VOLUMETRIC AND GRAVITY SLIDE TESTS FOR AIR-BORNE RAGWEED AND OAK POLLENS AT COLUMBUS, OHIO

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A more or less recent phase of atmospheric pollen research has been concerned with deriving a mathematical formula or a conversion factor with which gravity slide data[2] could be converted into equivalent volumetric units. Data so reported would be of greater value to allergists since the degree to which a patient is sensitized greatly depends upon the number of antigenic pollen grains entering the individual's lungs. Scheppegrell (1) in 1917, reported a conversion formula (partially derived by use of Stokes' law of falling bodies) for converting data obtained from freely exposed[3] gravity slides into equivalent volumetric units. Cocke (2) later corrected a mathematical error in the formula, and both Cocke (3) and Hawes (4), following simultaneous gravity slide and volumetric tests, reported that their experiments proved the validity of the use of the Scheppegrell-Cocke formula even when the specific gravity of the various pollens was considered as 1.0. However, Rosendall, *et al* (5), reported that the factors derived from Scheppegrell-Cocke formulas were also incorrect in certain instances. Dahl (6) then pointed out the inadequate knowledge concerning the specific gravity of the various pollens, and suggested that the assumption that this was approximately 1.0 might be incorrect and have a great deal to do with the apparent inaccuracies of the Scheppegrell-Cocke formula. He also pointed out that little was known concerning the relative rates of fall of the various pollens and suggested that no further progress could be made with the problem until the actual specific gravity of the pollen grains of different species, as well as their particular rates of fall in still air, could be determined experimentally. This information was supplied by Durham (7, 8). He found that the specific gravities of tree pollens are approximately 0.9, and those of most grass pollens are about 1.0; however, the specific gravity of ragweed pollen is approximately 0.5. Consequently Durham stated ". . . that calculations already made by Scheppegrell, Cocke, and Dahl, who have used Stokes' law for determining the rate of fall and number of pollens per cubic yard of air, may be expected to give reasonably accurate results for some tree and grass pollens, whereas they are evidently in error for the ragweeds."

The next step was to calculate theoretical atmospheric pollen concentrations by the use of the Scheppegrell-Cocke formula in which the experimentally determined specific gravities were included, and then compare these data with the actual concentration as determined experimentally. This was also done by Durham (9). He found great differences in the daily ratios as determined by the two methods, and concluded that ". . . the Scheppegrell-Cocke-Dahl tables are of no practical value in converting gravity slide figures to accurate volumetric equivalents." Durham's volumetric determinations were known to be essentially correct, therefore the large differences in the comparative ratios must have been the result of large errors involved in the gravity sampling procedure. This was in many instances verified by his data which indicate that on days of approximately the same degree of atmospheric ragweed pollen concentration the catch

[1]Paper from the Department of Botany and Plant Pathology, The Ohio State University, No. 514.

[2]Data collected by the use of sticky coated microscope slides exposed to the atmosphere for a given period of time.

[3]That is, slides in no way sheltered.

on the freely exposed slides usually, varied directly with the wind velocity. Durham also exposed a set of gravity slides in various positions and found that a slide placed in a horizontal position with the coated side down collected approximately half as many pollen grains as a horizontal slide with the coated side upward. This led Durham to conclude that convection currents, deflection currents, and wind eddies must interfere with a horizontal flow of air hence with the deposit of pollens and spores on the gravity slides. Since the gravity slide method of sampling is by far the simplest and most convenient method so far devised, Durham proceeded to construct a collector which would decrease the turbulence over the slide and consequently result in a more uniform collection of pollens (10). Simultaneous gravity slide and volumetric collections were made during the ragweed season of 1945 using this new gravity slide sampler, and the comparative ratios were found to be much more uniform. The catch per cubic yard averaged 3.6 times greater than the catch per square centimeter of gravity slide, and Durham submitted this as a conversion factor for calculating the volumetric incidence of ragweed pollen when this type of sampler was used in areas where short ragweed is predominate. He further concluded that conversion factors for other pollens would be comparable to that of short ragweed in proportion to their relative rates of fall, and on this basis presented a table of conversion factors for some 40 important etiologic hay fever pollens.

