Classification, analysis and interaction of solid airborne particles in urban environments

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Abstract

An analysis was made of airborne solid particulate matter in Córdoba, a city in the southwestern Iberian Peninsula with a Mediterranean climate. The detection and analysis techniques used enabled solid particles to be classified by size, by biogenic or non-biogenic origin, and by natural source of emission, e.g. pollen grains released by vascular plants during the pollen season, or particles attributable to human activity. Airborne particles of biogenic origin were predominant in the spectrum of the air in Córdoba. Intradiurnal variations in solid-particle counts closely reflected human activities, especially traffic. Peak biogenic-particle counts at times coincided with peak non-biogenic particle counts, suggesting that in certain weather conditions, particulate matter is not dispersed due to the high degree of atmospheric stability, and also that there may be interactions between the two types of particle, mediated by the presence of very small allergenic particles. This joint action may prompt a worsening of symptoms in pollen-allergy sufferers, as well as a deterioration in biological air quality.
Keywords: solid suspended particles, PM10 particles, pollen grains, aerobiology, urban air pollution.

1 Introduction

In many places, urban development – often with little regard for environmental sustainability – has prompted a sharp increase in air pollution, to the extent that the air is fast becoming a health threat rather than a healthy element. Of the six

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major air pollutants listed by the US Environmental Protection Agency [1], solid particulate matter is deemed to be among the most hazardous, because particles are small enough to reach the alveoli (Dockery and Pope [2], Osunsanya *et al* [3]).

In measuring air pollution, a distinction has traditionally been made between particulate matter of non-biogenic origin, i.e. traceable to human activity (mainly traffic), and biological particles, such as pollen grains released by natural and ornamental vegetation. A number of studies have highlighted a correlation between episodes of environmental pollution and increased mortality (Schwartz *et al* [4], Rusznak *et al* [5], Kim *et al* [6]). Biological particles – mainly pollen grains and fungal spores – are largely responsible for two major respiratory diseases: pollen allergy and associated asthma, which according to recent reports currently affect over 15% of the European population (D'Amato *et al* [7]). This figure is expected to increase considerably over the next few years as a result of global warming due to climate change, which is likely to prompt a lengthening of plant flowering cycles (D'Amato *et al* [8]; Fernandez *et al* [9]).

Although relatively few studies address the reactions prompted by the joint presence of biogenic and non-biogenic particles in the atmosphere, some authors report that the allergenic potential of pollen grains may be enhanced by the presence of other atmospheric pollutants (Muranaka *et al* [10], Ishizaki *et al* [11]). Paucimicronic allergen particles measuring less than 2.5 microns have been detected in air quality tests (Spieksma *et al* [12], Rantio-Lehtimaki *et al* [13], De Linares *et al* [14]), and research has shown that pollen grains are the major cause of deterioration of biological air quality (Cariñanos *et al* [15]).

The present paper reports the results of a five-year air-quality assessment carried out in the city of Cordoba, southern Spain. The main sources of airborne particles were identified and classified; the effect of the weather on particle counts was analyzed; and an assessment was made of potential interactions between different types of particles, and of their damaging effect on human health.

2 Material and methods

Air sampling was performed in the city of Córdoba, south-western Iberian Peninsula (4º45´W, 37º50´N), Mediterranean Europe, between 2000 and 2004. The Mediterranean climate, with mean temperature 17.6ºC and average annual rainfall 536mm, favors the flowering of plant species over a long period of the year. Two major sources of airborne particles can be distinguished: natural origins and human activity. Córdoba province contains a great deal of arable land, largely given over to herbaceous crops, cereals and olive groves; pollen grains from these crops, as well as from natural vegetation and ornamentals, therefore constitute a major, permanent component of the solid-particle spectrum. Sand and dust also arise from natural sources. Other, nonbiological, particles are attributable to human activity, and particularly to traffic.

Air samples were taken daily using a Lanzoni VPPS 2000 volumetric suction sampler (Lanzoni Manufacturing, Italy). This kind of trap is suitable for the study of airborne particles in general, and for aerobiological analysis in particular, because it efficient captures particles over a wide range of diameters, from 1 to 100 µm (Cariñanos *et al* [16]). Biological material sampled was analyzed using the standardized protocol drawn up by the Spanish Aerobiology Network, (REA) (Galán *et al* [17]). Results were expressed as the daily average pollen count per cubic meter of air. Material was identified by light microscopy at 400X magnification. This method enables differentiation between the various types of particle collected (Acuña [18]); however, since the local Environmental Agency already supplies data on pollutants, including suspended particles, this study focused on biological components, and in particular on pollen grains. Data for other pollutants (SO2, NO2, CO, Ozone, NO_3 and particles) were measured at an automatic pollutant-monitoring station located in the city center. Recordings, expressed as micrograms/m^3 of air, were interpreted using the Environmental Protection Agency (EPA) index.

