Science of the Total Environment 538 (2015) 672–682

Contents lists available at ScienceDirect

Science of the Total Environment

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

Effect of land uses and wind direction on the contribution of local sources to airborne pollen

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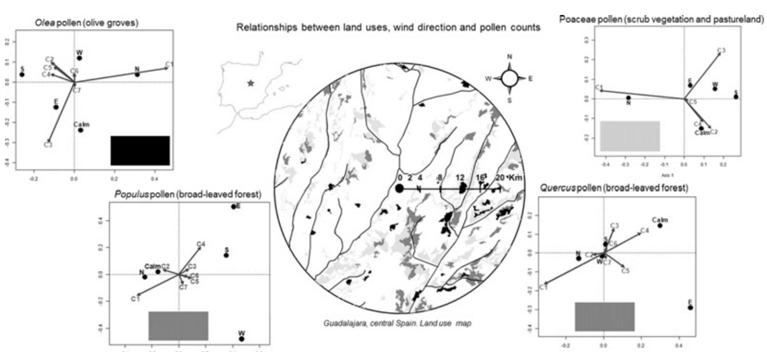
HIGHLIGHTS

- We identified the major sources of urban airborne pollen from maps of land uses.
- Pollen spectrum was governed by the location of pollen sources and wind direction.
- The flora of parks and gardens had a marked impact on airborne pollen level.
- Our findings enabled to recognize the major sources of allergenic pollen.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 9 May 2015
Received in revised form 28 July 2015
Accepted 13 August 2015
Available online 30 August 2015

Editor: D. Barcelo

Keywords:
Aeropalynology
Pollen spectrum
Urban green areas
Vegetation
Meteorological variables

ABSTRACT

The interpretation of airborne pollen levels in cities based on the contribution of the surrounding flora and vegetation is a useful tool to estimate airborne allergen concentrations and, consequently, to determine the allergy risk for local residents. This study examined the pollen spectrum in a city in central Spain (Guadalajara) and analysed the vegetation landscape and land uses within a radius of 20 km in an attempt to identify and locate the origin of airborne pollen and to determine the effect of meteorological variables on pollen emission and dispersal.

The results showed that local wind direction was largely responsible for changes in the concentrations of different airborne pollen types. The land uses contributing most to airborne pollen counts were urban green spaces, though only 0.1% of the total surface area studied, and broadleaved forest which covered 5% of the study area. These two types of land use together accounted for 70% of the airborne pollen. Crops, scrubland and pastureland, though covering 80% of the total surface area, contributed only 18.6% to the total pollen count, and this contribution mainly consisted of pollen from *Olea* and herbaceous plants, including Poaceae, Urticaceae and Chenopodiaceae–Amaranthaceae. Pollen from ornamental species were mainly associated with easterly (*Platanus*), southerly (Cupressaceae) and westerly (Cupressaceae and *Platanus*) winds from the areas where the city's largest parks and gardens are located. *Quercus* pollen was mostly transported by winds blowing in from holm-oak stands on the eastern edge of the city. The highest *Populus* pollen counts were associated with easterly and westerly winds blowing in from areas containing rivers and streams. The airborne pollen counts generally rose with increasing temperature, solar radiation and hours of sunlight, all of which favour pollen release.

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http://dx.doi.org/10.1016/j.scitotenv.2015.08.074

In contrast, pollen counts declined with increased relative humidity and rainfall, which hinder airborne pollen transport.

1. Introduction

Airborne pollen is a major exogenous trigger for allergies affecting a considerable proportion of the population (D'Amato et al., 2007). Knowledge of the pollen types circulating in the air and a detailed interpretation of the airborne pollen spectrum are thus of great value in the environmental and public health sectors (Domínguez et al., 1993; Sánchez-Mesa et al., 2005).

The composition of the airborne pollen spectrum varies as a function of several factors, including the geographical location (Alcázar and Comtois, 2000; Fernández-Rodríguez et al., 2014b), the vegetation (i.e., natural vegetation, crops and ornamentals) in the area of influence (González and Candau, 1997a; Cariñanos and Casares-Porcel, 2011), the time of year (Stefanic et al., 2007; Pérez-Badia et al., 2011) and the weather conditions (Damialis et al., 2005; Latorre and Caccavari, 2009; Kizilpinar et al., 2011).

The vegetation in the area surrounding the sampling station (pollen trap) has a decisive impact on local airborne pollen counts (González and Candau, 1997b). The most common pollen types in regions with a Mediterranean climate (Cariñanos et al., 2004; Pérez-Badia et al., 2010; Boi and Llorens, 2013) have therefore been found to differ from those reported in biogeographically different regions, such as Central European cities (Melgar et al., 2012; Piotrowska-Weryszko and Weryszko-Chmielewska, 2014). Widely planted ornamental species also have a major impact on airborne pollen counts (Cariñanos et al., 2014; Velasco-Jiménez et al., 2014), given the proximity of urban pollen traps to parks and gardens.

