

New Orleans asthma

V. Relationship between Charity Hospital asthma admission rates, semiquantitative pollen and fungal spore counts, and total particulate aerometric sampling data

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A 2 year study of the relationship between climatologic variables, semiquantitative roto-slide pollen and fungal spore aerometric sampling data, and emergency room asthma admission rates at New Orleans Charity Hospital was made. An interrelationship between certain climatologic factors, high airborne spore and pollen concentrations, and asthma admission rates was noted. Large asthma "epidemics" (above 40 asthma admissions per 24 hours) occurred almost exclusively from June through December and in greater magnitude during September, October, and November. High summer asthma admission rates were significantly associated with high "total spore and pollen," "basidiospore-like," and "small spore" roto-slide counts. Asthma "epidemics" occurring during the peak September and October local Ambrosia pollination season were not necessarily associated with sudden influxes of Ambrosia pollen, but there was a significant relationship between high daily asthma admission rates (above 20 daily asthma admissions) and 24 hour roto-slide Ambrosia counts during September and early October. Asthma "epidemics" of considerable magnitude occurred in late October and November immediately following the peak Ambrosia pollination season. High total and "basidiospore-like" roto-slide spore concentrations plus heavy deposits of amorphous chitinous material resembling plant debris were noted on slide samples during these episodes. We currently postulate that New Orleans epidemic asthma does not involve a point source chemical or particulate pollutant but rather results from sensitization of the local atopic population by diverse natural inhalant allergens acting in seasonal patterns.

Periodic outbreaks of obstructive pulmonary disease, often of epidemic proportion, have been noted in the city of New Orleans for years.¹⁻⁴ Previous data suggested that outbreaks were primarily seasonal in nature, and that atopic individuals with broad patterns of immediate skin reactivity to common inhalant allergens and exquisite bronchial sensitivity to acetyl beta methylcholine and histamine were involved.^{5, 6} Large outbreaks occurring during the fall months were also significantly associated with low relative humidity, temperature, and wind velocity.⁷ Studies focusing on likely sources of industrial pollution have incriminated no point source chemical or natural pollutant.

These findings suggest that sensitization of atopic individuals by "natural"

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pollen and mold spore inhalant allergens acting in combination with climatological factors might be responsible for outbreaks. The current report compares Charity Hospital asthma admission rates with climatologic variables and semi-quantitative pollen and mold spore aerometric sampling data during the years 1967 and 1968.

MATERIALS AND METHODS

Adult daily asthmatic admissions were recorded from the Charity Hospital Emergency Room files on a 7 A.M. to 7 A.M. basis from January 1, 1967, through December 30, 1968.* Patients consisted primarily of indigent individuals who received only intermittent conventional bronchodilator therapy at the Charity Hospital Emergency Room during intractable episodes of bronchospasm.

On obvious "epidemic" days the minimum number of daily emergency room asthma admissions was previously arbitrarily set at 35 to 50, depending on the monthly mean.⁷ Several peaks of over 100 asthma admissions in 24 hours were noted, but clusters of high admit days with a gradual rise and fall in daily admissions were the rule. Using 40 daily asthma admissions as a cutoff point for definition of an asthma "epidemic," 36 days during the current 2 year study period were "epidemic" days. Although 35 of these days occurred during the last 7 months of each year (June 1 through December 31), this number of "epidemic" days was insufficient for meaningful statistical analysis. For purposes of over-all statistical analysis of the interrelationships between aerometric spore and pollen sampling data, climatological variables, and asthma admissions, we used a cutoff point of 20 daily asthma admissions and confined our statistical analyses to the last 7 months of each year. This cutoff point represented the number of daily asthma admissions separating the upper one-third and lower two thirds of all daily adult Charity Hospital Emergency Room asthma admission rates for the months of study. It was sufficiently high to exclude most of the obviously nonepidemic days (below 40 daily asthma admissions) and sufficiently low to ensure an adequate number of high asthma admit days for meaningful statistical analysis.

Intervals of high asthma admission days occurring during these months were divided into small summer (June 1 through August 31) and larger fall varieties (September 1 through December 31) for better comparison with seasonal fluctuations in pollen and spore counts and climatologic data. The latter data for 1967 and 1968 included temperature, relative humidity, wind velocity, rainfall, and barometric pressure and were gathered at New Orleans International Airport 8 miles west of the city limits.

Aerometric sampling for spores and pollen was performed with automatic intermittent rotoslide samplers^{8,9} which collect particulate matter on the leading edges of 1.0 mm. thick, 7.5 × 2.5 cm. microscope slides coated with silicone grease. Samplers rotated periodically for one minute at 1,650 r.p.m. every 12 minutes. The type and location of samplers, methods of collection, and staining were previously described.^{9,10} All semiquantitative aerometric sampling data were taken from a single "shield" rotoslide sampler located approximately 150 feet above ground level atop the Louisiana State University medical student dormitory near the central shopping area. Our central city sampler rotoslide counts may not be representative of other city areas and they may not necessarily reflect a representative average of counts obtained at many city locations. Periodic analyses were made of other samplers for purposes of comparing different sampling elevations, locations, and slide-shielding devices as described in the preceding report.¹⁰ Pollen grains were identified and classified as previously described.⁹ Small and large spores were individually quantitated according to genus where possible and taxonomic spore classification was attempted on the basis of morphology.¹¹ Considering the limitations of the aerometric sampling device employed, we chose to group spores into the three general categories

*Previously reported results indicated that pediatric admissions were small in comparison with adult admissions even when diagnoses of bronchitis, bronchiolitis, and asthma were tabulated together.

TABLE I. Relationship between high-volume sampler suspended particulate matter, sulfate

Suspended particulate matter ($\mu\text{g}/\text{mm}^3$)	Asthma admits		Sulfates (%)
	High	Low	
≥ 104	41	39	≥ 10.1
≤ 103	38	101	≤ 10.0
% High admit days with high pollutant level		51	
% High admit days with low pollutant level		27	
Chi square		11.57*	

Analysis covers 219 days for the months of March 1 through December 31, 1967 and 1968, during which the following conditions were those in the upper one third of the range of all daily recorded values for the

*Significant at 0.01 per cent level.

described in the preceding report¹⁰: (1) "small spores", (2) large deuteromycete and ascomycete spores, and (3) spores resembling large basidiospores.