Meteorological data were supplied by the regional Division of the Spanish Institute of Meteorology, emphasis being placed on temperature and rainfall, since these have been shown to be largely responsible for aggravating pollution episodes.

3 Results

Weekly average values for PM10 particle concentrations and pollen counts from 2000 to 2004 are shown in Figure 1.

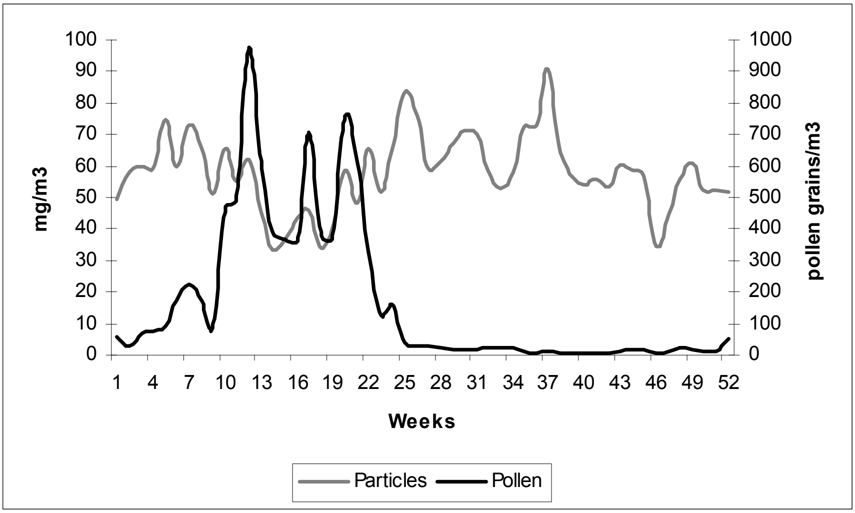

Figure 1: Weekly average values for airborne PM10 particle concentrations and pollen counts in Córdoba from 2000 to 2004.

Total pollen counts, expressed as pollen grains/m^3 of air, comprised at least 35 different pollen types released by anemophyllous plant species present in the

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area, including both natural Mediterranean vegetation and ornamental species – some of them allochthonous – grown in the city. The highest airborne pollen counts were recorded from February to June, a period marked by the successive flowering of the wind-pollinated species which most contribute to the city's pollen spectrum: *Cupressus*, *Platanus*, *Quercus*, *Morus*, *Olea*, grasses and other herbs (e.g. nettles, pellitory, Asteraceae, Chenopodiaceae-Amaranthaceae). A significant decrease in pollen levels was detected in mid-summer due to high maximum temperatures, often above 40ºC, which accelerated withering in most species, except those better adapted to arid conditions. In some years, autumn rainfall prompted a secondary peak coinciding with the flowering of certain herbaceous species displaying a rapid response to water (Figure 2).

Data for PM10 particles displayed no appreciable seasonality in their pattern of annual distribution, although rainfall exerted an evident washout effect (Figure 2). Interestingly, at certain times of year curves for non-biogenic particles and pollen grains ran in parallel, peaking at the same time.

Weather conditions during the monitoring period (Figure 2) were typical of the Mediterranean climate: semi-arid with at least two consecutive months of drought, and temperatures rarely falling below 0ºC, while maximum temperatures often exceeded 40ºC.

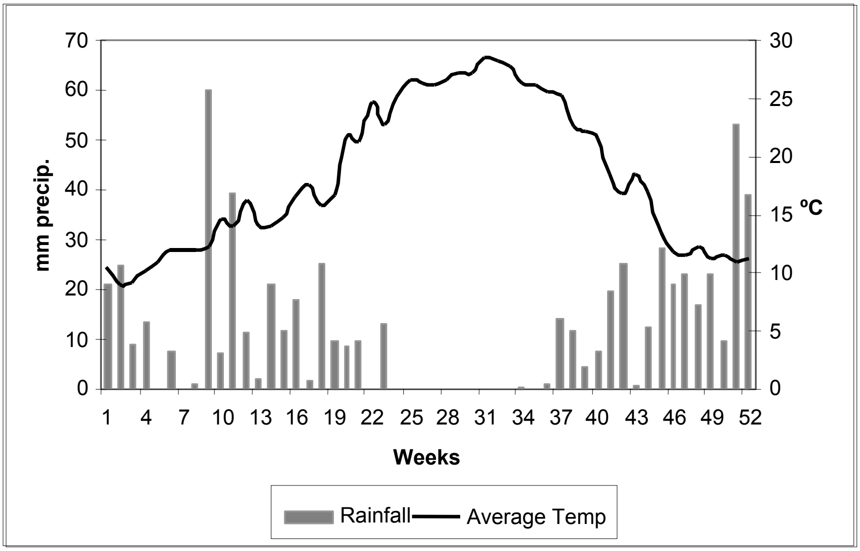

Figure 2: Weekly average temperature and total annual rainfall in the city during the period 2000–2004.