The purpose of the volumetric studies reported herein was to obtain a better understanding of the atmospheric concentrations of ragweed and oak pollens at Columbus, Ohio, as well as to check the feasibility of using Durham's conversion factors for volumetric incidence determinations in this area.

VOLUMETRIC APPARATUS AND TECHNIQUE FOR COUNTING POLLENS

The volumetric apparatus (Fig. 1) used in the following experiments was operated approximately 60 feet above the ground at the edge of the flat roof of the Botany and Zoology Building of The Ohio State University.

By the passing of air through a glycerin-water-alcohol solution,[4] the pollen grains are trapped and the sampled air is metered. Pyrex test tubes, 32 by 200 mm., hold the collection solution, while others of the same size catch any of the solution escaping the collection tube. Air enters the system through a three and one-half inch pyrex funnel which is connected to a three and one-half inch length of ⅜-inch diameter butyrate tubing. The end of this tubing is perforated with 12 one-millimeter holes to break up the air stream. Glass beads in the collection tube further break up the air stream and consequently result in a greater washing of the air.

At the completion of each volumetric test, the complete collection unit was taken into the laboratory where the trap tube and funnel were washed with a small amount of water which in turn was added to the collection solution. This solution was then removed from the collection tube. The glass beads were washed several times with several milliliters of water, and the wash added to the collection solution which was then measured for total volume. After removing the washed beads, the solution was replaced in the collection tube for storage until counts of the trapped pollen grains could be made.

A Rafter Counting Cell, which holds one-milliliter of solution, was used to determine the approximate number of pollen grains collected during each test. All counts were made with a 10X objective in conjunction with a 12.5 ocular. In all instances at least three one-milliliter aliquots were observed for trapped pollen grains, and in cases where the first three counts were not approximately the same, additional counts were made until the average number of pollen grains per milliliter did not appreciably change. In the determinations of oak pollen abundance, one drop of a saturated solution of basic fuchsin was added to the

[4]60% glycerin, 30% water, and 10% ethyl alcohol.

collection solution, approximately 40 ml., to facilitate counting. In all cases the entire counting chamber was observed, and all of the pollen grains were counted.

The efficiency of the apparatus to trap pollens was checked several times during the course of ragweed pollen sampling by placing a coated slide in the trap tube where it was adjacent to the entering washed air. Following each test, Calberla's staining solution (11) was added to the slide, and the area covered by a 22 mm. square cover slip was observed for pollen. In every instance the observed area was found to be free of pollen. The apparatus was further checked in the laboratory at the end of the ragweed season by directing a visible cloud of commercially dried ragweed pollen into the entry tube every 15 minutes over a period of two hours. A coated slide was again placed in the trap tube. Following the check the number of pollen

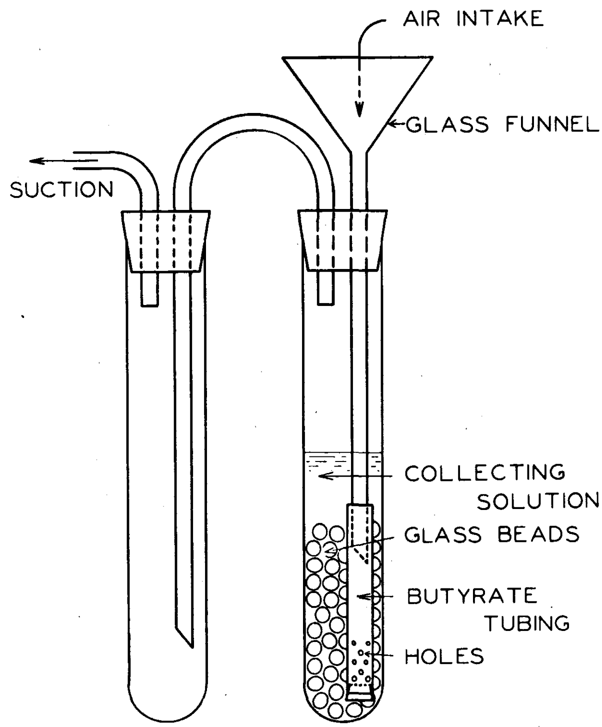

FIG. 1. Pollen collection unit of the volumetric apparatus.

grains in the collecting solution was approximately 150,000 while only eight were found on approximately five square centimeters of the check slide. It was therefore concluded that, for all practical purposes, when the apparatus was operating properly it was essentially 100 per cent efficient.