The interpretation of the pollen spectrum also requires detailed knowledge of the weather conditions governing the emission and airborne dispersal of pollen. Meteorological variables, such as temperature, solar radiation and relative humidity, significantly influence on pollen counts, in that they regulate anther dehiscence and thus increase or reduce pollen release (Liem, 1980; Recio et al., 1996). Once pollen grains have been released into the air, wind speed and direction (Silva et al., 2000; Damialis et al., 2005) and rainfall (Bonofiglio et al., 2008) determine the extent of pollen dispersal and airborne transport.

Although some pollen may reach the upper layers of the atmosphere, where pollen can be transported over long distances (Smith et al., 2008; Hernández-Ceballos et al., 2011; Rojo and Pérez-Badia, 2015) particularly in the case of small pollen grains (Hernández-Ceballos et al., 2014), most pollen is dispersed locally, and travels only a short distance from the source of emission (Lavee and Datt, 1978). Therefore, the pollen spectrum is a key indicator of the vegetation present in the immediate area (González and Candau, 1997b; Damialis et al., 2005).

This study investigated the relationship between the airborne pollen counts and the land uses that predominate in the area surrounding a city in central Spain (Guadalajara), with a view to identifying and locating sources of airborne pollen to enable people suffering from allergies to specific types of pollen to plan their outdoor activities. A second objective was to determine the meteorological variables most influencing local pollen emission and dispersal over the whole pollen season, for the most common airborne pollen types in the city under study.

2. Materials and methods

2.1. Regional flora

The city of Guadalajara is located in the extreme northeast of the autonomous region of Castilla-La Mancha (40° 37′ N, 3° 9′ W) (Fig. 1) and lies on the Mesomediterranean bioclimatic belt, which is characterised by a dry ombroclimate (Rivas-Martínez, 2007). Biogeographically, Guadalajara is part of the Mediterranean region and, according to Rivas-Martínez (2007), belongs to the Manchego sector of the Mediterranean Central Iberian Province (Castilian Subprovince). The natural vegetation of the area surrounding the city of Guadalajara is largely dominated by holm-oak forests (*Quercus ilex* L. subsp. *ballota* (Desf.) Samp), whereas the stands near rivers include poplars (*Populus alba* L. and *Populus nigra* L.), *Salix* spp. and some elms (*Ulmus minor* Mill.). The city's green areas primarily include cypresses (*Cupressus sempervirens* L. and *Cupressus arizonica* Greene), London planes (*Platanus orientalis* L. var. *acerifolia* Dryand), elms (*Ulmus pumila* L.), broad-leaved privets (*Ligustrum lucidum* Aiton) and maples (*Acer negundo* L.).

2.2. Airborne pollen

The sampling method used complied with the recommendations of the Spanish Aerobiology Network (REA) (Galán et al., 2007). Sampling was carried out over a period of 6 years (2008–2013) using a Hirst-type Burkard volumetric spore trap. The main pollen season (MPS) was calculated following the method proposed by Andersen (1991) for all woody pollen types except Cupressaceae. This method includes 95% of the seasonal total pollen count, starting on the day on which 2.5% of the total pollen was recorded and ending on the day on which 97.5% of the total pollen was registered.

Conversely, pollen types from herbs and Cupressaceae, include many species whose flowering periods occur at different times of the year, remains in the air for long periods that may exceed several months. In these cases, the MPS was determined following the method described by Nilsson and Persson (1981); this method includes 90% of the seasonal total pollen counts.

In order to ascertain the influence of wind direction on the airborne pollen counts, hourly counts were assigned to exponential pollen-frequency classes (C) following the method described by Stix and Ferretti (1974): C1 1–2, C2 3–5, C3 6–11, C4 12–23, C5 24–43, C6 50–99, C7 100–199, and C8 200–399 pollen grains/m^3.

2.3. Weather data and statistical analysis

The correlations between the hourly pollen-count classes and hourly wind direction (N, E, S and W) were subjected to a χ^2 test of independence; the *p* value was computed by a Monte Carlo simulation. Periods with wind speeds of less than 0.5 m/s were designated "calm" following routine Spanish Meteorological Agency (www.aemet.es) practice. A correspondence analysis then enabled the wind direction to be associated with the highest pollen counts.

The relationship between the airborne pollen counts and the vegetation growing within a radius of 20 km of the pollen trap was investigated. A spatial scale of 20 km was selected following the criterion of the division of atmospheric dynamics defined by Orlanski (1975) because atmospheric phenomena, such as convection, turbulence, and storms, that occur in this spatial scale and developed on an hourly temporal scale, are responsible for most of the transport of pollen.

The area was mapped using the vegetation and land use mapping system developed by the Corine Land Cover project (CLC, 2006) in conjunction with a map of the parks and gardens based on orthoimages obtained from the Spanish National Aerial Orthophotography Plan (© National Geographic Institute of Spain).

To ascertain the influence of meteorological variables on daily airborne pollen counts, the following weather data were analysed: the