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ANALYSIS OF SOLID PARTICULATE MATTER SUSPENDED IN THE AIR OF CÓRDOBA, SOUTHWESTERN SPAIN

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Abstract: An analysis was made of solid particulate matter suspended in the air in the city of Cordoba. Particles greater than 10 micra were collected using volumetric particle samplers (Lanzoni VPPS 2000, Bologna, Italy), and analysed by means of aerobiological methods enabling identification of the source of biological particulate material (BPM). Particles smaller than 10 micra were collected using automatic high-volume air samplers. Subsequent analysis showed that traffic, and particularly diesel engine exhaust emissions, were the main source of non-biological particulate matter (nBPM). The dynamics of airborne BPM and nBPM were also studied over one year: although distribution patterns differed – BPM displaying marked seasonality and non-BPM exhibiting dependence on human activity – the curves ran parallel at certain times of the year. Statistical results point to the possible presence of plant residues on smaller particles. The occurrence of simultaneous peaks in airborne pollen-grain and PM10 counts suggests potential coadjuvant acivity, which may lead to high-risk situations for people with respiratory disease.

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INTRODUCTION

The presence of pollutants in the air, and their harmful effects on human health, including respiratory-tract irritation, headache, vomiting, cough, breathing difficulties and even premature death, are well known and have been widely addressed in the literature [12, 22, 23, 30, 31]. Concentrations of airborne pollutants are currently measured and monitored, and have been used to draw-up accepted air-quality criteria. Some criteria distinguish between primary standards that set limits to protect public health, including the health of sensitive populations such as asthmatics, and secondary standards that set limits to protect public welfare, including protection against decreased visibility, as well as damage to animals, crops, vegetation and buildings [15, 34, 35].

Of the EPA general list of 6 principal pollutants, particulate matter is deemed to be the most hazardous in terms of its effects on the respiratory tract, since particles are small enough to reach the alveoli [13]. In recent years, and due to a considerable increase in the number of people affected by respiratory diseases, ambient air-quality standards for particulate matter have been revised. However, particulate matter of biogenic origin, including mainly pollen grains and fungal spores, has not received the same treatment in these Directives as other air pollutants. Nonetheless, and

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although most – with the exception of some fungal spore types – are larger than 10 micra, these biological pollutants produce harmful effects on health and aggravate respiratory diseases [29]; they are also released in quantities sufficient to affect air quality [10] and are sometimes the main cause of altered composition of pure air.

A number of papers report that the co-adjuvant action of EPA-listed pollutants and biological particles aggravates respiratory symptoms in the general population [20, 25]. However, reported results tend to be highly localized, which hinders the establishment of generally-applicable air-quality standards in terms of biological particle counts. This study focuses on the distribution and probable interactions between airborne biological and non-biological particles of varying sizes and origins in the city of Cordoba, southwestern Spain. This paper also considers a number of criteria for setting biological air-quality standards.

MATERIAL AND METHODS

The study was carried out in the city of Cordoba, southwestern Spain (4º 45'W, 37º 50'N), in Mediterranean Europe; this medium-size city (300,000 inhabitants) lies 120 m above sea level and is situated in a semi-rural environment. Total annual rainfall is 536 mm and the yearly average temperature is 17.6ºC, according to average data for 1971-2000 supplied by the Spanish National Institute of Meteorology. Point source emissions are mainly from a cement factory, some low-activity industrial estates (jewelry, furniture, feed) and agricultural activities; mobile sources include traffic within and surrounding the city. There is also a certain amount of air pollution from more distant sources, outstanding among which is the Saharan dust transported in dust clouds from North Africa, 3-4 times per year [9]. Biogenic sources, i.e. those emitting biological matter, make up a third category; here, these comprise chiefly plants (ornamental, natural Mediterranean vegetetation and crops). Although each species has a specific flowering period, the Mediterranean characteristics of the climate allow different species to flower in succession for over 7 months of the year; in favourable weather conditions, some species may flower twice a year. The pollen records for the city give a spectrum of around 35 pollen types [4]. Data for biological matter were obtained using Hirst-type suction volumetric samplers, applying normalized aerobiological methods [14]. This study used the aerobiological sampling unit placed on the roof of the Education Faculty (southwest of the city), and included annual pollen index data for 2000, 2001 and 2002. The spectrum included pollen counts for largely wind-pollinated plants, some of which are a major cause of allergic reactions.