Volumetric and Gravity Slide Studies of Ragweed Pollen During 1948

Gravity Slide Studies

Four standard gravity slide collectors were erected at various locations within the city prior to the 1948 ragweed pollen season. One collector was located in the heart of the downtown business district on top of a six-story office building. Two collectors were placed in residential districts, one being located approximately two miles east of the center of the city in a back yard of a densely populated area, while the other was located in a moderately populated and wooded district approximately six miles north of the central business district. The fourth collector was located on top of the Botany and Zoology building at The Ohio State University. Although the University district is only three miles north of the center of the city,

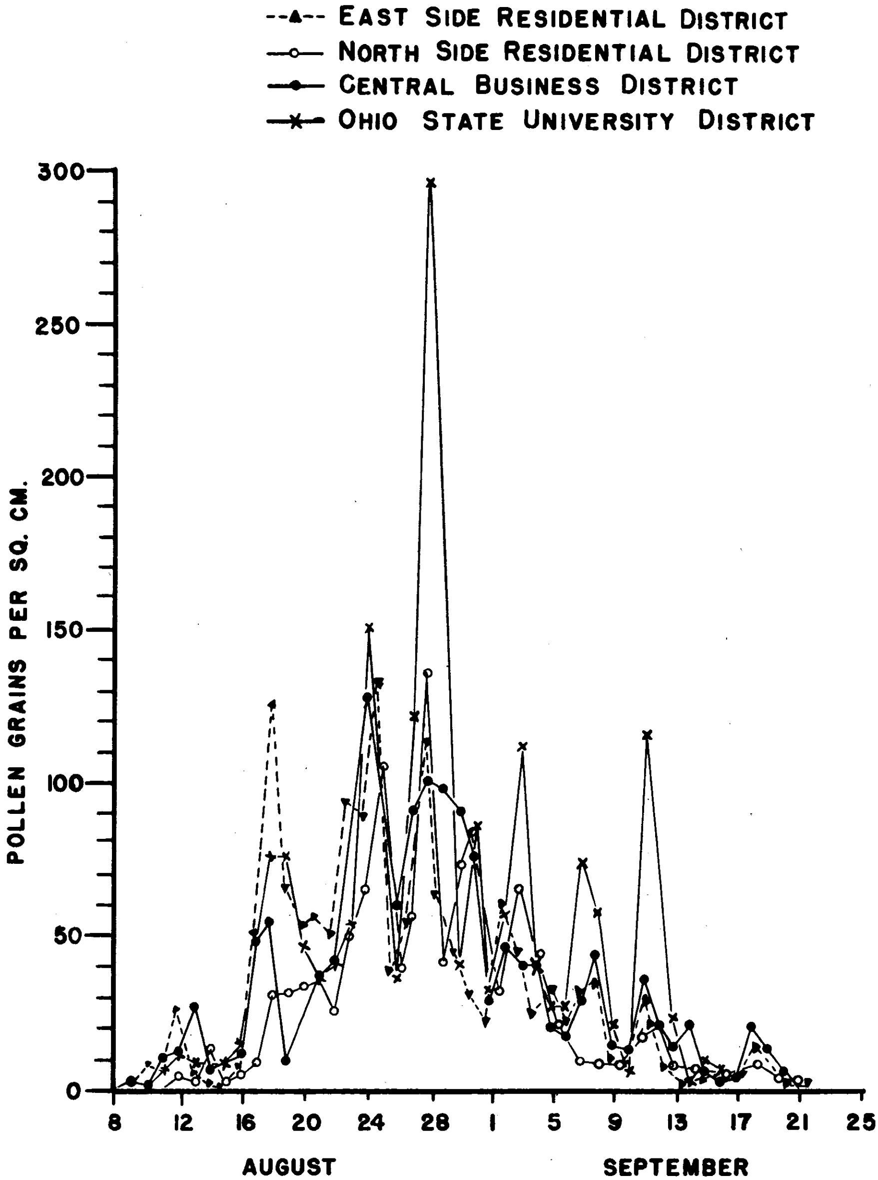

FIG. 2. The 1948 ragweed pollen season as determined from data collected in standard gravity slide collectors.

it is located near the city boundary, and open farming country lies immediately to the west and northwest. All collectors were held approximately five feet above their respective bases by ¾-inch rod standards.

Flowering of giant ragweed (*Ambrosia trifida*) occurred several days in advance of short ragweed (*A. elatior*) and was first observed on August 5. Ragweed pollen was first collected by gravity slides on August 9, and by August 11 was being collected at each of the four stations. Omitting daily variations, mainly due to climatic fluctuations, the resultant frequency curves of all the stations indicate that there was a daily increase in the number of air-borne ragweed pollen grains until the period of August 24 to 29, during which time maximum concentrations occurred. There was then a rather steady decrease in the number of air-borne ragweed pollen, and by September 21 the daily catch at each station was less than five grains per square centimeter of gravity slide. The curves of the downtown and two residential stations are essentially the same, the maximum collection at each of these stations being between 126 and 132 pollens per square centimeter (Fig. 2).