All pollen and spore counts were performed by the same two technicians throughout the study. Both had been trained in identification procedures during 1966 by studying preliminary local pollen and spore collections obtained with a roto-slide apparatus at the main sampling site. At periodic intervals the same slide was counted separately by both technicians and by the authors and results were in close agreement. Slides were stored in covered plastic slide boxes for several weeks prior to counting. In all cases counts were performed without knowledge of the number of emergency room asthma admissions. Pollen and spore counts were also performed 5 days weekly using a conventional gravitational Durham sampler. These slides were used only when necessary for confirmation of roto-slide pollen identification, since roto-slide samplers at times tended to distort certain thin-walled pollen grains.

Total suspended particulate matter was quantitated with a standard high-volume air sampler at a previously described centrally located sampling station¹² near the roto-slide sampling site.* Glass fiber filters, 8 x 10 inches, were conditioned for 24 hours at 40° to 50° relative humidity prior to and after 24 hours sampling at 50 cubic feet per minute. Exposed filters were weighed on an analytic balance and results expressed as "suspended particulates," micrograms per cubic meter. It is estimated that the particle size collected by such filters is above 3 μ with a considerable portion of the total particulate load ranging well above the size required to penetrate the lower respiratory tract. However, with heavy layers of particle deposition, smaller particles are retained.

The sulfate fraction was determined in a water extract obtained from an aliquot of the filter. Sulfates were precipitated as barium sulfate and measured with a colorimeter. The organic (benzene-soluble) fraction was obtained by evaporating one half of the filter at room temperature and weighing the residue.

Total dustfall was collected in plastic buckets. The insoluble dust portion was collected on a dried preweighed filter and the soluble portion determined on a 200 ml. aliquot of water contained in the bucket. Results were calculated and expressed as tons per square mile per month.

The high-volume sampler was operational approximately every second day. Correlations between asthma admissions and particulates were calculated from March 1 through December 31, 1967 and 1968. Correlations were not computed for the months of January and

*Chemical analyses of suspended particulates and total dustfall were performed by one of the authors (E. S.) in the New Orleans City Health Laboratories through the courtesy of Drs. Rodney Jung (past director) and Doris Thompson (current director). This sampling site was centrally located at 1330 Lafitte Avenue and was previously employed in gaseous and particulate pollutant sampling within the city.¹²

fractions, and asthma admissions

Asthma admits		Benzene-soluble organics (%)	Asthma admits	
High	Low		High	Low
25	50	≥ 11.8	24	48
61	83	≤ 11.7	54	93
	33			33
	42			37
	1.33			0.12

which the sampler was operational. High asthma admission days and 24 hour particulate concentration of study.

February, 1968, because of road construction and excavation in the immediate vicinity of the sampling site which resulted in extremely heavy particulate filter deposits at that time.

RESULTS

Table I lists the relationship between high-volume sampler suspended particulate matter and asthma admissions for all months of study. This standard high-volume sampler collects many particles of large size* and has previously proved less meaningful than electrostatic elutriator or photoelectric cell samplers in correlating with New Orleans asthma epidemics.¹² Despite this fact, there was a significant association between high-volume sampler total suspended particulate matter and asthma admissions ($p = < 0.01$). Although this sampler was not operational daily and we have not compared asthma epidemic peaks with particulate concentrations, prospective comparison revealed definite increases in total particulate loads during large epidemic intervals (above 40 daily asthma admissions).

There was no association between high asthma admission rates and sulfate or benzene-soluble particulate fractions ($p = > 0.5$). Total insoluble and water-soluble dustfall in tons per square mile per month varied markedly with no observable seasonal or periodic patterns.

Table II lists the relationships between asthma admissions and semiquantitative counts of five organic particulate categories (total pollen and spore, pollen alone, and the three general spore categories). High 24 hour counts in all categories were considered to be those in the upper one third of the range of all daily counts registered from June 1 through December 31, 1967 and 1968. There was a significant association between high total pollen and spore counts and increased asthma admissions during the summer months, fall months, and total period of study. A significant relationship in all categories (summer, fall, and total) was also noted between asthma admissions and high concentration of spores resembling large basidiospores. High small spore counts correlated sig-

*Maximal particle size of 90μ as compared with 22μ for electrostatic precipitator and 8μ for high-volume elutriator.

TABLE II. Relationship between asthma admissions and semiquantitative roto-slide counts of resembling basidiospores, small spores, and large deuteromycete and ascomycete spores

Total pollen and spore	Asthma admits		Basidiospore-like	Asthma admits		Small spore
	High	Low		High	Low	
Summer months 1967 and 1968 (June 1-August 31)						
≥ 2,926	17	21	≥ 700	20	22	≥ 1,641
≤ 2,925	31	99	≤ 699	28	98	≤ 1,640
% High admit days with high count		44.7			47.6	
% High admit days with low count		23.8			22.2	
Chi square		5.306*			8.750†	
Fall months 1967 and 1968 (September 1-December 31)						
≥ 2,926	47	41	≥ 700	46	38	≥ 1,641
≤ 2,925	46	76	≤ 699	47	79	≤ 1,640
% High admit days with high count		53.4			54.8	
% High admit days with low count		37.7			37.3	
Chi square		4.493*			5.540*	
Total summer and fall (June 1-December 31)						
≥ 2,926	64	62	≥ 700	66	60	≥ 1,641
≤ 2,925	77	175	≤ 699	75	177	≤ 1,640
% High admit days with high count		50.7			52.4	
% High admit days with low count		30.6			29.8	
Chi square		13.858†			17.421†	

Cutoff point for high daily asthma admission represented the dividing point between the upper of study.

*Significant at 0.05 per cent level.

†Significant at 0.01 per cent level.