The presence of particles smaller than 10 micra (PM10) was detected automatically by 2 pollutant-measuring stations managed by the Local Division of the Environmental Council over the same period, one situated in the city centre, in Puerta del Colodro (PC), and the other in the western district of the city, close to the aerobiological unit, in Gran Via Parque (GVP). Air quality was defined in terms of the revised National Standards established by the US Environmental Protection Agency [35], the Corinne Atmosphere Programme for non-biological particles, and the Biological Air Quality Index developed by the Spanish Aerobiology Network [2]. The latter was based on a range of criteria, including average counts for various pollen types over a number of years, their proven allergenic potential, the arboreal/herbaceous nature of the plant, and the simultaneous presence of several airborne pollen types with tested cross-reactivity, which would lower the reaction threshold. For general purposes, counts were classed as: "border risk" (i.e. counts sufficient to cause symptoms in at least 30% of allergy-sufferers) for values of 50 pollen grains/m^3 of air; "acceptable risk" for > 100 pollen grains/m^3 of air, i.e. enough to cause symptoms in 70% of the affected people and "high risk", i.e. 100% of allergy-sufferers affected, some by acute respiratory crisis, for counts over 200 pollen grains/m^3 of air.

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

For the periods displaying the highest airborne pollen counts, Spearman´s correlation analysis was used to chart relationships between PM10 and biological particles.

RESULTS

Airborne PM10 and pollen counts for 2000, 2001 and 2002 are shown in Figure 1. Pollen counts exhibited marked seasonality, maximum values being recorded from February to late June, coinciding with the flowering of key local species: *Cypress*, plane trees, *Quercus*, olive trees,

Table 1. Number of days in which concentrations of PM10 and pollen grains surpassed the limit acceptable or values of risk in 2000, 2001 and 2002. In brackets under the PM10 values are indicated the reductions that will be progressively applied in 2005.

		2000	2001	2002
	Limit values			
GVP-PM10	50 µg/m^3 (25 µg/m^3)	295	87	209
PC-PM10		177	144	222
Pollen	50 pgrains/m^3	38	32	39
	Aceptable values			
GVP-PM10	150 µg/m^3 (50 µg/m^3)	0	0	0
PC-PM10		0	0	0
Pollen	100 pgrains/m^3	55	28	33
	Values of Risk			
GVP-PM10	350 µg/m^3 (75 µg/m^3)	0	0	0
PC-PM10		0	0	0
Pollen	200 pgrains/m^3	58	75	79