The curve of the University station is similar to the curves of the other stations, but the daily collections are, in most instances, considerably greater. This is probably due to the predominate westerly and relatively unobstructed air movements from adjacent farming and river areas where extensive stands of both tall and short ragweed occur. As the velocities of these air movements are reduced by such obstructions as city buildings and vegetation, there is probably a dropping out of some of the pollen which results in lower collections at the stations other than the University station. The greatest catch at the University station was 295 grains per square centimeter of gravity slide and occurred on August 28.

The atmospheric ragweed pollen concentration, as it occurs over most of the city, can therefore be considered as a blanket of air in which the density of the ragweed pollen is essentially uniform. Consequently, the data collected by a standard collector located well within the city proper can be used to represent the atmospheric incidence of this particular pollen, as it occurs over most of the city. Data collected by a single collector during the tree and grass pollen seasons cannot be so used since the atmospheric abundance of these grains varies greatly between the downtown and northern residential districts.

VOLUMETRIC STUDIES

Volumetric determinations were made during 29 consecutive days of the ragweed pollen season beginning on August 19 and ending on September 16, 1948. At the latter date the concentration of these pollen grains was less than 100 per cubic yard of air (Fig. 3).

The weather during the greater part of the period of volumetric sampling was clear, hot to warm, and with little cloud formation or air movement. The eight days prior to the date of maximum concentration, August 30, were all cloudless, hot, summer days during which the maximum temperatures recorded at the local Weather Bureau were, in most cases, high in the nineties. The day of August 30 began as another hot, clear, quiet day, but by 10 a. m. thunderheads had developed, and at 12 o'clock a heavy thundershower commenced and continued for an hour. This was the first precipitation in 12 days, and marked the end of the hottest and driest summer weather of the year. A distinct daily fluctuation in the number of atmospheric ragweed pollen grains occurred during the first 10 days of sampling, days with a greater concentration of pollen being followed by days in which the concentration was markedly and proportionally less. Since the meteorological conditions during the first 10 days of sampling were similar, the days being cloudless, dry, hot, and quiet, during which the temperature regimes were much the same, it is suggested that this daily fluctuation may be due to some inherent factor of the ragweed species.