TABLE III. Relationship between high asthma admission days and semiquantitative pollen count during months of major Ambrosia pollination

	July	August	September	Mid-September through mid-October	October
High count	≥ 57 ≤ 56	≥ 119 ≤ 118	≥ 263 ≤ 262	≥ 372 ≤ 371	≥ 157 ≤ 156
No. high admit days	8 17	18 12	10 9	13 10	13 26
No. low admit days	6 31	13 29	9 32	9 28	10 13

High asthma admission days and 24 hour pollen counts were those in the upper one third of the range of all daily recorded values for the months of study (July 1 through October 31, 1967 and 1968).

nificantly with high asthma admission rates for the total period and for the summer months alone.

In contrast to these findings, there was no correlation between high large spore counts and high asthma admission days. (During the fall months a correlation between low large spore counts and high asthma admissions was noted.)

five major organic particulate categories: total pollen and spores, pollen alone, spores

Asthma admits		Large spore	Asthma admits		Pollen	Asthma admits	
High	Low		High	Low		High	Low
16	17	≥ 419	20	47	≥ 80	19	31
32	103	≤ 418	28	73	≤ 79	29	89
	48.5			29.9			30.0
	23.7			27.7			24.6
	6.811†			0.0155			2.478
45	43	≥ 419	19	40	≥ 80	25	51
48	69	≤ 418	74	77	≤ 79	68	66
	48.4			32.2			32.9
	41.0			49.0			50.7
	0.859			4.198*			5.561*
61	65	≥ 419	39	87	≥ 80	44	82
80	172	≤ 418	102	150	≤ 79	97	155
	48.4			31.0			34.9
	31.7			40.5			38.5
	9.277†			2.863			0.318

one third and lower two thirds of the range of all daily asthma admission rates for the months

A similar absence of significance was noted between Ambrosia pollen counts and asthma admissions when the same cutoff point for daily counts was used for all months studied. However, with variable cutoff points based on the monthly mean and range of daily Ambrosia counts, a significant relationship was noted between Ambrosia counts and high asthma admission days during August and the peak September and early October local Ambrosia pollination season (Table III). At this time, with the exception of small amounts of grass and plantain pollen, virtually all pollen detected was of the composite group, notably the Ambrosia tribe.

Although this association was significant for daily asthma admission rates above 20 (upper one third of all daily asthma admission rates), many peak days of Ambrosia pollination were clearly not associated with large asthma “epidemics,” particularly during the 1968 season, as shown in Figs. 1 and 2 which illustrate the 1967 and 1968 Ambrosia pollen seasons. Large “epidemics” of asthma (above 40 daily asthma admissions on one or more successive days) are represented by the letter, **E**. A relationship between several “epidemics” and influxes of Ambrosia pollen is apparent in 1967, particularly during the late September and early October peak Ambrosia season. However, in 1968 (Fig. 2)

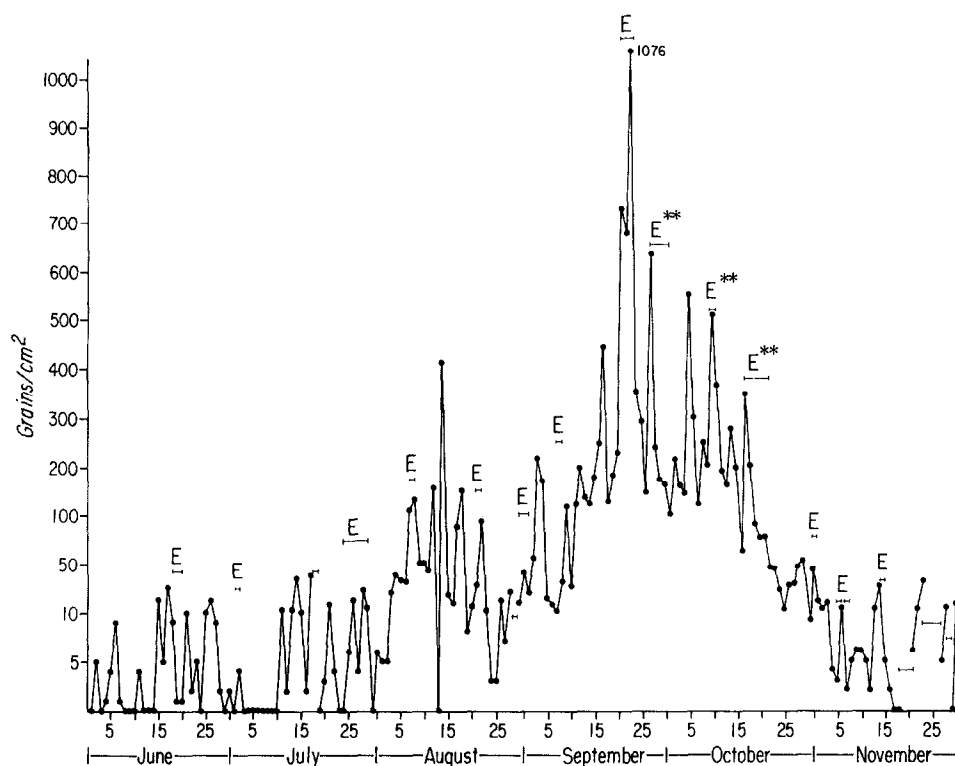


FIG. 1. Relationship between 1967 Ambrosia pollination season and major asthma epidemics. Large asthma "epidemics" (above 40 daily emergency room asthma admissions on one or more successive days) are represented by the letter **E**. Asterisks refer to epidemics of greatest magnitude.

such "epidemics" occurred only in late July and early August, the initial period of major Ambrosia pollination, and in late October and November at the termination of the Ambrosia season. Daily adult asthma admissions increased noticeably beginning in late September, but no major "epidemics" occurred during the peak 1968 Ambrosia season, which was identical in intensity and duration to the 1967 season. Climatologic conditions were different during the peak 1967 and 1968 Ambrosia pollination season and might account for this difference. Mean daily relative humidity during this interval was 73.8 in 1967 and comparatively higher (82.3) in 1968. Of the seven major "epidemic" intervals recorded during September and October of 1967, five were associated with a marked decrease in relative humidity and six with low resultant wind velocity. Conversely, in September and October of 1968 there were only two intervals with extremely low minimum relative humidities (below 40 per cent), one of which was associated with a marked decrease in temperature and minimal wind velocity and a large asthma "epidemic." The second was not associated with a corresponding fall in temperature or wind velocity, and no asthma epidemic occurred. Furthermore, there were only 9 days in September and October of 1968 with minimal resultant wind velocity (as previously defined), three of which were associated with the

