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RESPIRATORY ALLERGY AND CLIMATIC CONDITIONS

II. *Own Investigations*

By

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The aim of this study is to discover whether it is possible to influence the content of large airborne allergens in the air, *e.g.* pollen, by changing the electric climate and the relative humidity of the air.

Therefore the amount of Pinus Montana sedimentation during a certain period in an appropriate room was measured, simultaneously with registration of conductivity, electric field, relative humidity and temperature of the air.

By performing the experiments in different electric climates and levels of relative humidity, it may be recorded whether different combinations of these climatic parameters keep pollen suspended in the air for longer than is normal. It was decided to examine variations found in nature, and thus no measurements were made at artificially great conductivity and at extremely high electric fields.

METHODS AND DEVICES

A complete review of the atmospheric, electric experimental conditions would demand a simultaneous measurement of a number of air electric parameters such as field strength, currents, conductivity, ion concentration and ion distribution.

As complete measurement of this is impossible in practice, among other things because no suitable apparatus exists for it, it was decided for this investigation to measure the specific polar conductivity of the air and to control and calculate the electric field strength.

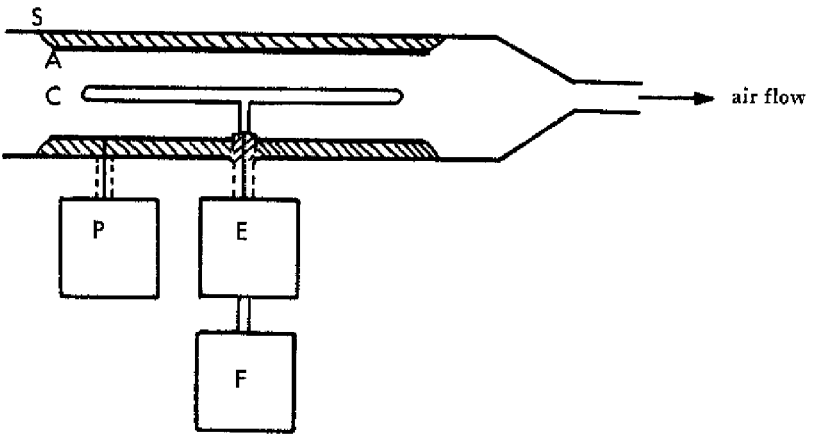


Fig. 1.
A: field cylinder, C: centre electrode, E: ammeter, F: recorder,
P: voltage supply, S: shield cylinder.

The specific conductivity is given by

$$\lambda = e \int_0^\infty k \cdot f(k) \cdot dk,$$

where e is an elementary charge and f(k) is a function for mobility distribution defined by the fact that the concentration of ions with mobility between k and k + dk equals f(k) dk.

Owing to the high mobility of small ions they will be dominant in relation to medium and large ions, and so conductivity may be used as a measure of the concentration of small ions. This is demonstrated by *Jonassen & Wilkening* (16).

An experimental set-up was used, as shown in Fig. 1. The principle of this set-up is as follows:; an air current is sucked through a cylindrical condenser consisting of a shield cylinder S, a field cylinder A and a centre electrode C connected to a sufficiently sensitive ammeter E.

By means of the voltage supply P, an electric field is established between A and C, whereby positive ions will be moved in the direction of the field and negative ions against the field direction. Thus there is a current to the centre electrode, determined by the voltage difference between A and C, the air flow, the geometry of the set-up and the distribution and concentration of the ions. If thus A is positive in relation to C, the current to C will be due to positive ions exclusively.

When a series of conditions, not accounted for here (15), are met, the current I to the centre electrode is a measure of the parts of the specific conductivity that are due to ions so charged that they are attracted by the centre electrode.

For sufficiently great values of the air flow the specific polar conductivities lambda pos. and lambda neg. may be written

$$\lambda+ = \frac{\ln \frac{R}{r}}{2\pi \cdot V+ \cdot L} \cdot I \text{ and } \lambda- = \frac{\ln \frac{R}{r}}{2\pi \cdot V- \cdot L} \cdot I,$$

where R and r are radii of A and C respectively, and where L is the length of C. V+ and V— are the positive or negative voltage differences between A and C, and I is the current to the centre electrode.

The electrometer used does not directly indicate the current I, but the voltage drop V_1 which I causes over the input resistance of the electrometer R_1, *i.e.*

$$\lambda+ = \frac{\ln \frac{R}{r}}{2\pi \cdot V+ \cdot L} \cdot \frac{V_1}{R_1}$$

The voltage drop V_1 is registered at the recorder F, where the conductivity is depicted as a function of time.