The maximum atmospheric concentration of ragweed pollen was slightly more than 10,000 grains per cubic yard of air, and occurred on the morning of August 30 immediately preceding the heavy thundershower mentioned above. Field observations substantiated the fact that this peak concentration was largely due to the flowering of tall ragweed. A second peak due to the flowering of short ragweed was expected but failed to materialize due to the dessication of the majority of the flowers during the hot, dry weather prevailing in the latter part of August.

COMPARISON OF GRAVITY SLIDE AND VOLUMETRIC INCIDENCE DATA

Simultaneous gravity slide and volumetric incidence data were obtained during 29 consecutive days during the ragweed pollen season. However, during the first 14 days of testing the writer failed to expose one set of gravity slides *only* during the volumetric sampling procedure. Consequently, the gravity slide data for these days is of little comparative value. On September 3 this error in procedure was corrected, and the following comparative data were obtained during the remainder of the season (Table I).

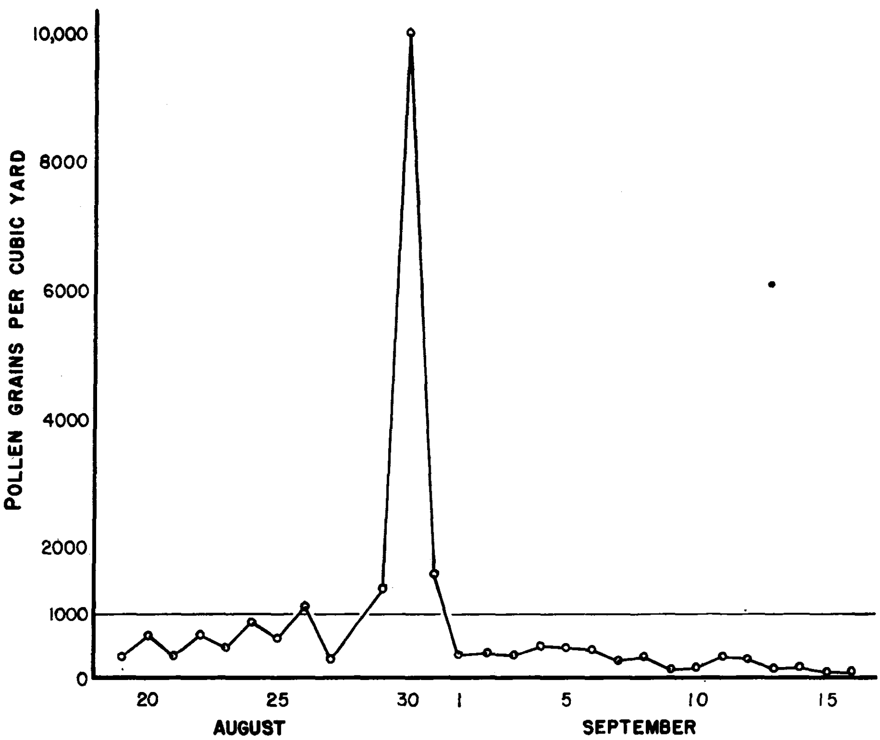

FIG. 3. Volumetric incidence of ragweed pollen at Columbus, Ohio (1948).

The gravity slide and volumetric data can be compared in two ways, (A) by determining the ratio of the total pollens collected by each method during the 12 days of testing, or (B) by deriving the average daily ratio of the pollens collected by each method. In this case the ratio of the total pollens collected by each method is 3.05, while the average daily ratio is 4.57. Durham used the ratio of the totals as the conversion factor, but in this instance the average daily ratio of 4.57 was found to give a more accurate conversion of the gravity slide data into equivalent volumetric units.

