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Solid Suspended Particles Affecting the Quality of Air in Urban Environments

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When one thinks of air pollution, the first thing that generally comes to mind are emissions from non-natural sources, arising from man´s daily activities, such as traffic, industrial production and building work. Airborne material arising from natural sources, such as volcanoes, earthquakes or sand storms, is also sometimes considered pollutant. All these cases involve particles of non-biological composition, which are considered pollutants not only because they alter the composition of pure air, but also because they have detrimental effects on health (Friedlander and Lippman 1994). Less attention has been paid to naturally-occurring particles of biological composition when evaluating air quality, even though they may at times account for a large percentage of the total amounts recorded and can have serious adverse effects on human health (ACS 1980; D´Amato and Spieksma 1991; Dominguez et al. 1995; Lebowitz and O´Rourke 1991). Pollen grains from the higher plants are listed as one of the most abundant foreign elements with respect to pure air, in some areas even outnumbering diesel-exhaust particles. Moreover, they are directly involved in diseases such as asthma or pollen allergy.

The purpose of this study was to highlight the need to include pollen in the list of atmospheric pollutants together with other parameters (NOx, O3, CO2 and SSP) when defining air quality. Apart from the ill-effects on health, attention must be paid to the co-adjuvant effect of pollen in combination with other pollutants, which exacerbate symptoms (Ishizaki et al. 1987; Muranaka et al. 1986).

MATERIALS AND METHODS

The study was been carried out in the city of Cordoba, in the south-west of the Iberian Peninsula (4º45´W, 37º50´N), defined as a medium-size city of 300 000 inhabitants, 120 m above sea level, in a semi-rural area. The climate is typically Mediterranean, i.e. mild, rainy winters and hot, dry summers. According to the records from the last 25 years, the annual average temperature is 18ºC and total annual rainfall is around 600 mm, but unequally distributed, with long cycles of severe drought (Torreño and Requena 1997).

Reports on Air Quality in Spain (MOPTMA, 1997), do not list Cordoba among the country's most polluted cities, due to the low degree of industrial development. The main source of solid-material emissions into the air is road traffic, since the city lies on the route for goods transported from the southern to the central regions of the country. However, farming activities, which are the basis of the local economy, and a climate that enables plant species to flower over a very long period, are the most important sources of emissions of biological material.

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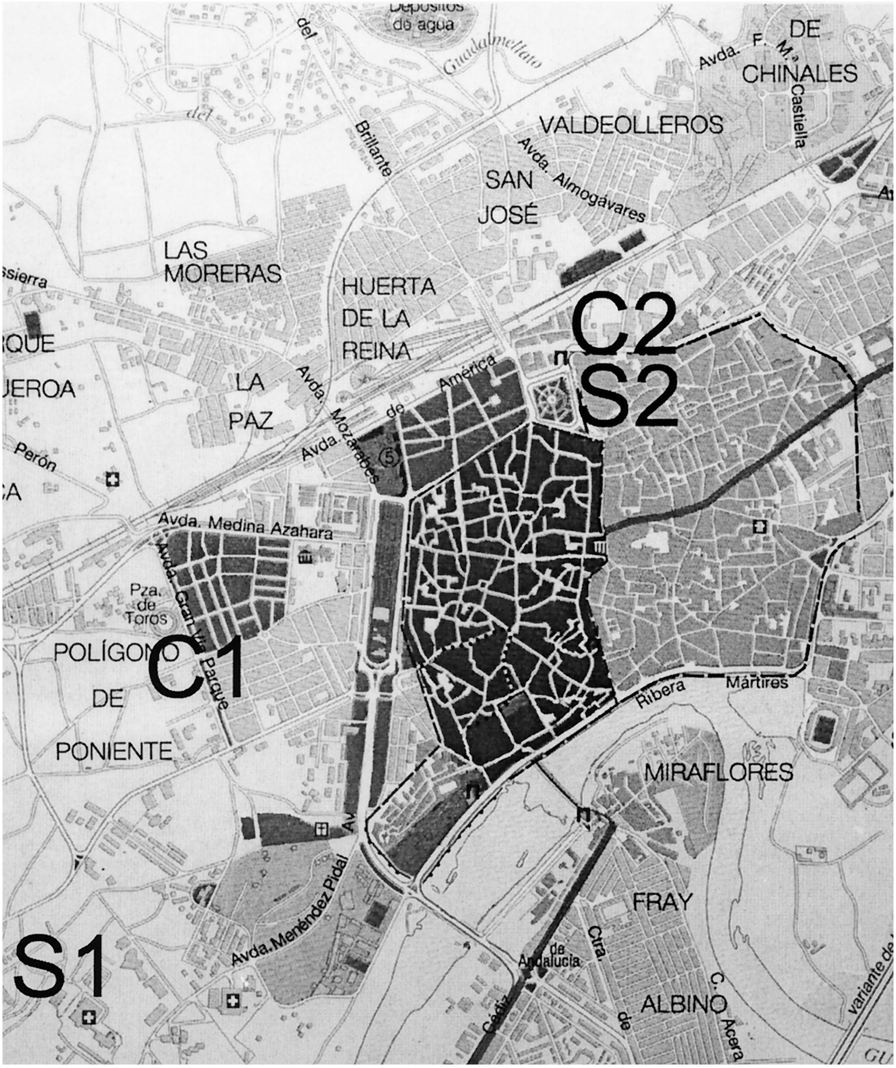

