favor pollutant accumulation is responsible for the worrying air quality in the Po Valley, especially in winter. The anthropogenic pressure includes large cities separated by a continuum of scattered urban settlements, roads with heavy traffic, industrial areas, and farmland. The particular weather conditions are determined mainly by the orographic arrangement of Alps and Apennines that protect the valley from long distance winds and favor extended periods of low temperatures, winds and mixing layers and frequent temperature inversions (e.g., Tomasi, 1983; Vecchi et al., 2004, 2007; Pecorari et al., 2013).

The Veneto Region lies in the eastern Po Valley and extends over ~$18.4 \cdot 10^3$ km^2 hosting a population of ~4.9 million. Its territory includes the northern alpine environments (29% of the total surface area), the intermediate hill areas (15%), the heavily anthropized plains to the south (56%) and the eastern ~95 km long coastlines (Fig. 1). In 2011, the standards fixed by the European directives were exceeded at many sites monitored by the Environmental Protection Agency of Veneto (ARPAV): i.e. the annual limits for PM_{10} (40 μg m^{-3}) at 50% of the sites, the target values of $PM_{2.5}$ (25 μg m^{-3}) at 78%, the PM_{10}-bound benzo(*a*)pyrene (1 ng m^{-3}) at 53%, the annual limit for NO_2 (40 μg m^{-3}) at 20% of the sites. At all the stations the long-term objective for ozone for the protection of human health (ARPAV, 2012) was critically breached. According to data published by the European Environment Agency in the Veneto, at least 10–15 premature deaths per year per 10,000 population are attributable to $PM_{2.5}$ pollution (de Leeuw and Horálek, 2009). It is therefore urgently necessary to find quick and effective solutions to reduce the population's exposure to harmful air pollutants.

Following the popular Venetian tradition, large piles of wood and branches are burned on the eve of Epiphany, the night of January 5th–6th . This event, called "*Panevin*", "*vècia*" or "*pìroła-pàroła*" and probably deriving from pre-Christian rites, marks the beginning of the new year and it is celebrated regularly all over the region. In the past small piles of wood were prepared in front of the farmhouses, recently many local authorities, parishes and various local associations have been organizing the event. The real number of fires in Veneto is unknown, but it is reasonable to assume that about thousand piles are burnt every year. The tradition is particularly strong in the provinces of Treviso and Venice (Fig. 1).

Piles can be large in size (up to 10 m high and 4 m wide) and are made of various wooden materials, from dry branches to green underbrush weeds, from hardwood to chipboard and old wooden objects, many of which may be painted, varnished or contain metal or plastic components. In most of the Veneto, the 2013 fires started on January 5th at 18:00 local time and ended at about midnight, when the flames died out. Because these fires are poorly controlled, the organic material easily pyrolyzes and large amounts of soot are produced.

3. Materials and methods

3.1. Sampling

A set of 122 daily samples (38 $PM_{2.5}$ and 84 PM_{10}) was collected simultaneously from January 4th to 7th 2013 at 32 sites in the Veneto categorized as rural (RUR, 3 sites), suburban (SUB, 6), urban backgrounds (URB, 14), industrial (IND, 5) and traffic hot-spots (TRA, 4). The sampling campaign covered 6 provinces: Belluno (BL), Treviso (TV), Vicenza (VI), Venice (VE), Padova (PD) and Rovigo (RO). At least one site was selected as an urban background in the capital of each province, namely sites 4, 9, 12, 17, 22 and 30 located in Belluno, Treviso, Vicenza, Venice-Mestre, Padova and Rovigo, respectively. The sites were identified by a number, the initials for the province and their category. The map of selected sites is shown in Fig. 1, while Table 1 summarizes some of sites' characteristics. Sites are included in the monitoring network of the Veneto Agency for the Environmental Control (ARPAV) and were carefully placed in areas representative of each category. For example, urban background sites are broadly representative of city-wide levels of air pollutants, rural background stations are not directly influenced by roads with traffic and/or urban and industrial settlements. Since the event being studied is by nature occasional, unpredictable, and outside the authorities' control, it is impossible to know the number of fires and whether or not they were lit in the vicinity of the sampling sites. Furthermore, it is not obvious that inside the cities more fires were burnt than in suburban or rural areas. The purpose of this study is to describe the episode on a large regional scale and therefore the sampling sites should be considered representing a portion of territory rather than a specific category.

3.2. Experimental

Samplings (24-h starting at 0:00 local time) were carried out according to the EN 14907:2005 (CEN, 2005a) and EN 12341:1998 (CEN, 1998) standards for $PM_{2.5}$ and PM_{10}, respectively, using 47 mm Ø quartz fiber filters (Whatman QMA, GE Healthcare). PM_x masses were measured gravimetrically after conditioning at 20 ± 1 °C and 50 ± 5% relative humidity for 48 h. Some samples were also tested automatically using samplers based on the beta gauge method. Validation experiments were conducted on the gravimetric and automatic procedures before the sampling campaign. In addition, several tests were also performed routinely (at least 1 test every week) to keep a constant check on the automatic samplers. Pairs of filters were measured with both methods and the results were checked to ensure they were