The conversion factor for giant ragweed, as calculated by Durham, is 3.87, and was derived from the experimentally-determined conversion factor of 3.6 for

TABLE I

Calibration of Standard Sampling Device for Giant Ragweed Pollen

Date	Volumetric: Vol. of Air Sampled cu. ft.	Volumetric: Pollen Grains per ml. of Solution	Volumetric: Vol. of Solution ml.	Volumetric: No. of Pollen Grains Collected	Volumetric: No. of Pollen Grains per cu. yd. of Air	Gravity Slide: Av. No. of Pollen Grains per sq. cm.	Gravity Slide: Duration of Tests Hrs.	Gravity Slide: No. of Grains Collected 24 Hr. Basis	Ratio Vol./ Gravity	Wind: Dir.	Wind: Vel.	Weather
9/3	33.1	12.0	38.5	462.0	376.8	15.9	4.2	91.4	4.1	S.	1–3	Clear in A. M.; Cloudy in P. M.; Warm
9/4	33.0	12.0	48.5	582.0	476.1	18.4	4.7	94.6	5.0	Var.	0–1	Clear, Hot
9/5	27.0	9.5	50.0	475.0	475.0	4.1	2.7	36.8	12.9	S. E.	4–7	Clear, Hot
9/6	20.5	8.0	44.0	352.0	463.6	6.0	3.3	43.9	10.6	S. E.	4–7	Cloudy, Rain
9/7	30.0	6.0	51.5	309.0	278.1	42.9	4.2	246.2	1.1	S. E.	4–7	Heavy shower in A. M.
9/8	37.0	10.7	41.0	438.7	320.1	18.4	4.3	101.9	3.1	S. W.	1–3	Clear, Warm
9/9	33.0	4.0	47.5	190.0	155.4	6.4	3.5	44.1	3.5	N. W.	3–6	Overcast, Cool
9/10	30.0	3.5	44.5	155.7	140.1	4.3	2.9	35.6	3.9	W.	2–5	Clear, Warm
9/11	43.0	12.5	42.0	525.0	329.6	50.7	4.7	260.1	1.3	S.	4–7	Clear, Warm
9/12	33.0	11.3	33.5	378.5	309.7	24.5	3.8	155.6	2.0	S.	1–3	Clear, Warm
9/13	34.0	5.3	42.5	225.2	178.8	7.9	4.5	42.1	4.2	Var.	0–1	Clear, Warm
9/15	30.0	3.3	31.5	103.9	93.5	3.7	2.9	30.4	3.1	Var.	1–2	Clear, Warm
Totals					3596.8			1182.7				
Ratio of Totals						3.04						
Average Daily Ratio								4.57				

short ragweed by taking into account the relative rates of fall between the two species. In doing this, Durham assumed that the number of pollens falling, or impinging upon, a gravity slide are in proportion to their relative rates of fall. Since the pollens of short ragweed were found to fall 0.93 times as fast as those of short ragweed, the conversion factor of 3.87 was obtained by dividing the conversion factor for short ragweed (3.6) by 0.93.