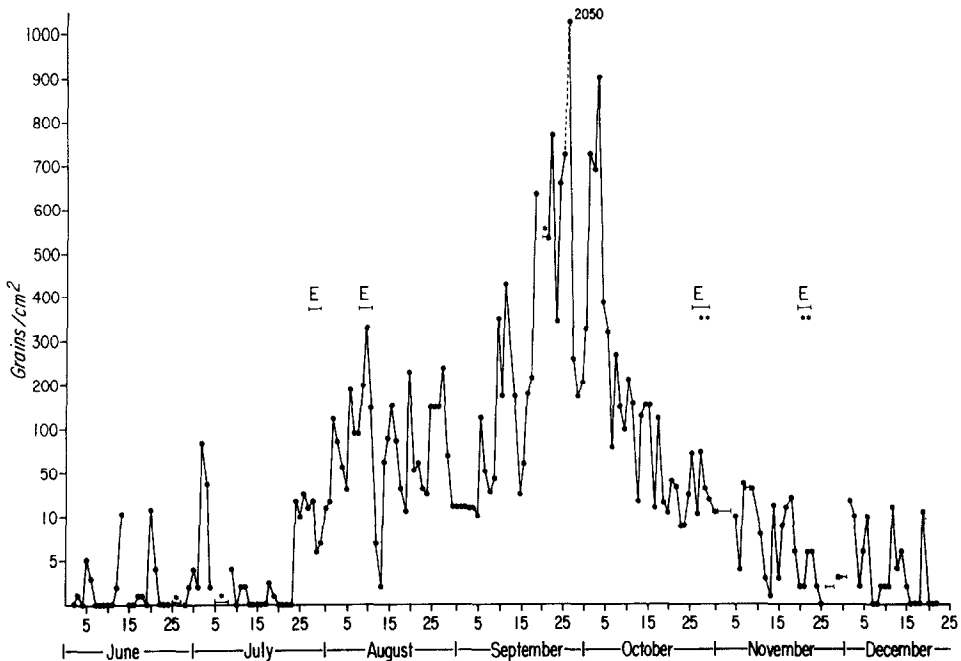


FIG. 2. Relationship between 1968 Ambrosia pollination season and major asthma epidemics. Asterisks refer to epidemics of greatest magnitude.

large late October epidemic and three with overt precipitation, high mean relative humidities, and low asthma admission rates. These findings suggest that a combination of high Ambrosia counts and proper climatologic conditions (low relative humidity, wind velocity, and temperature) is necessary to precipitate a major asthma epidemic during the peak Ambrosia pollination season. This interrelationship is illustrated in Fig. 3 which depicts four recorded asthma epidemic intervals during late September and October of 1967, together with Ambrosia pollen counts and climatologic variables. Ambrosia and total spore and pollen counts increased during, or at the onset of, the three initial outbreaks in late September and early October. A decrease in minimum relative humidity and resultant wind velocity occurred with each epidemic. A decrease in minimal humidity and wind velocity was noted on October 5, but no asthma epidemic occurred. However, a marked increase in total spore and pollen count was not noted at this time, and no sharp decrease in temperature occurred as in the case of the other outbreaks, again suggesting that the proper combination of particulate concentration and climatologic conditions needed to precipitate an asthma epidemic was not present.

The largest asthma "epidemic" illustrated in Fig. 3 involved approximately 200 asthma admissions over a 3 day period in late October and occurred immediately after the peak Ambrosia pollination season. Although it was associated with a sharp increase in Ambrosia pollen count at its onset, little pollen was detected during the peak epidemic days of October 20, 21, and 22. Of significance