At the experiments $\frac{R}{r} = 10.0$, $L = 0.500$ m, $R_1 = 10^{11}\ \Omega$ and $V = \pm 10$ Volt. If the recorded deflection is named A, the following applies to the relation between the conductivity and A measured in mm:

$$\lambda = 0.61 \cdot 10^{-15} \cdot A\ \Omega^{-1}m^{-1}$$

A high air flow is chosen, so that the limiting mobility for the apparatus (for $V = 10$ volt) is about $3 \cdot 10^{-4}m^2 \cdot V^{-1} \cdot s^{-1}$, by which it is ensured that none of the ions coming into the condenser at the edge of the outer cylinder will be caught. This is a necessary condition if the equation for conductivity as a function of current and deflection voltage shall be valid.

The apparatus used is described by *N. Jonassen* (15).

The room temperature was measured by a mercury thermometer with a graduation of 0.2° C. The air humidity was measured by a psychrometer, the precision of this instrument lies around 3–4 per cent of relative humidity.

The test chamber is shielded, so that outer static fields have no effect inside. In the ceiling and floor insulated iron sheets were placed, between which voltage differences of 0 to ± 5000 volt may be applied. If the voltage difference is called U, and the distance a, the field in the chamber is approaching

$$E = \frac{U}{a} \text{ volt/meter.}$$

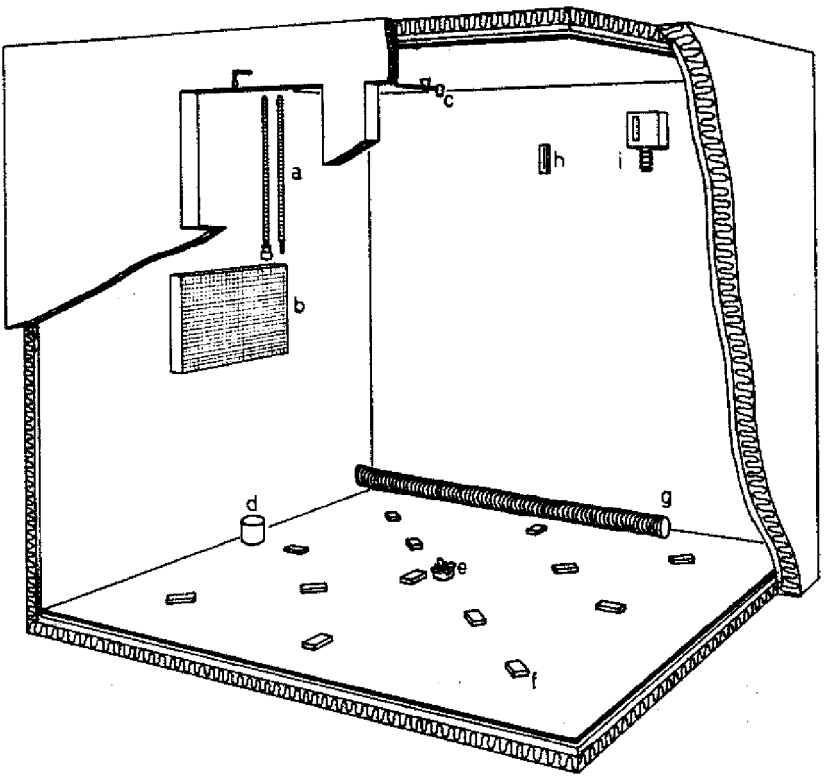


Fig. 2.

Schematic drawing of the test chamber. a: wet and dry thermometer, b: air-conditioner, c: metal cup, d: evaporator, e: ventilator, f: covered dishes for slides, g: suction tube for measuring the conductivity.

As the distance from floor to ceiling is 2.02 m, E may be varied from —2500 to +2500 $V.m^{-1}$.

The chamber measured 250 × 227 × 202 cm, *i.e.* 11.46 m^3. The chamber is made of hard masonite plates with external thermal insulation. Ceiling and floor are lined with iron sheets, insulated from underlying material by means of polyvinyl. In the centre of the ceiling a lid-covered brass cup is suspended with insulation. This cup may be moved from outside the test chamber. In one of the walls an air-conditioning plant gives flow of ca. 800–1000 l airchanges per min. The air for the test chamber is drawn in through two layers of air filter. Below the inlet an electric evaporator is mounted. On the floor 13 covered dishes were placed for mounting the slides. The lids of these dishes can be

opened and closed from outside the test chamber. These is also a ventilator on the floor immediately under the cup in the ceiling. (Fig. 2).

The pollen concentration of the air is measured by the gravimetrical method. Pollen is collected on a slide, covered by a thin film of petrolatum, to which the pollen grains adhere. The number of pollen per cm^2 slide are counted microscopically using a magnification of 10 × 7, yielded a diameter of the visual field of 1.4 mm. The cover glass measures 18 × 18 mm. By counting 4 tracks, an area of 1.0 cm^2 is surveyed. More than 2 cm^2 per slide is counted and the average calculated.

