

Interpreting atmospheric pollen counts for use in clinical allergy: allergic symptomology

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Background: Allergists generally consider atmospheric pollen counts to be an estimate of the antigenic challenge confronting allergic individuals. The nature of this challenge depends on the particular pollen types found in the atmosphere and also the airborne concentration of these pollen types. Both clinical experience and clinical investigations support these assumptions; however, a coherent system for relating pollen counts and allergic symptomology does not exist.

Objective: This review article will systematically review the medical and technical literature concerning the clinical significance of atmospheric pollen counts.

Data sources: This review article will consider three independent bodies of literature: 1) data contrasting human exposure patterns with rooftop pollen counts; 2) data concerning dose-response relationships between atmospheric pollen counts and allergic symptomology; and 3) data concerning methods for indexing atmospheric pollen counts based on a pollen type's *in vivo* allergenicity and terminal velocity.

Results: Three principal results emerged. First, rooftop pollen counts imperfectly approximate human exposure to atmospheric pollen. Differences in both the concentration and type of pollen encountered by humans can be expected to differ from samples obtained on rooftops.

Second, allergic symptomology is positively correlated with atmospheric pollen counts. Investigations involving *Betula* (birch) pollen offer quantitative dose-response models. Complex, nonlinear relationships that seem to reflect both the priming effect and late-phase reactions exist.

Last, atmospheric pollen counts can be indexed based on a contemporary application of Thommen's postulates. This system provides allergists with a means to estimate the clinical significance of various pollen types by combining data concerning *in vivo* allergenicity and terminal velocity.

Conclusions: These conclusions should allow allergists to judge the clinical significance of atmospheric pollen counts with greater sophistication than was previously possible.

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INTRODUCTION

Allergists generally consider atmospheric pollen counts to be an estimate of the antigenic challenge confronting allergic individuals. The nature of this challenge depends on the particular pol-

len types found in the atmosphere and also the airborne concentration of these pollen types. Both clinical experience and clinical investigations support these assumptions; however, a coherent system for relating pollen counts and allergic symptomology does not yet exist.

A systematic evaluation of the medical and technical literature concerning the relationship between atmospheric pollen counts and allergic symptomology appears long overdue. This review

article will summarize the available evidence on the subject and present guidelines for estimating the public health impact of pollen counts.

Approach

This review article will consider three bodies of literature concerning atmospheric pollen counts and allergic symptomology. First, studies concerning human exposure to atmospheric pollen will be presented. These data will be contrasted with pollen counts supplied by rooftop pollen samplers to demonstrate the limits of rooftop data for estimating human exposure.

Second, investigations that related atmospheric pollen counts to allergic symptomology will be evaluated. The implications and limitations of these studies will be explored.

Last, the properties of common pollen types will be considered. A pollen type's *in vivo* allergenicity and terminal velocity will be offered as a means to judge its clinical significance.

Human Exposure

One must consider whether rooftop pollen samples reasonably approximate human exposure to atmospheric pollen before exploring the relationship between pollen counts and allergic symptomology. Several investigations that used personal samplers and samplers placed near homes will be reviewed. Pollen counts from these environments will be contrasted with rooftop pollen measurements.

Personal Samplers

Kailin¹ conducted a study involving 94 people in the Washington, DC, metropolitan area. Her personal samplers

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consisted of a greased microscope slide placed within a protective housing. The sampler was worn in the lapel area (waking hours) or placed near the bed (sleeping hours) during one 24-hour period in September. These data were then compared with atmospheric pollen counts obtained with three Durham samplers.

Kailin's data suffer the various liabilities of nonvolumetric devices and are therefore difficult to interpret.² She found that pollen recovery varied between patients; those with greater exposure to outdoor air tended to offer higher pollen counts. In all cases, however, the personal samplers offered much lower pollen counts than the Durham samplers.