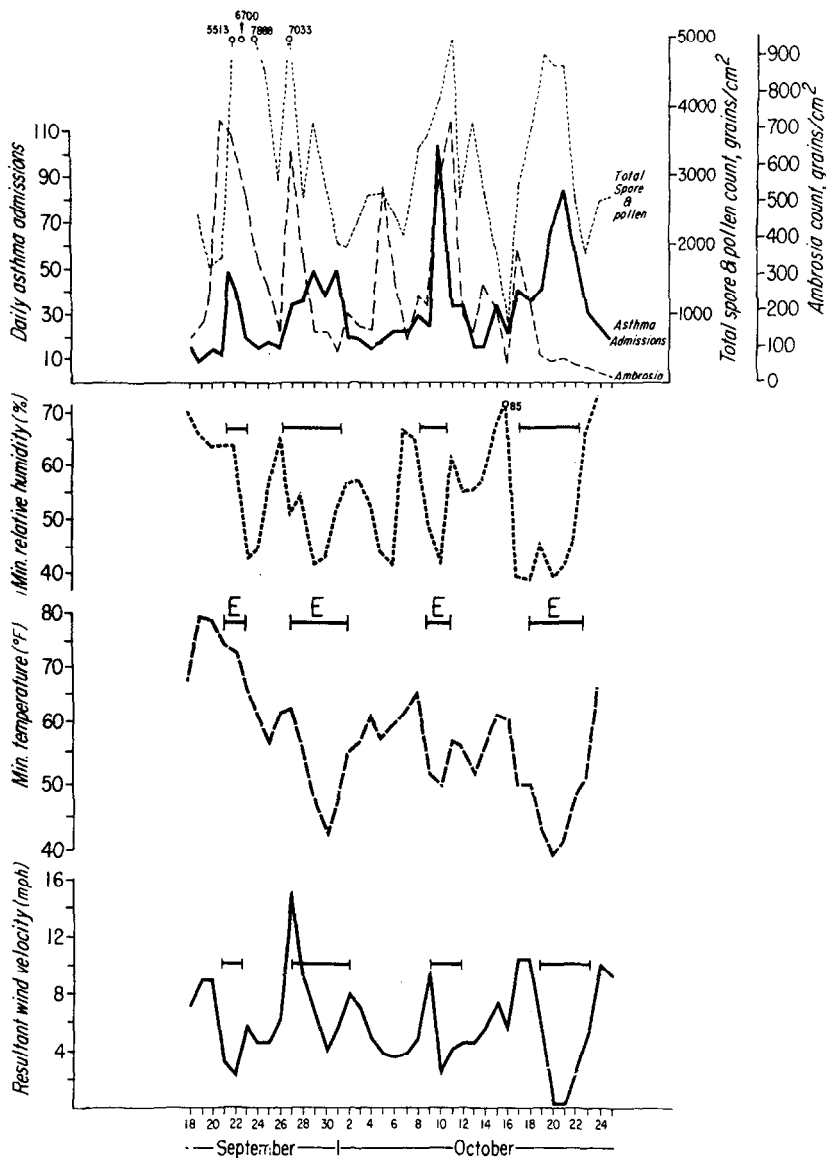


FIG. 3. Relationship between semiquantitative Ambrosia counts, total spore and pollen counts, climatologic variables, and major late September-October 1967 asthma epidemics.

was the rise in total count (predominantly small spores and spores resembling large basidiospores) and the striking decrease in relative humidity, temperature, and wind velocity associated with this major outbreak.

Three similar "postragweed" asthma epidemics of lesser magnitude were noted in early November of 1967 and 1968. A fourth epidemic involving 204 adult asthma admissions during a 4 day interval occurred in late November of 1968 (Fig. 4). This epidemic demonstrates the clear relationship between rising barometric pressure, low temperature, low relative humidity, minimal wind velocity, and high asthma admission rates which was particularly evident during

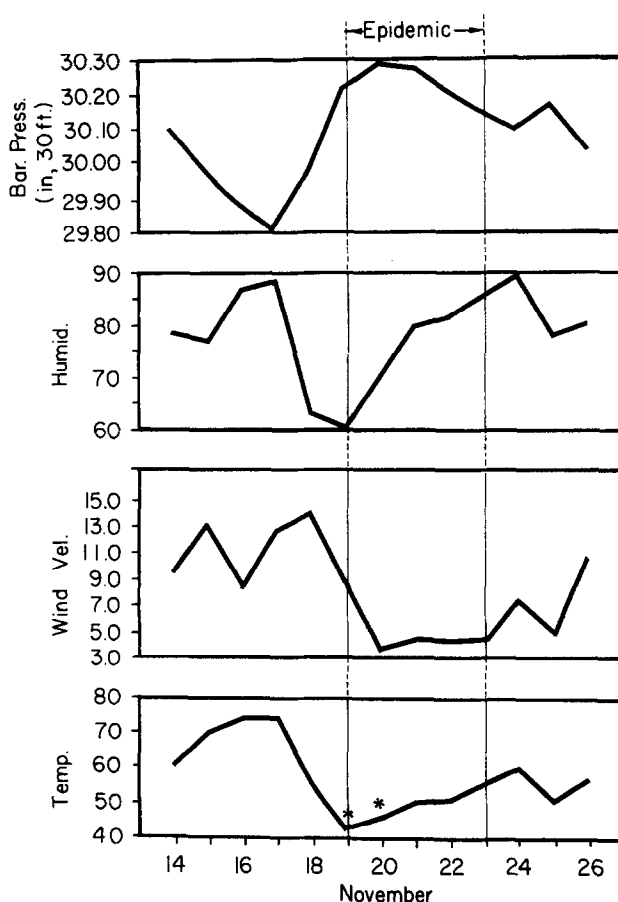


FIG. 4. Relationship between daily mean temperature, minimum relative humidity, resultant wind velocity, and major late November, 1968, asthma epidemic. Asterisks indicate unusually cold subfreezing minimal temperatures in the New Orleans area (November 19 and 20).

these late fall "postragweed" outbreaks. High total roto-slide counts were noted during these epidemics, but slides also generally revealed heavy deposits of unidentifiable amorphous chitinous particulate debris. This material could not be quantitated or distinguished from the usual debris gathered on the silicone-coated slides.

Considering all days between June 1 and December 31, 1967 and 1968, without regard to relative humidity, there was a highly significant relationship between total spore and pollen counts and number of high asthma admission days ($p = < 0.01$), indicating that humidity per se was not a prime determining factor. However, when mean relative humidity plus total spore and pollen counts were divided into low, intermediate, and high categories (Fig. 5), a significant trend was noted toward the association of low and intermediate relative humidities, high roto-slide counts, and percentage of high asthma admission days ($p = < 0.05$). Conversely, high total roto-slide counts recorded on days of high relative humidity were associated with a significantly lower percentage of high

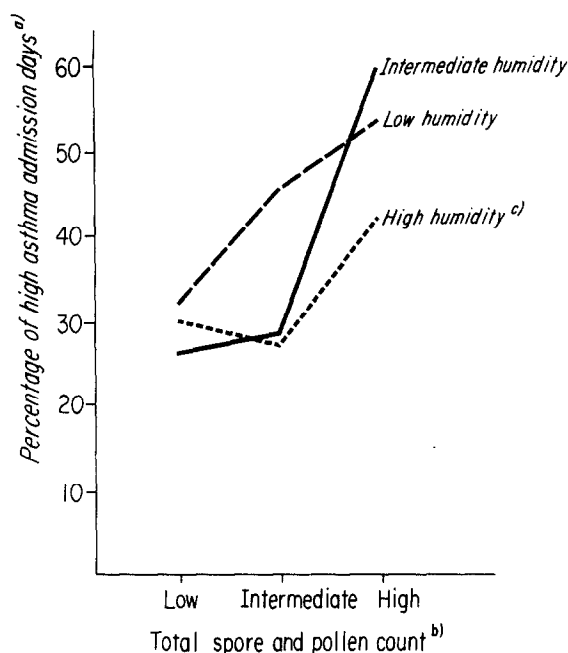


FIG. 5. Interrelationship between total daily semiquantitative spore and pollen counts, mean relative humidity, and percentage of high asthma admission days. Period of analysis was from June 1 through December 31, 1967 and 1968. **a**, Cutoff point = nearest number to P_{67} which is evenly divisible by 5 (high asthma admit days are high $\frac{1}{3}$ of all days). **b**, Low, intermediate, and high count days represent the $\frac{1}{3}$ of all days on which the total count was lowest, in the mid $\frac{1}{3}$ or upper $\frac{1}{3}$ of all counts. **c**, Low, intermediate, and high relative humidity days are the $\frac{1}{3}$ of all days on which the relative humidity was lowest, in the mid $\frac{1}{3}$ or upper $\frac{1}{3}$ of all recorded daily mean humidities.

asthma admission days ($\chi^2 = 0.98$; $p = < 0.05$). Thus total pollen and spore concentrations appeared to affect the asthmatic population in a different manner under conditions of low versus high or intermediate relative humidity.