Table 1 shows air quality standards based on concentrations of different types of airborne particles: maximum PM10 values as listed by the Environmental Protection Agency [1], and pollen counts sufficient to cause symptoms allergy-sufferers, according to Biological Quality of Air index developed by the Spanish Aerobiology Network (REA) [19].

Table 1: Air quality standards for PM10 particles and concentrations of pollen grains.

Air Quality Standards	Daily quality intervals (μg/m^3)	Biological quality intervals (pollen grains/m^3)
Good	0-25	50
Acceptable	25-50	100
Poor	50-75	200
Very Poor	>75	>200

5 Discussion

Analysis of the results obtained shows that airborne pollen counts in Córdoba are sufficiently high, over a long period of the year, to cause adverse reactions in people suffering from respiratory-tract disorders. A pollen count of 100 grains/m^3 of air, considered sufficiently high to cause symptoms in a large percentage of allergy sufferers, was exceeded in over 20 weeks in the year. A more detailed analysis of the main types comprising the pollen spectrum has been provided by Alcázar *et al* [20], Acuña [18], and Cariñanos *et al* [15].

Microscopic analysis of samples enabled the identification of non-biological particles using existing classification manuals (Acuña [18], McCrone [21]). At certain times of year, considerable amounts of Saharan dust were detected, since Córdoba is located in the path of air masses travelling across the European continent (Reiff *et al* [22], Cariñanos *et al* [23]). Sand clouds contained quartz, feldspars and mica flakes, as well as pollen grains from remote origins that could be used as biomarkers to identify both the original source of emission and the air-mass trajectory.

However, a large proportion of non-biogenic material comprised partially-burnt hydrocarbon residue from diesel-engine exhausts; sample analysis disclosed characteristic black soot with a disorganized structure. In previous studies, daily air samples were examined using a DU7 spectrophotometer (Beckman, Palo Alto, CA, USA), a technique enabling quantification of airborne particle concentrations in terms of light absorption; dark particles (e.g. soot) can thus be distinguished from light or hyaline particles, such as pollen grains. Analysis of intradiurnal variations revealed higher counts coinciding with rush hour traffic (Cariñanos *et al* [24]).

Results also highlighted a close correlation between weather-related parameters and airborne particle counts (Figures 1 & 2). In the case of PM10 particles, released by non-natural sources, sporadic dips in the particle count coincided with rainfall, due to wash-out. However, the routine nature of human activity favored a rapid return to normal levels. These particles attained peak concentrations in rain-free periods, i.e. during the summer, due to greater atmospheric stability which allows this material to accumulate (Cariñanos *et al*

[24]). Summer also marks the arrival of additional allochthonous material (Cariñanos *et al* [23]).

Biological particle counts also fell during rainy periods. However, pollen counts at times returned to even higher levels, due to the rapid response of some herbaceous species to water (Cariñanos *et al* [25]). Analysis of weekly average pollen counts over the five-year period (Figure 1) showed that the key local pollen-releasing species – *Cupressus, Platanus, Morus, Quercus, Olea* and grasses – did not all flower at the same time. In some years the annual pollen peak was recorded earlier or later than the Principal Pollination Period.

The most striking finding was that at certain times of year – between the 10th and 22nd weeks – the distribution curves for PM10 particles matched pollen grain curves (Figure 1). This is the period in which annual peak pollen counts are recorded, due to the overlap of species coming into flower in late winter and early spring with those flowering in the middle of spring. It is also a period of atmospheric instability in the Mediterranean area, characterized by storms and heavy rainfall, sometimes over 50mm/day. As suggested earlier, this may lead to the disruption and alteration of some pollen grains, giving rise to paucimicronic particles with allergenic activity (Spieksma *et al* [12], Rantio-Lehtimaki *et al* [13]). Although the methods used here could not confirm the presence of such paucimicronic particles in the < 10 micron fraction, other authors measuring the potential allergenic activity of non-pollen airborne particles report intense activity following the *Olea* pollination period in particles of ≤ 3.3 microns (De Linares *et al* [14]). Similar results have been recorded for other pollen types such as grasses (Schäppi *et al* [26]) and *Quercus* (Fernandez-Caldas *et al* [27]), both of which contribute strongly to the airborne pollen spectrum in Córdoba, and may therefore be involved in any interactions between biological and non-biological particles.