Kailin's data may reflect differences in human exposure and illustrate a discordance between rooftop pollen concentrations and personal environments. A more probable explanation, however, is that her instruments sampled unequal volumes of air. The Durham samplers probably sampled the most air and patients with minimal exposure to outdoor air the least.

Leuschner and Boehm^{3,4} extended this work with a modified version of Kailin's sampler. Pollen recovery by personal samplers exposed outdoors was compared with volumetric pollen counts obtained from Burkard spore traps (Burkard Manufacturing Co., Rickmansworth, Hertfordshire, England)⁵ in several cities in Switzerland. Although direct comparisons between the devices are not possible, qualitative analyses appear permissible.

Paired samples from 19 sampling periods were analyzed.⁴ In some cases the personal samplers recovered pollen types that were absent in Burkard samples, and vice versa. In addition, on certain days, the personal samplers collected large rafts of packed pollen grains, a phenomenon that the authors described as pollen "clouds" or "swarms." On these occasions, the Burkard recovered little or no pollen of that pollen type.

These data reflected differences in the composition of pollen counts obtained in personal environments and

rooftop samples. One could cautiously speculate that differences in the airborne pollen concentrations also existed.

Various volumetric personal samplers have been developed for industrial hygiene applications.⁶ This technology has occasionally crossed over into clinical allergy.⁷

Gautrin et al⁸ employed volumetric personal samplers to evaluate pollen exposure among municipal park workers who mowed lawns. Pollen counts obtained from employees' shirt collars were compared with pollen recovery by a device placed 25 meters away and a rooftop pollen sampler that represented the general community.

Paired samples were obtained on 8 days. The median pollen count was 11, 4, and 1 pollen grains per meter of air (p/m^3), from shirt, park, and community, respectively. In five cases, the highest pollen counts occurred on the shirt and in four cases, shirt > park > community.

Like the previous investigations, the particle collection efficiencies of the three devices were probably unequal. These data, however, likely argue for a discordance between rooftop samples and personal environments. Pollen counts were highest near pollen sources (shirt) and lowest at a distance from source regions (community).

Home Environments

O'Rourke and Lebowitz⁹ compared pollen counts collected on rooftops to those obtained near homes. Four clusters (2 to 4×3 to 5 km) in Tucson, AZ, were studied. A Burkard spore trap (5 m above grade) placed in each cluster provided regional pollen counts. Rotorod Samplers (Sampling Technologies Inc., St. Louis Park, MN)^{10,11} (1.5 m above grade) were placed in the yards of 51 homes; pollen was collected over 72-hour periods.

The rooftop devices recovered pollen in every sample, and in 50 cases, yielded higher pollen concentrations than samplers placed near homes; a 10-fold difference was noted overall. In 21 cases, no measurable pollen was

recovered near homes. An equal or greater number of pollen types was collected on the rooftops.

These results reflect intrinsic differences in particle recovery between the devices^{12,13} and the effect of long sampling periods.¹⁴ Despite these confounding factors, however, it appears that real differences existed between the rooftop pollen samples and those obtained near homes. Rooftop samples were higher than pollen counts obtained near homes, generally by an order of magnitude. In addition, the former offered a greater diversity of pollen types compared with the latter.

Differences are perhaps best explained by the filtering effect of urban buildings. Houses and other structures probably interfered with pollen transport near the ground, leading to lower pollen counts and less taxonomic diversity compared with the less obstructed rooftop samples.

Discussion

A recent review article demonstrated that spatial variability in atmospheric pollen concentrations exists within a city.¹⁵ One could therefore anticipate similar variation in human exposure to pollen. The investigations considered in this section evaluated the evidence concerning this claim.

Although the available data are not overwhelming, these studies seem to demonstrate that pollen counts in personal environments differ from rooftop pollen measurements in both the amount and type of pollen recovered. This suggests that rooftop pollen measurements imperfectly approximate human exposure to atmospheric pollen.

Unfortunately, these studies do not permit formulation of general guidelines concerning human exposure. Rooftop samplers may offer pollen counts that are both greater or less than pollen counts obtained near the ground; diversity in the pollen types recovered can be similarly variable. Any system that relates pollen counts to allergic symptomology must therefore accept these potential limitations.