In view of this interrelationship between humidity and particulate counts and our⁷ previously determined association of low relative humidity, temperature, and wind velocity with large fall asthma "epidemics," we determined the interrelationship between other selected climatologic variables and total spore and pollen counts during the years 1967 and 1968.

The interrelationship between temperature, barometric pressure, resultant wind velocity, asthma admissions, and total spore and pollen counts is listed in Table IV. Under conditions of low resultant wind velocity and high barometric pressure, the percentage of high asthma admission days was significantly higher when high total spore and pollen counts were recorded ($p = < 0.01$). Temperature and high total particulate counts did not appear to have such a synergistic effect ($p = > 0.05$).

Based on our⁷ previous report and current findings, it appears that high particulate counts in combination with either low resultant wind velocity, low humidity, or high barometric pressure are associated with high daily asthma admission rates, although high asthma admission rates were associated with low

TABLE IV. Interrelationship between high asthma admission days, total spore and pollen counts, temperature, resultant wind velocity, and barometric pressure, June 1 through December 31, 1967 and 1968

Weather condition	Season	No. of days	Per cent of high asthma days		χ^2	p Value
			Low total count	High total count		
Temperature (high/low)	Summer (high)	56	41.5	53.3	0.238	N.S.
	Fall (low)	70	58.3	81.8	2.720	N.S.
High barometric pressure		126	35.5	69.7	10.200	< 0.01*
Low resultant wind velocity		126	35.0	60.9	6.900	< 0.01*

Cutoff points for each high and low climatologic factor and total particulate count were the recorded daily value separating the upper (or lower) one third from the remaining two thirds of the range of all daily values during the months of study.

*Significant at 5 per cent level.

temperature alone during the fall months⁷ and with high temperature alone during the summer months (Table V).

Summer asthma "epidemics" (June through August) differed from those occurring during the peak Ambrosia season and from major "postragweed" outbreaks. Although significantly associated with high total spore and pollen counts, particularly small spores and spores resembling large basidiospores (Table II), they were not related to decreased humidity or rising barometric pressure as were large fall outbreaks. Many followed days of overt precipitation and occurred under hot, stagnant weather conditions. The only climatologic variables significantly related to high summer asthma admissions were high mean daily temperature and low resultant wind velocity (Table V).

An example of a typical summer epidemic is illustrated in Fig. 6. An increase in asthma admissions began on August 6, 1967, and within the next 3 days, 166 Charity Hospital Emergency Room asthma admissions were recorded. Resultant wind velocity was very low during the outbreak, but there was only a 6 per cent decrease in minimum relative humidity and no change in mean temperature. Unlike major fall epidemics, overt precipitation was recorded on 6 days surrounding the outbreak. Although other outbreaks of this type in June and July were clearly unrelated to Ambrosia pollen concentrations, this particular epidemic occurred at the time of initial major Ambrosia pollination for that year. Coinciding with a rise in Ambrosia pollen there was a three- to fourfold increase in total detectable spores, particularly small spores and spores resembling large basidiospores, suggesting a synergistic effect of a stagnant weather condition, Ambrosia pollen, and total airborne spore concentration on a susceptible local asthmatic population. A second sharp increase in Ambrosia pollination without a corresponding increase in asthma admissions was detected on August 12 following 2 days of rainfall and a decrease in mean temperature. However, total spore counts did not rise and stagnant weather conditions no longer prevailed at this time with high recorded resultant wind velocity of 12.6 m.p.h., again suggesting

TABLE V. Effect of temperature, low relative humidity, low wind velocity, and high barometric 1967 and 1968

High mean temperature	Asthma admits		Low mean relative humidity (%)	Asthma admits	
	High	Low		High	Low
≥ 84° F.	25	33	≥ 72.3	36	86
≤ 83° F.	23	103	≤ 72.2	19	43
Chi square	11.46341*			0.00012; N.S.	

High asthma admission days were those in the upper one third of the range of all daily asthma determined as those in Table IV.

*Significant at 0.01 per cent level.

matter necessary for induction of an asthma epidemic was not present. that the proper combination of climatologic variables and airborne particulate

DISCUSSION

Semiquantitative particulate counts and asthma admissions

Previous results¹² showed no relationship between large fall New Orleans asthma epidemics and measureable increases in specific chemical pollutants. Asthma "epidemics" occurred almost exclusively from June 1 through December 31 and involved atopic individuals with broad patterns of wheal and flare skin reactivity to common inhalant allergens and heightened bronchial reactivity to acetyl beta methylecholine and histamine.⁵

Our current data demonstrate a significant relationship between total high-volume sampler particulates, semiquantitative total pollen and spore counts, concentrations of spores resembling large basidiospores, small spore concentrations, and daily Charity Hospital Emergency Room asthma admissions. Total spore and pollen counts appeared to affect the asthmatic population unfavorably under conditions of low relative humidity, low wind velocity, and high barometric pressure during the total study period, and stagnant climatologic conditions were significantly related to large outbreaks. These data suggest that a combination of certain climatologic conditions and airborne particulate matter concentrations is necessary to precipitate asthma epidemics.