Finally, attention is drawn to potential changes to these models as a result of future climate change. A number of studies have suggested that flowering periods for some plant species – mainly those flowering in winter and early spring – are starting earlier and lasting longer all over Europe (Emberlin *et al.* [28], Garcia-Mozo *et al* [29]). Other research has examined the possible effect of increased temperatures on biodiversity in various ecosystems [9]. Analysis of historical pollen data has shown that species better adapted to increasing aridity are extending their range in parts of southern Iberian Peninsula, as desertization progresses (Cariñanos *et al* [30]). Given this outlook, and taking into account the sometimes-unsustainable nature of urban development, steps must clearly be taken to prevent the increased incidence of respiratory-tract disorders prompted by airborne allergenic particles, and at the same time to check the constant increase in emission of non-biological particles, which is proving difficult to control.

6 Conclusion

Local climate characteristics favor high airborne pollen counts during much of the year, while heavy rush-hour traffic is the main source of emission of particles

< 10 microns. Measures should be taken to minimize the hazardous effects on human health that may be prompted by any change in current conditions.

References

[1] US-EPA., *Air Quality criteria for particulate matter*. EPA/600/P.95/001F, US Environmental Protection Agency: Washington DC, 1996.

[2] Dockery, D. & Pope, A., Epidemiology of acute health effects: summary of time-series studies. Particles in Air: Concentration and Health Effects, ed. Wilso, R. & Spengler, J.D., Harvard University Press: Cambridge, USA, pp. 123–146, 1996.

[3] Osunsanya, T., Prescot, G. & Seaton, A., Acute Respiratory effects of particle: Mass or number? *Occupational Environmental Medicine*, **58**, pp. 154–162, 2001.

[4] Scwartz, J., Particulate Air Pollution and daily mortality in Detroit. *Environmental Research*, **56**, pp. 204–213, 1991.

[5] Rusznak, C., Devalia, J.L. & Davies, R.J., The impact of pollution on allergic diseases. *Allergy*, **49**, pp. 21–27, 1994.

[6] Kim, V.K., Back, D., Koh, V.I. & Cho, S.H., Outdoor air pollutants derived from industrial processes may be casually related to the development of asthma in children. *Annals of Allergy and Clinical Immunology*, **86**, 456–461, 2001.

[7] D'Amato, G., Liccardi, G. & D'Amato, M., On the interrelationship between outdoor air pollution and respiratory allergy. Aerobiologia, **16**, pp. 1–6, 2000.

[8] D'Amato, G., Liccardi, G., D'Amato, M. & Cazorla, M., The role of outdoor air pollution and climatic changes on the rising trends in respiratory allergy. *Respiratory Medicine*, **95**, pp. 606–611, 2001.

[9] Fernandez, F., Loidi, J., Moreno, J.C., Del Arco, M., Fernandez, A., Galan, C., Mozo, H., Muñoz, J., Perez, R., Sardinero, S., Telleria, M.T., Impacts on Plant Biodiversity. *A preliminary assessment of the impacts in Spain Due to the effects of climate change*. Ministerio de Medio Ambiente, 2005.

[10] Muranaka, M., Suzuki, S., Koizumi, K., Takafuji, S., Miyamoto, T., Ikemori, R. & Tokiwa, H., Adjuvant activity of diesel-exhaust particles for the production of IgE antibody in mice. *Journal of Allergy and Clinical Immunolog*y, **77**, pp. 616–623, 1986.

[11] Ishizaki, V., Koizumi, K., Ikemori, Y., Kushibiki, E. Studies of the prevalence of Japanese cedar pollinosis among the residents in a densely cultivated area. *Annals of Allergy*, **58**, pp. 265–270, 1987.

[12] Spieksma, F.Th.M., Kramps, J.A., Van der Linden, A.C., Nikkels, B.H., Plomps, A., Koerten, H.K. & Dijkman, J.H., Evidence of grass-pollen allergenic activity in the smaller micronic atmospheric aerosol fraction. *Clinical and Experimental Allergy*, **20**, pp. 273–280, 1990.

[13] Rantio-Lehtimaki, A., Viander, M. & Koivikko, A., Airborne birch pollen antigens in different particle size. *Clinical and Experimental Allergy*, **24**, pp. 23–28, 1994.