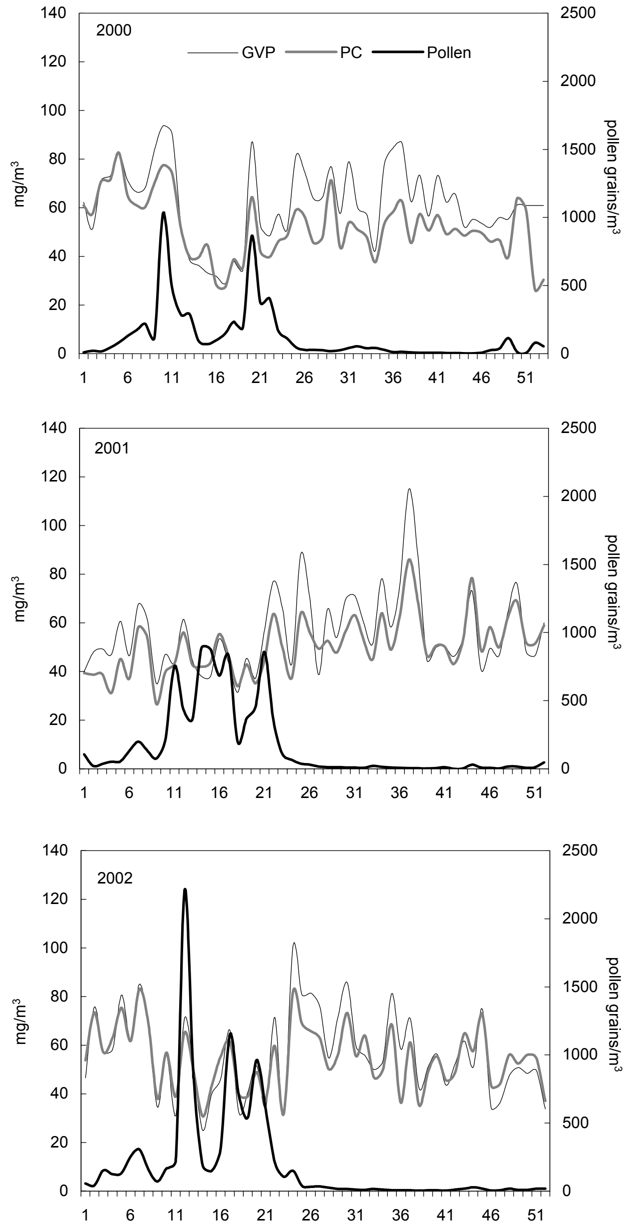

Figure 1. PM10 measured in Gran Via Parque Cabin (GVP) and Puerta del Colodro Cabin (PC), and total pollen grains detected in the Hirst type sampler during 2000, 2001 and 2002.

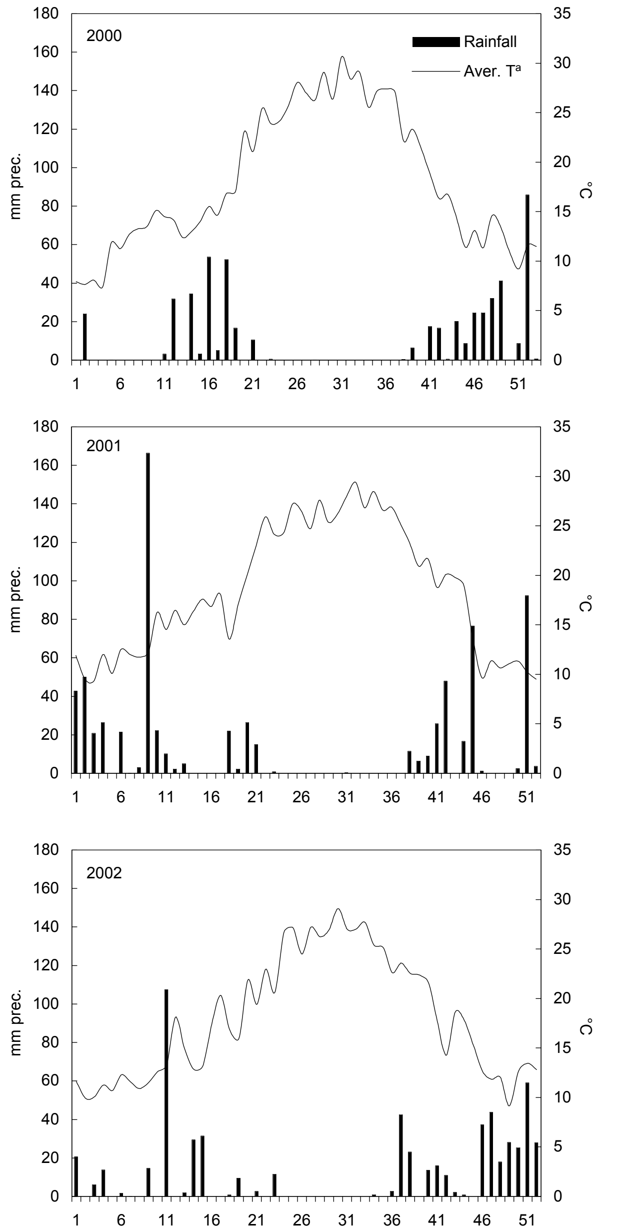

Figure 2. Average temperatures and total annual rainfall in the city of Córdoba during 2000, 2001 and 2002.