Relationship between "summer asthma admissions," particulate counts, and climatologic variables

Different airborne particulate matter appears to be associated with high "summer," "peak Ambrosia season," and "post-Ambrosia" daily asthma admission rates. High summer daily asthma admission rates (June 1 through August 31) were recorded prior to the peak Ambrosia pollination season during a period in which tree pollens, grass pollen, and spores of basidiomycetes and imperfect fungi are commonly recognized as dominant aeroallergens. Summer outbreaks were significantly associated with high total spore and pollen rotoslide counts. They occurred under hot stagnant weather conditions with particularly low resultant wind velocities and were not related to marked decreases in relative humidity or temperature.

pressure on adult asthma admission rates during summer months (June 1 to August 31) of

Low resultant wind velocity (m.p.h.)	Asthma admits		High barometric pressure (inches)	Asthma admits	
	High	Low		High	Low
> 3.5	20	79	> 30.07	11	26
≤ 3.4	34	51	≤ 30.06	44	103
	7.71678*			0.03128; N.S.	

admission rates for the months of study. Cutoff points listed for each climatologic factor were

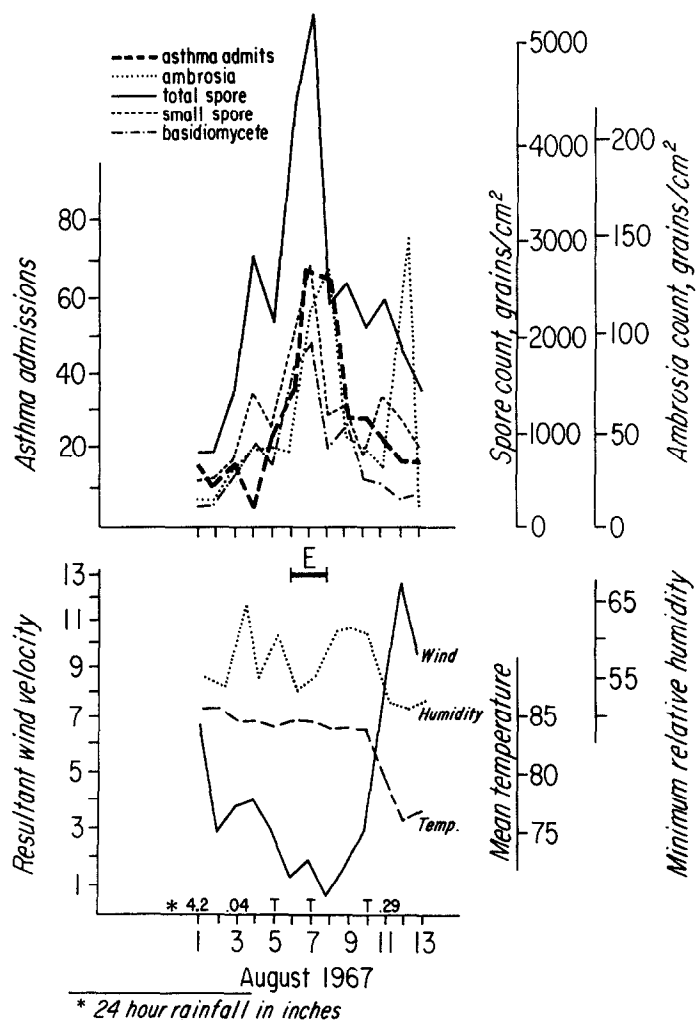


FIG. 6. Relationship between mean temperature, minimum relative humidity, overt precipitation, resultant wind velocity, airborne spore and pollen roslide counts, and typical "summer" asthma epidemic (August, 1967).

High summer daily asthma admission rates were also often associated with, or preceded by, periods of overt precipitation. Such hot, humid conditions are known to be favorable for propelling large numbers of basidiospores and ascospores into the atmosphere¹³⁻¹⁵ and may explain our observed high atmospheric concentrations of spores resembling large basidiospores and small spores at these times.

Relationship between "Ambrosia season," asthma admissions, climatologic variables, and particulate counts

Asthma "epidemics" occurring during the peak (September-October) local Ambrosia pollination season were not necessarily associated with sudden influxes of Ambrosia pollen, but there was a significant over-all relationship between high daily asthma admission rates and Ambrosia pollen counts during August and the peak September through mid-October Ambrosia pollination season. The association of low relative humidity, wind velocity, and temperature with high daily asthma admission rates at this time plus the high total spore and pollen roto-slide counts suggests a synergistic effect between Ambrosia pollen, airborne spores, and climatologic factors.

Relationship between "post-Ambrosia" asthma admissions, climatologic variables, and particulate counts

"Post-Ambrosia" asthma epidemics were of considerable magnitude and occurred in late October, November, and early December. They were particularly associated with sharp decreases in relative humidity, temperature, and wind velocity and with rising barometric pressure. These stable dry climatologic conditions are similar to those reported during low-level thermal inversions in which warm air overlies cold air and through which vertical air convection currents cannot penetrate.^{16, 17} Such inversions are often noted during fall months and are thought to be more persistent at this time due to lower solar altitude and a shortened period of daytime heating. They have been predominantly associated with high concentrations of point source atmospheric industrial chemical pollutants and episodes of irritative obstructive pulmonary disease in areas such as Donora, Pennsylvania, Nashville, London, Los Angeles, and the Meuse Valley of Belgium.¹⁸⁻²³ It is likely that the presence of such climatologic conditions favors "trapping" of those chemical or particulate pollutants common to the affected area. New Orleans is the only major city in the United States virtually surrounded by a system of swamps which provide ideal fertile growth conditions for most genera of fungi. Since the city is comparatively free from heavy industry and recently ranked nineteenth of 20 major cities in relative severity of eight major man-made chemical pollutants,²⁴ it is reasonable to postulate that spores of many fungal genera, along with other airborne particulate matter of "natural" origin rather than chemical pollutants, are preferably "trapped" under these late fall climatologic conditions and adversely affect only the previously sensitized atopic population. Our findings suggest that this is the case and obviate the necessity of postulating a single point source pollutant. It is thought that spores and other small organic particles are carried aloft on

rising masses of heated air during daytime heating²⁵ and descend with cooler air after sunset. The stable weather conditions present during thermal inversions would likely allow "trapped" cool spore-laden air to adversely affect the susceptible asthmatic population during nighttime hours, which is in keeping with the large numbers of nocturnal asthma admissions recorded during these epidemics.⁷ Other factors including simple assumption of the recumbent position may account for the commonly observed nocturnal exacerbation of bronchial asthma.