Dose-Response Data

Various publications have related allergic symptomology to the associated pollen challenge. These investigations will be grouped by type in increasing order of utility.

Burge's System

The most popular system for translating pollen counts into allergic symptomology appears to have been derived from Burge's work.¹⁶ She analyzed pollen counts from 51 pollen measuring stations to calculate ranges in pollen abundance for three broad categories of pollen types. Although she did not assign clinical significance to these statistical categories, her system has been widely construed by others to have such meaning.^{17,18} Table 1 presents Burge's ranges and their apparent clinical consequences. It is not clear how the clinical inferences were developed and on what evidence they rest.

Another obvious liability of this system is that certain pollen types are nonallergenic or poorly allergenic. A high *Pinus* (pine) pollen count, for example, has little clinical significance but would be interpreted quite differently under this system.

Controlled-Exposure Experiments

Some investigators have exposed humans to pollen in special chambers¹⁹⁻²⁷ or via inhalation devices^{28,29} and then recorded both subjective and objective allergic symptomology. In most cases, pollen concentrations greatly exceeded environmental conditions. For example, in Day's work,²⁷ the target *Ambrosia*

(ragweed) pollen concentration was 3,500 p/m³. Although these pollen conditions have been documented in outdoor air, the atmospheric pollen concentration is generally substantially lower.^{30,31} Data from these experiments are thus difficult to translate into typical human exposure patterns.

Nonstatistical Analyses

Various investigators have compared atmospheric pollen counts with symptom and/or medicine scores.³²⁻⁴² Data were presented graphically and often illustrated striking temporal associations between parameters. No statistical analyses were performed, however, which precludes operationalizing the results.

Correlational Analyses

Brown and Ipsen⁴³ compared symptom scores from patients with allergic rhinitis and/or asthma (n = 317) with meteorological variables, gravimetric pollen and spore counts, and pollution data obtained during a 3-month study period (August through October). *Ambrosia* pollen counts demonstrated the strongest correlation with the clinical data (r = 0.670, P < .01). Remaining nonpollen variables were poorly correlated with allergic symptomology.

Van Metre et al⁴⁴ replicated this finding during a clinical trial dealing with various immunotherapy schedules. Volumetric *Ambrosia* pollen counts were correlated with daily symptom-and-medication scores for two treatment groups and a placebo

group (r = 0.664 to 0.850, P < .001 for all groups).

Lebowitz et al^{45,46} investigated the relationship between allergic symptomology and environmental conditions using time series analysis. Unlike traditional correlational analyses, these methods can be used to explore time lags between potential stimuli and human responses.

Their first study obtained weekly symptom data from 80 patients randomly selected from a large population (n = 3,800) over a 143-week period.⁴⁵ Rhinitis symptoms were correlated with *Ambrosia* and Chenopodiaceae (pigweed/goosefoot) pollen counts lagged by 1 week (r = 0.325 and 0.234, respectively; P < .05 in both cases).

A follow-up investigation obtained daily symptom data from a pool of 204 patients over a 2-year period.⁴⁶ Rhinitis symptoms were associated with pollen counts lagged by 2 days (P < .05) during the spring and early summer.

In a derivative study, the relationship among daily symptom data, meteorology variables, and volumetric pollen counts was evaluated using path analysis (this type of analysis allows one to determine the independent contribution of each variable in a complex system in which many variables are interrelated).⁴⁷ Rhinitis symptoms were positively associated with pollen conditions during the early spring and fall (P < .01).

Table 1. Burge's System for Categorizing Atmospheric Pollen Counts (Pollen Grains per Cubic Meter of Air) and the Apparent Clinical Consequence of Each Category. Data are provided for discussion only; see main text for the various liabilities of this system. Adapted from References 16-18.