Figure 1. Map of sampling sites in Córdoba.

→ C1 & C2: Cabins for the Control and Environmental Vigilance

→ S1 & S2: Portable samplers Lanzoni VPPS 1000

Table 1. Classification of the quality of air proposed by the Environmental Protection Agency (EPA), according to the concentrations of the different pollutants. (micrograms/m^3/hour)

Index	Particles	SO2	CO	O3	NO2
Limit	50	50	5000	65	135
Acceptable	150	100	10000	110	200
Bad	350	250	15000	180	378
Very bad	420	350	34000	360	957

Collection of airborne biological particles was performed using Lanzoni VPPS 1000 portable suction volumetric samplers (Lanzoni, S.l., Italy) working uninterruptedly 12 hours a day. These samplers work on the impact principle, and material sucked in at flow-rate of 10 l/min, similar to that of the human lung, is deposited on a Melinex tape for subsequent analysis. Trapping effectiveness approaches 100% for particles of 4-100 microns, but is lower for smaller particles (Emberlin and Baboonian 1995). Although this method enables differentiation of particles collected according to their nature (Acuña 1979), since the Local Environmental Agency supplies data on pollutants, including Suspended Particles, the study focused on biological components, and in particular on pollen grains. Light microscopy was used to identify and count the types present. Each sample was scanned following the protocol proposed by the Spanish Aerobiology Network (REA) (Dominguez et al. 1992), with data are expressed in pollen grains/m3 of air/day, although hourly measures are also possible.

Data for other pollutants (SO2, NO2, CO, NO3 and particles) were obtained from Environmental Monitoring and Control Cabins, managed by the Local Division of the Environmental Agency. Pollutant recordings, expressed as micrograms/m3 of air, are interpreted according to the Index of the Environmental Protection Agency, EPA (Table 1). Two such cabins are currently active in the city: one in Puerta del Colodro (City Centre), and one in Avenue Gran Via Parque (Western District) (Figure 1). The VPPS 1000 portable samplers were installed in buildings close to these cabins in order to obtain comparable data. Thirty-day series, coinciding with the flowering of most contributory plant species in the local pollen spectrum, were analysed in order to ascertain the impact of biological particles on air quality in different environmental conditions. Pollen concentrations were classified according to the existing threshold scale.