grasses and herbs. Weekly average counts during the main pollen period approached 100 grains in 2000 and exceeded that figure in the other years. In all 3 years a number of peaks were recorded, coinciding with the flowering of different species; in 2001, successive peaks of similar intensity were detected. An appreciable decline in pollen counts occurred in late July/early August in all years. An autumn peak was detected only in 2000 due to regular rainfall and warm temperatures that favoured the flowering of some herb species.

PM10 readings were taken from 2 automatic stations. Neither displayed any appreciable seasonality, although rainfall patterns exerted visible influence (Fig. 2): spring and autumn rainfall prompted a decrease in PM10 counts. Although PM10 distribution patterns were rather irregular, there were similarities between the results recorded at the 2 stations; these are discussed in detail below. Generally speaking, PM10 counts at GVP were slightly higher than those recorded at PC, particularly in 2000.

Application of air quality standards, using US-EPA guidelines for PM10 (micrograms/m^3), and the SAN Biological Air Quality Index (pollen grains/m^3), are shown in Table 1. PM "borderline risk" levels (50 micrograms/m^3) were surpassed on many occasions at both stations. However, at neither station were "acceptable risk" (150 micrograms/m^3) or "high risk" levels (350 micrograms/m^3)

Table 2. Spearman's statistical correlation results between the daily concentrations of pollen during the period of highest incidence in the atmosphere (February-June), and the PM10 daily records measured in Gran Via Parque Cabin (GVP) and Puerta del Colodro Cabin (PCC) during 2000, 2001 and 2002.

PM10 vs. Pollen	Results	2000	2001	2002
GVP vs. Pollen	Correl Coeff.	0.469**	0.222**	0.341**
	Sig (2-tailed)	0.000	0.126	0.000
PC vs. Pollen	Correl Coeff.	0.377**	0.265**	0.304**
	Sig (2-tailed)	0.000	0.003	0.001
GVP vs. PC	Correl Coeff.	0.880**	0.817**	0.901**
	Sig (2-tailed)	00.000	0.000	0.001

exceeded in any year. Application of biological air-quality standards to the total pollen count showed that counts sufficient to prompt discomfort among allergy-sufferers were recorded relatively often: on 38, 32 and 39 days in 2000, 2001 and 2002, respectively. Moreover, counts of over 200 grains/m^3, sufficient to affect 100% of allergy-sufferers, were recorded on over 50 days in all 3 study years

Statistical analysis (Tab. 2) revealed a significant positive correlation between biological and non-biological particle patterns at both stations, as well as a strong correlation between particles counts measured at GVP and at PC. There was a stronger correlation between pollen counts and PM10 counts at GVP than at PC.

DISCUSSION

Analysis of airborne biological-particle counts in Córdoba shows that pollen peaks were recorded in the first half of the year, over a period or roughly 17 weeks between February and June, a period marked by the successive flowering of the wind-pollinated species which most contribute to the city's pollen spectrum: *Cypress*, plane trees, *Quercus*, olive trees, grasses and herbs. Given the proven allergenic capacity of all these species [14, 18, 36], this is therefore a problem period for people suffering from pollen allergies or any respiratory disease whose symptoms are aggravated by high airborne pollen counts, particularly given the number of days on which high counts were recorded. The "borderline risk" level, i.e. air quality not considered "good", was set at < 50 pollen grains/m^3 of air. This figure may seem low for wind-pollinated species such as plane tree, *Cypress*, *Quercus* or olive tree, all of which are associated with high pollen production and therefore high airborne pollen release [17, 19, 33]. However, given that patients display differing degrees of sensitization, and that symptoms may be aggravated by the presence of other atmospheric pollutants [5, 26], these pollen counts may be sufficient to trigger symptoms in a low to moderate number of patients. Moreover, symptom-onset thresholds may be exceeded more readily in the case of grass and herb pollens, which are smaller, since their airborne pollen remains at lower heights [3].