Category	Tree	Grass	Weed	Allergy symptoms
Absent	0	0	0	No symptoms
Low	1-15	1-5	1-10	Only individuals extremely sensitive to these pollen types will experience symptoms
Moderate	16-90	6-20	11-50	Many individuals sensitive to these pollen types will experience symptoms
High	91-1500	21-200	51-500	Most individuals with any sensitivity to these pollen types will experience symptoms
Very high	≥1500	≥200	≥500	Almost all individuals with any sensitivity to these pollen types will experience symptoms; extremely sensitive people could have severe symptoms

Dose-Response Modeling

Taudorf and Moseholm⁴⁸ studied daily symptom and medicine scores in *Betula*-sensitive patients (n = 15) over two consecutive pollen seasons. An analysis involving volumetric *Betula* pollen counts yielded three principal conclusions.

First, the relationship between the clinical measures and pollen counts was found to be nonlinear (Fig 1a; see

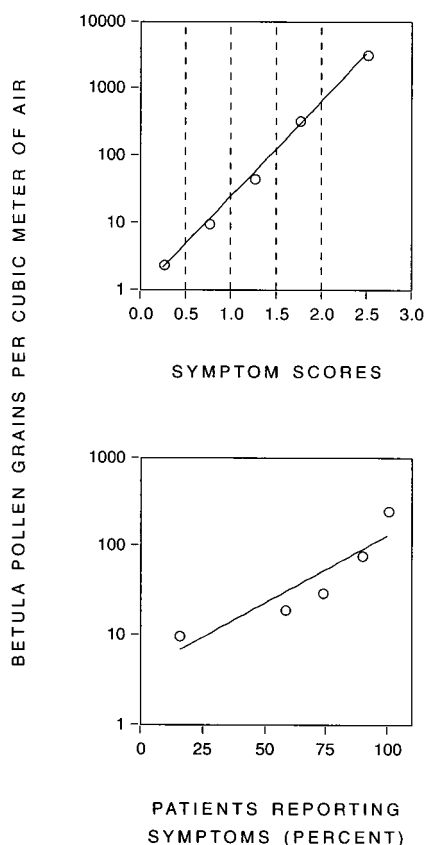


Figure 1. Relationship between *Betula* pollen counts, symptom scores and the percent of patients reporting symptoms. Symptom scores range from 0 to 3 (<0.5 = Few symptoms; 0.6–1.0 = Some symptoms; 1.1–1.5 = Many symptoms; 1.6–2.0 = High symptoms; >2 = Very high symptoms). Adapted from References 48 and 49. See also Appendix 1.

Appendix 1). This finding agrees with data from an earlier clinical trial⁴⁹ (Fig 1b) and appears to be the experience of other investigators.^{50,51}

Second, the clinical consequences of a given pollen load increased as the season progressed. This likely represented Connell's priming effect where repeated pollen challenges increased nasal sensitivity and thus allergic symptomology despite a constant or declining antigenic challenge.^{28,52}

Last, development of significant symptom scores lagged peaks in atmospheric pollen conditions by several days; the effect decayed exponentially with a characteristic half-life of 1 to 2 days. Broström and Möller⁵³ uncovered a similar phenomenon in their analysis of data from two clinical trials.^{54,55} This finding was thought to be distinct from the priming effect and may represent late phase reactions.

Discussion

Many studies published throughout the last century demonstrated a positive association between allergic symptomology and atmospheric pollen conditions. Formal statistical analyses confirmed this association and quantified the strength of the correlation between these phenomena.

A nonlinear relationship appears to exist between allergic symptomology and atmospheric pollen counts. As demonstrated by Figure 1, human suffering reaches significant levels at modest pollen counts; substantial pollen challenges are required to achieve incremental changes in symptomology thereafter. These findings thus support the general approach, but not the numeric data, offered in Table 1.

Several investigators demonstrated that allergic symptomology can lag pollen events and also appears to change over the course of the pollen season. These observations may represent late phase reactions and the priming effect, respectively. These findings suggest that Table 1 may be too rigid and that a dynamic system may be more appropriate.