RESULTS AND DISCUSSION

The first series of data was collected in Autumn 1999 (Tables 2-3). This is a usually-rainy transition season, in which only a few species of plants flower. However, pollen from 19 different species was found in the sampler placed in the City Centre, while 15 species were counted in Western District sampler. The most numerous pollen types were from local populations of surrounding Mediterranean species: *Quercus*, Urticaceae, Poaceae and Chenopodiaceae-Amaranthaceae. Pollen from plants used for ornamental purposes in urban areas, such as *Casuarina* and *Cupressus*, was also frequently encountered. All these pollens, with the exception of *Quercus*, are listed as allergens, although the amounts recorded were not considered sufficient to cause symptoms in pollen-allergy sufferers. In terms of the existing scales used to define the biological quality of air by reference to the amounts of pollen present (Galán at al. 2000), the air at this time was good.

Table 2. Characteristics of the biological particles found in the air samples taken in the Centre and West Districts of the City of Cordoba during autumn 1999.

Center District	West District
Biological particles N° of pollen types: 19 Pollen Index: 518 grains/m3 Main pollen types: Quercus: 43.6% Parietaria: 20.8% Casuarina: 19.8% Cypress: 13.8% Artemisia: 4.4%	Biological particles N° of pollen types. 15 Pollen Index: 407 grains/m3 Main pollen types: Quercus: 45.4% Urticaceae: 23% Cupressus: 8.5% Chenopod: 6.6% Poaceae: 3.4%

Pollen Index: Total of pollen grains/m^3 of air collected in the period of sampling.

Table 3. Total rainfall and average temperature recorded in the series of 30 days sampling taken in autumn 1999.

Rainfall (mm	Aver. T^a (°C)	SO2	CO	NO2	Particles	O3
216.1	13.27°C			1	14	3

The number of days in which the measures for the different pollutants were acceptable are shown in the different columns.

Values for particles and other pollutants recorded Local Environmental Agency Cabins remained at no-risk levels throughout the period. Air quality was generally good or acceptable, thanks in part to steady and abundant rainfall throughout the season. Falling raindrops are known to prompt a washing-out; solid material, including pollen grains, is dragged towards the ground and the air is thus thoroughly cleaned.

Table 4. Characteristics of the biological particles found in the air samples taken in the Centre and West Districts of the City of Cordoba during winter 2000.

Center District	West District
Biological particles N° of pollen types: 20 Pollen Index: 3.091 grains/m3 Main pollen types: Cupressus: 59.1% Populus: 19.1% Urticaceae: 13% Ulmus: 2.2% Fraxinus: 1.5%	Biological particles N° of pollen types. 16 Pollen Index: 4.676 grains/m3 Main pollen types: Cupressus: 62.9% Urticaceae: 17.4% Populus: 11.2% Ulmus: 3% Fraxinus: 0.7%

Pollen Index: Total of pollen grains/m^3 of air collected in the period of sampling

Table 5. Total rainfall and average temperature recorded in the series of 30 days sampling taken in winter 2000.

Rainfall (mm)	Aver. T^a (°C)	SO2	CO	NO2	Particles	O3
0.2	10°C	1	1	5	23	8 (3*)

The number of days in which the measures for the different pollutants were acceptable are shown in the different columns (* indicates days in which the measures were above the first level of protection, that is, 110 micrograms/m^3 of air).

Table 4 and 5 show the major characteristics of the 2nd series, collected in Winter 2000. The number of plant species flowering in this period is similar to that of the autumn period: 20 different pollen types were recorded in the Centre, and 16 in the Western District. There was, however, a noticeable change in the most numerous species: *Cupressus* became the most abundant, due to large numbers in parks and gardens. Other winter-flowering trees were also frequently represented in the samples: *Populus, Ulmus* and *Fraxinus*. The most important herb pollen came from Urticaceae. *Cupressus* has a tested allergenicity (Guerra et al., 1998), being the main cause of winter allergy in this area. The threshold of 200 grains/m3 of air is considered a high value in the biological air-quality scale (Galán et al., 2000). This figure was surpassed on several occasions in both central and western areas. In the week from the 5th to the 11th of February, air quality was defined as bad or hazardous for health from a biological point of view. Analysis of reports on local atmospheric pollution revealed that this particle concentration was classified only as acceptable. Although amounts detected per cubic meter were not especially high, the allergenic load was enough to concern inhabitants. Figures for the next few days showed a tendency to improve, although the peak in the flowering curve of cypress was not yet passed.