It has been suggested that biological air quality may be deemed acceptable when pollen counts are between 100-200 grains/m^3 of air. Where a single pollen type is predominant, a large number of allergy-sufferers will experience adverse reactions, since the pollen counts detected by the sampler may not be uniformly distributed over the whole city [11]. By contrast, where several pollen types are recorded simultaneously, symptoms may develop earlier due to cross reactivity, prompted either by protein similarities between pollen types belonging to different families [21], or by the presence of a major allergen among pollen types of different species belonging to the same family [24].

When the total pollen counts exceed 200 grains/m^3, biological air pollution may be deemed a serious health risk, not only for people with respiratory diseases, but also for healthy people who may experience some discomfort. Biological air quality was classed as poor on 58 days in 2000, 75 days in 2001 and 79 days in 2002; air quality in terms of non-biological particles was more uniform over each study year. This is due, in part, to local, typically Mediterranean, climate conditions; mild temperatures and moderate but torrential rainfall cause a temporary wash-out of the atmosphere followed by a rapid recovery of pollutant levels. During rainy periods, flowering seasons are prolonged, particularly for grass and herb species which display a more immediate response to water [7]. The levels of non-biological airborne particles recover more quickly after rain than those of biological matter, reflecting the routine nature of human activities, including daily urban traffic, industrial activity and transport of goods. This was particuarly apparent in the decline in levels detected in weeks 32-34 (the first week in August), coinciding with the coastbound holiday exodus of much of the population. Routine activity was resumed in September, when a peak of some intensity was recorded in each year at both stations.

Microscopic analysis of samples enabled the qualitative identification of non-biological particles in terms of a set of morfological characteristics including size, shape and colour [1]; a large proportion of this matter comprised partially burnt hydrocarbon residue from diesel engine exhausts. Other matter identified included cement dust, soot, soil dust and, at certain times of the year, Saharan dust transported over long distances. The figures, and statistical correlations obtained show that in some years curves for biological matter and non-biological matter ran parallel, peaking at the same time. A statistically-significant correlation was noted between pollen counts and PM10 counts measured at both GVP and PC. The strong correlation observed for non-biological counts from the 2 stations suggests that, although point sources may be affected by local conditions preventing homogeneous dispersion, airborne particles are generally well mixed in the air above the city. The strong correlation recorded between pollen counts and non-biological particle counts at GVP was probably due to the location of both samplers in the west of the city, roughly 500 m apart. Previous studies have shown that paucimicronic particles collected with high-volume samplers may exert allergenic activity because they carry plant allergenic proteins. Research suggests that some of these small particles come directly from pollen grains exposed to the mechanical action of airborne transport [27, 28, 32], while in other cases allergenic proteins found in other parts of the plant [6, 16] have become airborne due to weather events or to the mowing of dry grass or the uprooting of herbs as a means of preventing forest fires [8]. Although the results obtained here do not serve to confirm the existence of plant material on particle fractions smaller than 10 micra, the correlation between peak pollen counts and peak PM10 counts suggests that this may be the case. If so, it would constitute a high risk for people with any respiratory disease, since both high pollen levels and high PM10 counts are enough to cause discomfort. Symptoms are therefore more likely to be severe due to the coadjuvant action of both.

CONCLUSION

Analysis of airborne solid particulate matter in Cordoba showed that pollen grains are among the major particles affecting pure air quality, counts recorded on a large number of days being enough to cause general discomfort. Impairment of air quality may be governed by weather conditions and by the joint effect of biological and non-biological matter. Information on the levels of both types of pollutants should be provided to the public to allow preventive measures to be taken.

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