[14] De Linares, C., Nieto-Lugilde, D., Alba, F., Díaz de la Guardia, C., Galán, C. & Trigo, M.M., Detection of airborne allergen (Ole e 1) in relation to Olea europaea pollen in S Spain. *Clinical and Experimental Allergy*, **37(1),** pp. 125–132, 2007.
[15] Cariñanos, P., Galán, C., Alcazar, P. & Domínguez, E., Analysis of solid particulate matter suspended in the air of Cordoba, southwestern Spain. *Annals of Agricultural and Environmental Medicine*, **14**, pp. 159–164, 2007.
[16] Cariñanos, P-. Prieto, J.C., Galán, C. & Dominguez, E., Solid Suspended Particles affecting the quality of Air in urban environments. *Bulletin of Environmental Contamination and Toxicology*, **67**, pp. 385–391, 2001.
[17] Galán, C., Cariñanos, P., Alcazar, P. & Domínguez, E., *Management and Quality Manual. Spanish Aerobiology Network (REA*). Servicio de Publicaciones Universidad de Córdoba, España, pp. 67, 2007.
[18] Acuña, R.H., *Criterios de Salud Ambiental aplicables a los óxidos de azufre y las partículas en suspensión*. Servicio de Publicaciones y Documentación de la Oficina de Publicaciones Biomédicas y de Salud OPS/OMS, 99 pp.
[19] Alcázar, P., Cariñanos, P., Galán, C. & Domínguez , E., La Calidad Biologica del Aire en Andalucia durante el año 2003. *Medio Ambiente en Andalucia. Informe 2003*. Consejeria de Medio Ambiente. Junta de Andalucia (ed), 2004.
[20] Alcázar, P., Cariñanos, P., Galán, C., Domínguez, E. Aerobiología en Andalucía. Estación de Córdoba (2000). *REA*, **7**:49–54, 2003.
[21] McCrone, W.C., Draftz, R.G. & Delly, J.G., *The particle analyst (compiled)*. Ann Arbor Science, Ann Arbor, MI, 1968.
[22] Reiff, J., Forbes, G.S., Spieksma, F.Th.M. & Keynders, J.J., African dust reaching Northwestern Europe: A case study to verify trajectory calculations. *Journal of Climate Applied Meteorology*, **25(11)**, pp. 1543–1567, 1987.
[23] Cariñanos, P., Galan, C., Alcazar, P. & Domínguez, E., Análisis of the Particles Transported with dust-clouds reaching Cordoba, Southwestern Spain. *Archives of Environmental Contamination and Toxicology*, **46**, 141–146, 2004.
[24] Cariñanos, P., Galan, C., Alcazar, P. & Domínguez, E., Diurnal variation of biological and non-biological particles in the atmosphere of Cordoba, Spain. *Aerobiologia*, **15**, pp. 177–182, 1999.
[25] Cariñanos, P, Galan, C., Alcazar, P. & Domínguez, E., Airborne pollen records response to climatic conditions in arid areas of the Iberian Peninsula. *Environmental and Experimental Botany*, **42**, pp. 11–22, 2004.
[26] Schäppi, G.F., Monn, C., Wüthrich, B. & Wanner, H.V. Concentrations of major grass group 5 allergens in pollen grains and atmospheric particles implications for hay fever and allergic asthma sufferers sensitized to grass pollen allergens. *Clinical and Experimental Allergy*, **29**, pp. 633–641, 1999.

[27] Fernandez-Caldas, E., Swanson, M.C., Pravda, J., Welsh, P., Yunginger, J.W. & Reed, C.E. Immunochemical demonstration of red oak pollen allergen outside the oak pollination season. *Grana*, **28**, pp. 205–209, 1989.

[28] Emberlin, J., Laadi, M., Detandt, M., Gehrig, R., Jaeger, S., Myszkowska, D., Noland, N., Rantio-Lehtimaki, A. & Stach, A., Climate change and evolution of the pollen content in the air of seven European countries. The example of birch. *Revue Francaise D Allergologie et D Immunologie Clinique*, **47(2)**, 57–63, 2007

[29] Garcia-Mozo, H., Galan, C., Jato, V., Belmonte, J., Diaz de la Guardia, C., Fernandez, D., Gutierrez, M., Aira, M.J., Roure, J., Ruiz, L., Trigo, M.M.,& Dominguez, E., Quercus pollen season dynamics in the Iberian Peninsula: Response to meteorological parameters and possible consequences of climate change. *Annals of Agricultural and Environmental Medicine*, **13(2)**, 209–224, 2006.

[30] Cariñanos P., Galan, C., Alcazar, P. & Domínguez, E. Airborne Amaranthaceae pollen records as indicators of increasing aridity in Mediterranean Europe. *Aerobiological Monographs* (in press) 2008.