Climate conditions also played an important role, since this was an atypically cold, dry winter. Lack of rain prevented thorough cleaning of the air, while sub-zero temperatures recorded in the early morning increased the occurrence of thermal inversion layers, trapping material in the lower layer, i.e. the layer in contact with the city (Oke, 1973; Cariñanos et al., 2000). By the end of the season, *Platanus* pollen started to appear, with the attendant allergy-related problems.

Table 6. Characteristics of the biological particles found in the air samples taken in the Centre and West Districts of the City of Cordoba during spring 2000.

Center District	West District
Biological particles Nº of pollen types: 32 Pollen Index: 23.961 grains/m3 Main pollen types: Olea: 38.6% Platanus: 27.2% Quercus: 11.3% Urticaceae: 6.5% Poaceae: 2.5%	Biological particles Nº of pollen types. 27 Pollen Index: 26.363 grains/m3 Main pollen types: Platanus: 43.6% Olea: 31.2% Morus: 6.2% Poaceae: 6.5% Quercus: 4.5%

Pollen Index: Total of pollen grains/m^3 of air collected during the period of sampling.

Table 7. Total rainfall and average temperature recorded in the series of 30 days sampling taken in spring 2000.

Rainfall (mm)	Aver. Tª (ºC)	SO2	CO	NO2	Particles	O3
139.3	16.8ºC			4	10	26

The number of days in which the measures for the different pollutants were acceptable are shown in the different columns.

The third series was collected in Spring 2000, which proved to be the most problematic season. Numerous plant species flower in Spring, as was evident from the variety of pollen types collected: 32 types in the City Centre and 27 in the Western District (Table 6). *Olea, Platanus*, Poaceae and *Quercus* topped the frequency lists in both areas, though with differing shares of the total. While *Platanus* was the most numerous species in the Western District, *Olea* was the most common in the Centre. *Platanus* is widely used in the city, both in gardens and for shade lining the roadsides; *Olea* is the main crop beyond the city limits. Differences in the amounts collected by the two samplers arise from their proximity to sampling points. The same is true of grass pollens, which were more frequent in the Western District, a semi-rural area with natural open spaces. The influence of local flora is evident in the presence of *Morus* in the Western District. This pollen type was not detected in other samplers around the City, has recently been shown to be allergenic.

As the pollen-concentrations recorded frequently exceeded risk thresholds for human symptoms, air quality was often defined as very poor and representing high risk for all pollen-allergy and asthma sufferers. Over 18 days in the City Centre and 12 days in the Western District, air quality was considered particularly bad due to high concentrations of airborne pollen and to interactions and cross-reactions involving several simultaneously-present pollen types. At the same time, over most of this period ozone values were no more than acceptable, i.e. above the minimum protection level laid down by the Spanish Government (table 7). In this situation, symptoms might worsen due to the adjuvant activity of biological and non-biological components (Ishizaki et al. 1987; Muranaka et al. 1986). Particle measurements were also recorded as acceptable, even when over 2000 grains/m3 of olive pollen were counted in one day, raising the question of how many particles are necessary in order for the situation to be considered a risk to human health.

Analysis of the above data underlines the need to include biological information in reports on urban air quality, since this information may be of value to the city's inhabitants, allowing them to take preventive measures in advance and thus improve their quality of life by avoiding unnecessary exposure.

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