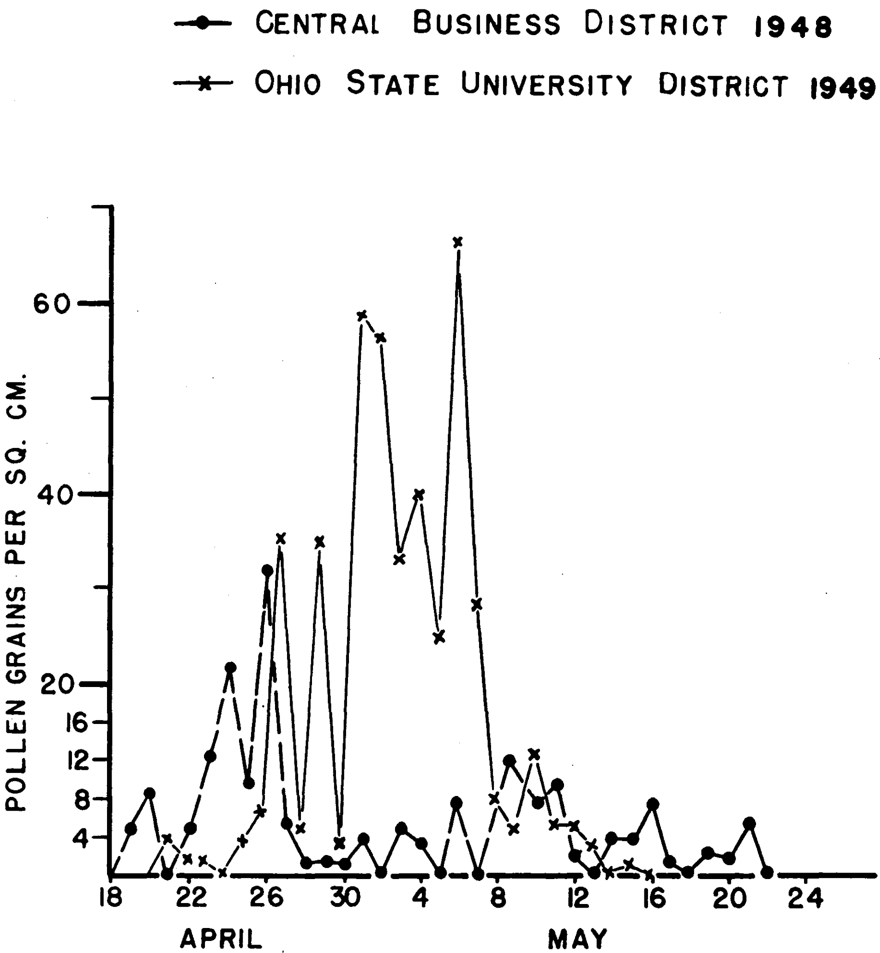

FIG. 4. The 1948 and 1949 oak pollen seasons as determined from data collected in standard gravity slide collectors.

This giant ragweed pollen conversion factor of 3.87 when corrected for the smaller size of these pollens in this area[5] is 4.68, and appears to compare favorably with the writer's experimentally determined factor of 4.57. It must be remembered that Durham's experimentally determined conversion factor for short ragweed is equal to the ratio of the total pollens collected by each method. Using the average of the daily ratios, his adjusted factor for giant ragweed pollen in this area would be 4.96. However, this factor is also considered to compare favorably with the writer's experimentally determined factor. It is therefore recommended that

[5]The average diameter of giant ragweed pollen in this area is 17.51 μ.

TABLE II

CALIBRATION OF STANDARD SAMPLING DEVICE FOR OAK POLLEN

Date	Volumetric					Gravity Slide						
	Vol. of Air Sampled cu. ft.	Pollen Grains per ml. of Solution	Vol. of Solution ml.	No. of Pollen Grains Collected	No. of Pollen Grains per cu. yd. of Air	Av. No. of Pollen Grains per sq. cm.	Duration of Tests Hrs.	No. of Grains Collected 24 Hr. Basis	Ratio Vol./ Gravity	Wind Dir.	Wind Vel.	Weather
5/2	153.5	2.28	41.0	93.71	16.48	6.19	10.5	14.16	1.16	W. to S. W.	8–12	Clear, Windy
5/3	156.0	2.33	35.0	81.55	14.11	5.57	10.7	12.51	1.13	N. W.	1–3	Clear, Hot
5/4	144.0	6.00	31.0	186.00	34.87	10.33	10.0	24.79	1.41	S. W.	1–3	Clear, Hot
5/5	123.0	6.00	33.0	198.00	43.46	6.40	9.0	17.07	2.55	N. W.	1–3	Clear, Hot
5/6	115.0	4.75	37.0	175.75	41.26	19.63	7.2	65.31	0.63	N. W.	1–3	Clear, Hot
5/10	165.5	2.66	40.5	107.73	17.57	9.09	10.5	20.62	0.85	N.	8–12	Clear, Cool, High Overcast
Totals					160.82			154.47				
Ratio of Totals						1.04						
Average Daily Ratio									1.29			

the conversion factor of 4.57 be used in those years when tall ragweed pollen is predominate, and that Durham's conversion factor for short ragweed pollen, corrected for size difference, be used when short ragweed pollen is the dominant type.