Possible role of other suspected particulates and asthma epidemics

Although total 24 hour rotoslide counts and concentrations of spores resembling large basidiospores were significantly elevated during large "post-Ambrosia" epidemics, the noticeably heavy deposits of amorphous, chitinous debris which could not be accurately quantitated might contribute significantly to the total allergic load during these outbreaks. Such material might represent plant debris, arthropod remnants, or hyphal fragments which are known to be associated with heavy concentrations of parasitic basidiomycete and other spores in organic dusts such as those from grain mills.²⁶ Grain elevators are present in the New Orleans area and could serve as a possible contributing point source pollutant in production of these asthma epidemics. Indeed, 85 per cent of asthmatic patients involved in New Orleans asthma epidemics and 74 per cent of the local atopic population have been reported to exhibit positive immediate wheal and flare reactions to grain dust extracts.^{26, 27} However, grain mill dusts have irritant properties, and the findings of positive wheal and flare skin tests to these extracts in 43 per cent of control nonatopic patients suggests that such extracts are not suitable for purposes of skin testing. The magnitude and seasonal nature of these epidemics also militate against this hypothesis.

Some of the amorphous material encountered on rotoslide samples during these major "post-Ambrosia" epidemics could also represent decaying vegetable matter, particularly minute particles of dried ragweed leaves and stems made airborne along with heavy concentrations of spores under conditions of low relative humidity. In this regard an increased asthma admission rate immediately following the peak Ambrosia pollination season, as observed in New Orleans epidemic asthma, has been a geographically widespread clinical observation. Antigenic relationships between ragweed leaf, pollen, and stem have long been noted,²⁸ and immunotherapy of ragweed-sensitive patients protects against symptoms both during and for some time after the Ambrosia season.²⁹

Whether or not Ambrosia pollen or spores of various fungal genera serve alone as causes of asthma epidemics remains unclear, and it is possible that they are rising in consort with other undetectable particulate matter which is the primary cause of the outbreaks. Indeed, poor-combustion silica-containing particles above 4μ in diameter arising from burning underground city dumps were detected in high atmospheric concentrations at the time of large fall epidemics in 1962² but were shown to play no primary role in their production, since outbreaks were unchanged in magnitude or duration after all subterranean fires

were extinguished. Furthermore, Greenburg and co-workers³⁰ have previously reported an increase in emergency clinic visits for asthma in New York at the beginning of the fall season during the onset of cold weather when heating was required. They postulated that dusts, spores, or other particulate matter lying dormant in closed spaces may be released at the onset of heating and the ensuing extremely low indoor humidity. Such factors could be a geographically widespread phenomenon and contribute to our late October and November "post-Ambrosia" outbreaks when initial heating is required locally. However, it seems unlikely that they could account for our summer and peak Ambrosia season outbreaks (June through early October).

Previous aerometric studies performed by Kenline¹² using a sensitive Royco photoelectric cell sampler, which discriminates particulate matter according to size, have shown a significant relationship between particulate matter and large 1963 fall New Orleans asthma epidemics. Although no attempt was made to identify particles, those approximately 16μ in size correlated well with large early October outbreaks while those below 4μ correlated best with a late October outbreak which, based on our⁹ current studies, likely immediately followed the peak local 1963 Ambrosia season. In view of our current findings and the lack of correlation between sulfation rates and nitrogen dioxide concentrations with epidemics,¹² it is likely that these particles represented Ambrosia pollen, large "basidiospore-like" spores, and small spores, all of which contributed to the allergic load imposed upon the local atopic population.

It is also possible that high Ambrosia pollen concentrations (Kenline's large particles?), which were significantly associated with high asthma admission rates during the peak local September and early October, 1967 and 1968, Ambrosia season, serve to "prime" mucosal tissues of affected patients for a greater inflammatory response to other particulates for example, small spores which in themselves might act as weak allergens but adversely affect the "primed" atopic population during large late October and November "post-Ambrosia" asthma epidemics. Such a phenomenon has been emphasized by Connell.³¹ Final resolution of this problem will require controlled provocative testing of affected patients at appropriate times and with wide dose ranges of suspected inhalants.

Current hypothesis of New Orleans asthma pathogenesis

We currently postulate that New Orleans epidemic asthma is not related to a point source chemical pollutant but rather involves sensitization of the local atopic population with a host of diverse particulates, notably "natural" inhalant allergens, as is commonly noted in such individuals. Ambrosia pollen, small deuteromycete and ascomycete spores, basidiospores, and possibly common antigens in plant remnants are the most likely major offenders. Ambrosia pollen and spores may act alone in some outbreaks but appear to have an additive effect in others. Certain climatologic conditions appear necessary for precipitation of epidemics, especially large fall outbreaks, and these factors may be directly responsible for increased atmospheric particulate matter concentrations. The usual epidemic peaks of asthma admissions may also be related to local socioeconomic factors (i.e., the presence of a large indigent asthmatic population

living from crisis to crisis without continuity of medical care and dependent upon a single centrally located charity hospital for emergency treatment). This situation, though medically undesirable, has perhaps afforded us a unique opportunity to study the epidemiology of bronchial asthma in a large metropolitan community.

Of great practical importance is the striking association between sharp decreases in relative humidity, decreased temperature, rising barometric pressure, and large fall epidemics, which may allow prediction of outbreaks by the local weather bureau with a sufficient time interval for institution of appropriate prophylactic measures by the local atopic population.

If our findings are correct, New Orleans epidemic asthma, which likely represents the largest and most chronic public health obstructive respiratory disease problem in the United States, may merely reflect the natural history of bronchial asthma as it affects the atopic population of a large metropolitan community, and it serves to remind us of the deleterious effects of natural pollutants on a restricted but large segment of the population. Such an awareness is timely in view of the magnitude of the "asthma problem" and current national emphasis exclusively on point source industrial, chemical, man-made atmospheric pollutants.

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