Allergen Indexing

Dozens of pollen types are recovered in atmospheric samples throughout the course of a typical pollen season. This section will present some guide-

lines for judging their clinical significance.

Thommen's Postulates

Thommen outlined five postulates that characterize the features of clinically important pollen types: 1) the pollen must contain an excitant of hayfever; 2) the pollen must be anemophilous (wind-pollinated); 3) the pollen must be produced in sufficiently large quantities to lead to human exposure; 4) the pollen must be sufficiently buoyant to be carried considerable distances; and 5) the plant producing the pollen must be widely and abundantly distributed.^{56,57} Although this framework was first presented 70 years ago, it withstands contemporary scrutiny and can scarcely be improved.

Thommen's first and fourth postulates are the most important tenets of his system because they can be used to quantify the significance of atmospheric pollen counts. These postulates will be explored in greater detail below.

Thommen's second postulate is obviously true, but should be slightly refined to recognize the clinical importance of amphiphilous (wind-and-insect-pollinated) genera.⁵⁸ *Acer* (maple) and *Salix* (willow) pollen, for example, are recovered in appreciable quantities in atmospheric samples and cause pollinosis.⁵⁹ Even pollen from entomophilous (insect-pollinated) genera can occasionally be aerobiologically and clinically significant.⁶⁰

Thommen's third postulate, although true, would be difficult to translate into clinical practice. Paleoecologists have estimated the pollen production of certain genera: one *Alnus* (alder) tree, for example, produces approximately 3.6×10^{11} pollen grains during a 50-year period.⁶¹ Data are not available for all genera, however, which precludes developing an indexing method based on this postulate.

Thommen's fifth postulate also seems to be true, but would be exceedingly difficult to translate into clinical practice. Most vegetation maps indicate the range, not geographic abundance of certain plants.⁶²

Allergenicity

Thommen recognized that certain pollen types such as *Pinus* rarely cause pollinosis, although others such as *Ambrosia* are strongly allergenic. The former apparently lacked an excitant possessed by the latter. From a contemporary perspective, this excitant represents a protein allergen or group of allergens.

Traditionally, the allergenicity of various pollen types has been established by in vivo methods such as skin testing. These data can be used to judge the clinical importance of pollen recovered in atmospheric samples.

Many skin test surveys have been conducted, but most must be interpreted with caution because the patient population was not broadly representative and/or the skin test extracts were not standardized. With these hazards acknowledged, some skin test data will be briefly reviewed.

Gergen et al⁶³ sought to establish the skin-test sensitivity of a large, random sample of the US population. Extracts of four pollen types were employed: *Quercus* (oak), *Lolium* (darnel or rye grass), *Cynodon dactylon* (Bermuda grass) and *Ambrosia*. Positive skin tests occurred in 4.7% ± 0.36, 10.2% ± 0.56, 4.4% ± 0.42, and 10.1% ± 0.57 of people tested, respectively.

Although this study used a large sample population, its results are limited by the narrow panel of allergens used. Several smaller studies are more helpful because they tested patients with larger panels of pollen allergens.

Lewis and Imber⁶⁴⁻⁶⁶ and Chapman^{67,68} conducted similar skin test surveys on large groups of atopic patients in Missouri. Data from those studies were reanalyzed for this review article and are presented in Table 2 (see Appendix 2). A pattern similar to Gergen et al's findings emerged. A larger fraction of the patient population was sensitive to weed and grass allergens than to tree allergens.

Terminal Velocity

Thommen recognized that pollen must be buoyant to be of clinical significance. He attributed buoyancy to a pol-

len grain's size, morphology, and weight (or specific gravity).

These variables have some explanatory power but are neatly subsumed by a pollen grain's terminal velocity, or its rate of fall per unit time (generally expressed in centimeters per second). A pollen grain's terminal velocity can be calculated from Stoke's law⁶⁹ (which considers a particle's size and density) and experimentally measured by various means. The latter approach is generally preferred for pollen grains because the terminal velocities of nonspherical particles often depart significantly from values offered by Stoke's law.