VOLUMETRIC AND GRAVITY SLIDE STUDIES OF OAK POLLEN DURING 1949

Locally, the most abundant oaks are white oak (*Quercus alba*), black oak (*Q. velutina*), red oak (*Q. rubra*), and pin oak (*Q. palustris*). However, shingle oak (*Q. imbricaria*), and burr oak (*Q. macrocarpa*) are also present within the city limits, or in the surrounding territory, and are probably minor contributors to the oak pollen concentration.

During three years of spring tree pollen sampling, pollens of the various oaks first appeared on gravity slides between April 16 and 21. Relatively high atmospheric concentrations during 1948, as determined from slides exposed at the downtown station, prevailed during the last week of April with a second minor peak occurring during the first three weeks of May. The greatest catch was collected on April 26 and was 32 grains per square centimeter. The 1949 season, as determined from slides exposed at the University station, began on April 21 and continued until May 11 with peak concentrations prevailing between April 25 and May 8. The greatest catch was collected on May 6 and was 67 grains per square centimeter (Fig. 4).

The early peak in the 1948 spectrum was due to an unknown oak pollen which was collected only in small quantities during the 1949 season. Since the 1948 peak occurred during days of relatively strong south winds, these unknown pollens probably originated in the southern portions of the state where chestnut oak (*Q. muhlenburgii*), scarlet oak (*Q. coccinea*), black oak and white oak occur in large numbers.

Comparative data were obtained by volumetric and gravity tests during six days of the oak pollen season (Table II). There was a consistent daily correlation between the results of the two methods, the number of oak pollens per cubic yard of air being approximately 1.3 times greater than the number of pollens collected per square centimeter of gravity slide; consequently the factor of 1.3 is recommended as an oak pollen conversion factor in the Columbus, Ohio, area when the standard sampler is used. Durham's calculated conversion factors for burr and shingle oak are 1.74 and 1.45 respectively. These conversion factors are remarkably close to the writer's experimentally determined conversion factor for oak pollen in the Columbus area. Since the pollen grains of all the oaks are very similar in size and configuration, this close agreement of the calculated and experimental conversion factors lends support to the accuracy of Durham's calculations for the determination of conversion factors for various important hay fever pollens by reference to their relative rates of fall as compared to that of short ragweed.

SUMMARY

1. A new volumetric method for determining the atmospheric concentration of pollens is reported.

2. Data from four standard gravity slide collectors, variously located within Columbus, Ohio, show that the atmospheric ragweed pollen concentration, as it occurs over most of the city is essentially uniform. Consequently, the data from a standard collector located well within the city can be used to represent the incidence, of this particular pollen, as it occurs over most of the city. Data from a single collector during the tree and grass pollen season cannot be so used since the atmospheric abundance of these grains varies greatly between the downtown and northern residential districts.

3. Volumetric tests were made during 29 consecutive days of the 1949 ragweed season. The volumetric incidence curve is included.

4. From simultaneous gravity slide and volumetric tests, made during 12 days of the ragweed pollen season, it was found that the number of giant ragweed pollen grains per cubic yard of air averaged 4.57 times greater than the number collected per square centimeter of a gravity slide exposed in a standard collector. Durham's calculated conversion factor for this pollen, when corrected for the smaller size of these grains in this area, is 4.96, and is considered to compare favorably with the writer's experimentally determined factor. It is therefore recommended that a conversion factor of 4.57 be used in this area during those years when giant ragweed pollen is predominate, and that Durham's conversion factor for short ragweed, corrected for size difference, be used when short-ragweed pollen is the dominant type.

5. The daily oak pollen concentrations during 1948 and 1949 are presented.

6. Simultaneous gravity slide and volumetric tests during nine days of the 1948 oak pollen season indicate that the average number of oak pollen per cubic yard of air is 1.3 times greater than the number of pollen per square centimeter of a slide exposed in a standard collector.

7. The close agreement between the writer's experimentally determined conversion factor for oak pollen in the Columbus, Ohio, area with Durham's calculated conversion factors for two species of oak lends support to the accuracy of Durham's calculations for the determination of conversion factors for various important hay fever pollens by reference to their relative rates of fall as compared to that of short ragweed.

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