Various investigators have measured the terminal velocities of many common pollen types.⁶⁹⁻⁷¹ Results frequently vary between studies because of different experimental approaches. Durham's data will be used for this review article because his effort involved 38 species from 31 genera, thus allowing comparisons among most major pollen types.⁷⁰

In Durham's investigation, *Ambrosia trifida* (giant ragweed) and *Zea mays* (corn) offered the lowest and highest terminal velocities, respectively (0.823 and 18.288 cm/sec). Considered as groups, the mean terminal velocity of weed pollen (1.311 ± 0.512 cm/sec; n = 17) was less than tree pollen (2.026 ± 0.786 cm/sec; n = 15) and grass pollen (2.128 ± 0.621 cm/sec; n = 6, *Zea* and *Secale cereale* (rye) excluded).

Pollen grains with lower terminal velocities travel farther from their source than grains with higher terminal

velocities.¹⁵ Data adapted from Sugita's work demonstrate that the relationship between terminal velocity and distance traveled is logarithmic (Fig 2; see Appendix 3).⁷²

Discussion

Data concerning allergenicity and terminal velocity can be combined to index the clinical importance of pollen recovered in atmospheric samples.

This new indexing system is presented in Figure 3 for nine pollen types. All data were scaled to values for *Ambrosia* because it is highly allergenic and has a low terminal velocity. Skin test data from Table 2 were transformed in a linear manner and appear on the y-axis. Terminal velocity data were transformed in a logarithmic manner (per an adaptation of Equation 3) and appear on the x-axis.

The right upper quadrant represents pollen types of greatest allergenic significance: pollen grains have a low terminal velocity and are highly allergenic. The left lower quadrant represents pollen types of least allergenic significance: pollen grains have a high terminal velocity and are poorly allergenic. Remaining quadrants are of intermediate clinical significance.

CONCLUSIONS

This review article explored the relationship between atmospheric pollen counts and allergic symptomology. On the basis of the literature explored, three principal conclusions emerged.

First, rooftop pollen counts imperfectly approximate human exposure to

Table 2. Skin Test Frequency (Percentage of Patients Responding 2-4+) and Terminal Velocity Data (cm/s) for Nine Pollen Types. Adapted from References 64-68 and 70. See also Appendix 2.

Pollen type	Lewis	Chapman	Mean	TV
<i>Betula</i>	5.3	2.1	3.7	1.676
<i>Fraxinus</i>	4.1	5.0	4.6	1.524
<i>Juglans</i>	7.0	6.2	6.6	2.835
<i>Quercus</i>	6.8	5.2	6.0	2.195
<i>Ulmus</i>	7.5	6.2	6.9	2.042
<i>Phleum</i>	16.8	19.2	18.0	2.804
<i>Amaranthus</i>	8.6	9.0	8.8	1.859
<i>Ambrosia</i>	22.4	25.6	24.0	0.823
<i>Plantago</i>	11.3	11.6	11.5	1.494

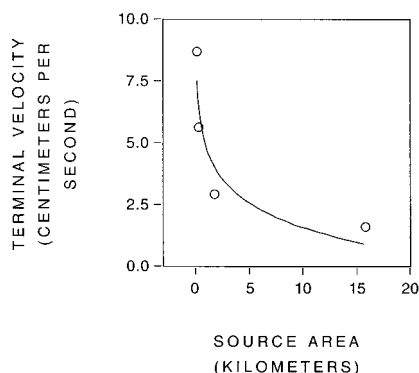


Figure 2. Relationship between terminal velocity and source area for four pollen types representing a spectrum of terminal velocities. Adapted from Reference 72. See also Appendix 3.

atmospheric pollen. Differences in both the concentration and type of pollen encountered by humans can be expected to differ from samples obtained on rooftops.

Second, allergic symptomology is positively correlated with atmospheric pollen counts. Investigations involving *Betula* pollen offer quantitative dose-response models. Complex, nonlinear relationships that seem to reflect both the priming effect and late phase reactions exist.

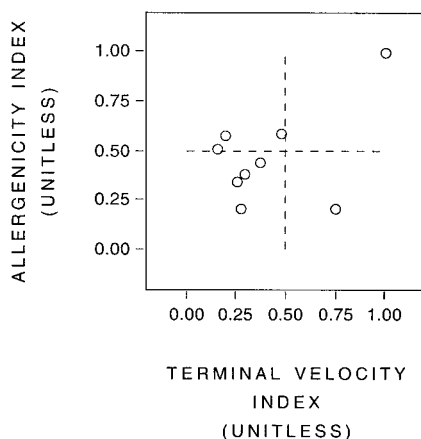


Figure 3. Allergen indexing. The nine pollen types presented in Table 2 were indexed to values for *Ambrosia* (1.00, 1.00). The right upper quadrant represents pollen types of greatest clinical significance. The left lower quadrant represents pollen types of least clinical significance. Remaining quadrants are of intermediate clinical significance.

Last, atmospheric pollen counts can be indexed based on a contemporary application of Thommen's postulates. This system provides allergists with a means to estimate the clinical significance of various pollen types by combining data concerning in vivo allergenicity and terminal velocity.

Taken together, these conclusions should allow allergists to judge the clinical significance of atmospheric pollen counts with greater sophistication than was previously possible.

APPENDIX 1

The purpose of this appendix is to supply equations for the curves depicted in Figure 1.

The top graph was derived from Table 4 of Taudorf and Moseholm.⁴⁸ Data for their most sensitive group of patients (group H) was reanalyzed for this review article. The midpoint of each symptom category was determined (0.25, 0.75, 1.25, 1.75, and 2.5). The midpoint in the range of pollen counts supplied for each symptom category was then calculated for the first four categories (2.5, 10.0, 45.0, and 337.5 p/m³). The pollen count associated with the fifth category (3223.9 p/m³) was determined by regression analysis because a range was not supplied.

The data depicted are described by the following equation:

$$b = 0.968 \times 10^{1.409s} \quad r = .998$$

where b is the *Betula* pollen count, s is the symptom score and r is the equation's correlation coefficient.

The bottom graph was derived from Table 2 of Viander and Koivikko.⁴⁹ Data for their control population was regressed against the *Betula* pollen count.

$$b = 3.945 \times 10^{0.015p} \quad r = .914$$

where p is the percentage of patients reporting symptoms.

APPENDIX 2

The purpose of this appendix to explain the derivation of the skin test data that are presented in Table 2.

Lewis and Imber⁶⁴⁻⁶⁶ presented skin test data obtained from a large popula-

tion of presumably atopic patients seeking care from two allergists over a 10-year period. Data for a sub-population (PS1) tested via the intracutaneous method were reanalyzed for this review article.

For the tree study, patients ($n = 1324$) were screened with an extract containing a mixture of various tree antigens ("mixed trees").⁶⁵ Those responding strongly (2 to 4+) were then tested with a panel of 12 individual tree extracts. Table 2 reflects the percentage of the total population tested that reacted (2 to 4+) to each tree extract.

Similar efforts were conducted for grass and weed pollen.^{64,66} Unlike the work with tree pollen, patients were not screened with grass or weed mixtures before skin testing with individual grass and weed extracts. Table 2 reflects the percentage of each population tested ($n = 1,341$ to 1,407) that reacted (2 to 4+) to the various extracts.

Chapman^{67,68} conducted a similar study involving patients referred to him by other physicians for an allergy consultation. Data for a sub-population ($n = 629$) tested via the intracutaneous method were reanalyzed for this review article. Table 2 reflects the percentage of this population that reacted (2 to 4+) to each extract.

APPENDIX 3

The purpose of this appendix is to explain the derivation of Figure 2.

Sugita's work was reviewed at length previously.¹⁵ His mathematical investigations yielded the source areas for lakes of various radii for certain pollen types. A striking relationship between a pollen type's terminal velocity and the source area was evident: pollen types with low terminal velocities offered very large source areas compared with pollen types with high terminal velocities.

The source radius contributing 50% of pollen to the center of a lake (radius 50 m) was obtained for four pollen types representing a spectrum of terminal velocities.⁷² Terminal velocity was then plotted against source radius. The resulting curve in Figure 2 is described by the

following equation

$$t = -3.246 \log R + 14.495 \quad r = .930$$

where t is the pollen type's terminal velocity (cm/sec) and R is its corresponding source radius (m).

Notice the dramatic relationship between terminal velocity and source radius. Initially, the latter increases only minimally despite a significant reduction in terminal velocity. Between the third and fourth points, however, source radius increases from 1,637 to 15,759 m despite a comparatively small decrease in terminal velocity (2.9 to 1.6 cm/sec).

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CME Examination (5 Questions Total)

No 2001-002

1-5, Frenz DA. 2001;86:000-000.

CME TEST QUESTIONS

1. Taudorf and Moseholm demonstrated that the relationship between pollen counts and symptom scores is:
 - a. Linear.
 - b. Nonlinear.
 - c. Linear for *Betula* pollen but nonlinear for Poaceae pollen.
 - d. Linear for *Betula* pollen but nonlinear for *Ambrosia* pollen.
 - e. Random.
2. Taudorf and Moseholm demonstrated that a given *Betula* pollen load caused greater allergic symptomology as the pollen season progressed. This likely represented:
 - a. The contribution of other pollen types such as *Populus*.
 - b. Connell's priming effect.
 - c. Late phase reactions.
 - d. Comorbid food allergies.
 - e. Comorbid psychiatric illness.
3. Taudorf and Moseholm demonstrated that the development of significant symptom scores lagged peaks in atmospheric pollen conditions by several days. This likely represented:
 - a. The contribution of other pollen types such as *Populus*.
 - b. Connell's priming effect.
 - c. Late phase reactions.
 - d. Comorbid food allergies.
 - e. Comorbid psychiatric illness.
4. Thommen:
 - a. Outlined five postulates that characterize the features of clinically important pollen types.
 - b. Was a nineteenth century pulmonologist.
 - c. Conducted the first experiments concerning immunotherapy.
 - d. Elucidated the tertiary structure of IgE.
 - e. Deduced the intracellular signaling pathways for several cytokines.
5. In this review article, pollen types were indexed by combining data concerning their:
 - a. Mass and morphology.
 - b. Morphology and specific gravity.
 - c. Mass and terminal velocity.
 - d. In vivo allergenicity and terminal velocity.
 - e. In vivo allergenicity and morphology.

Annotated answers

1. The correct answer is b. Figure 1 demonstrates a nonlinear relationship between pollen counts and symptoms scores. Please refer to References 48-51.
2. The correct answer is b. Connell's now classic series of investigations (Refer-

ences 28, 29, and 52) explored various features of the pathophysiology of allergic rhinitis. Taudorf and Moseholm invoked his "priming effect of the end organ" to explain their clinical observations.

3. The correct answer is c. Several authors, including Taudorf and Moseholm, have demonstrated that allergic symptoms sometimes lag peaks in atmospheric pollen conditions. Although one could argue that this represents Connell's priming effect, the temporal characteristics seem to favor late phase reactions. Please refer to References 48 and 53-55.
4. The correct answer is a. Thommen first outlined his postulates in Reference 56. He presented an amplified and refined treatment in an early textbook on allergic disease that he co-authored with Coca and Walzer (Reference 57).
5. The correct answer is d. This review article argued for an evidential approach for judging the clinical significance of atmospheric pollen counts. Modified versions of two of Thommen's postulates—in vivo allergenicity and terminal velocity—were used to index a pollen type's potential to cause allergic disease. Please refer to Table 2 and Figures 2 and 3.