Time is an important factor in the value of this method. By using an "adequate period of time", a summation is obtained of the amount of pollen grain found in air columns above the slide. By using fractions of the time needed for sedimentation of all the pollen grains, a corresponding fraction of total amounts of pollen will be found on the slide. Provided the total amount of pollen is known, as well as the amount falling during a certain period, the amount of pollen still suspended in the air can be calculated. This way of evaluating the pollen concentration requires that, while the measurements are made, no new pollen enters the air column, and that the air current does not carry any pollen away. It is also necessary that no electric or thermal conditions exist to prevent the pollen from falling smoothly towards the slide.

For these experiments the gravimetrical method is preferred to other methods, as it does not necessitate air currents in the test chamber, by which temperature, humidity and conductivity of the air might be changed. Furthermore the gravimetrical method offers the advantage in this experiment, that pollen may be collected in various places in the test chamber. The conditions for the employment of the method are met, as only very few air currents exist in the room, and new pollen is not added during the experiment.

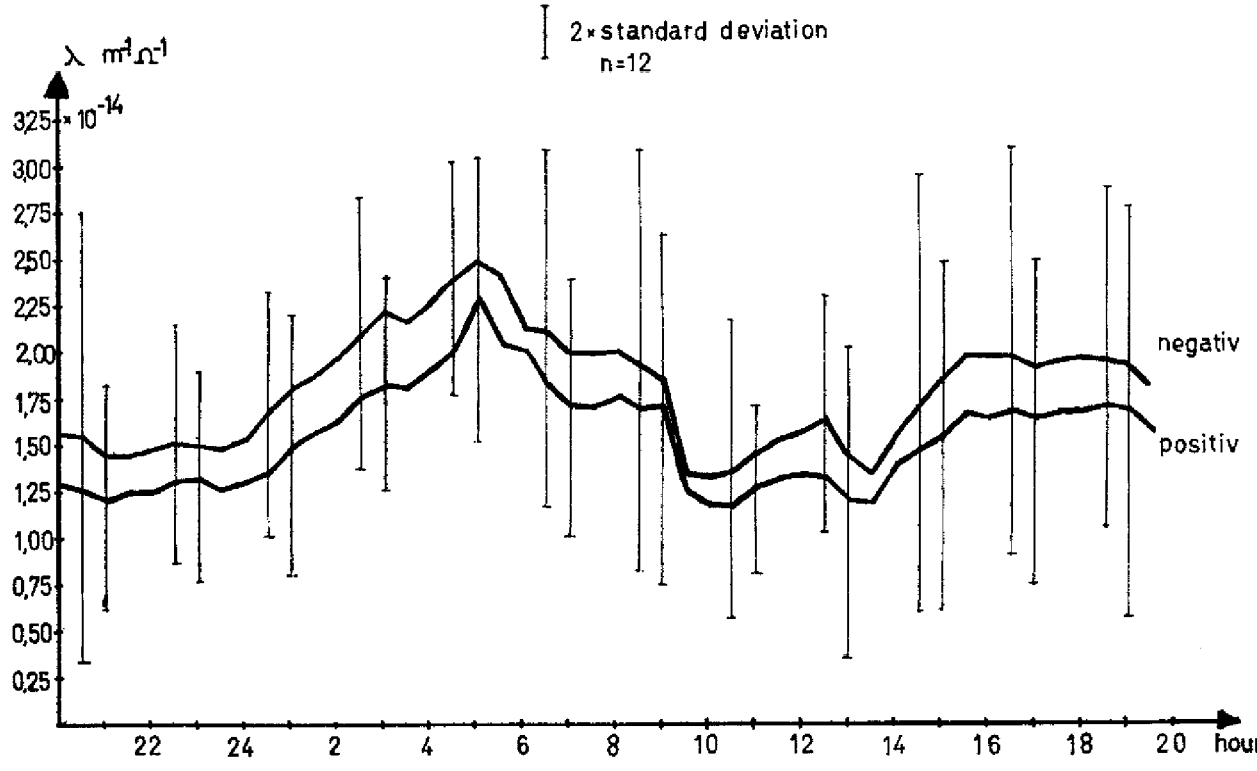
The specific charge of pollen has been measured by the following method:

On a small foil dish pollen is strewn from an earthed metal plate. The foil dish is insulated and shunted to an electrometer on which the direction and magnitude of the deflection is recorded. The entire arrangement is shielded against electric noise. The pollen on the foil dish is weighed to an accuracy of 0.1 mg, after which the specific charge/mg pollen grain is calculated. In order to obtain a true value of the specific charge the figure has to be further multiplied by the capacity of the collecting system.

RESULTS

In order to examine the eventual correlation between rate of fall of pollen grain and the climatic conditions, it is necessary partly to be able to vary these factors and partly to keep them reasonably constant during a period sufficiently long to permit measurement of the sedimentation of the pollen grains.

Fig. 3.
The variation in the conductivity, measured continually in the test chamber for 4 days, including range of results.



Temperature as well as humidity and electric field strength can be regulated and measured directly. On the other hand, the electric conductivity cannot be determined immediately.

In order to obtain a general knowledge of this condition, the conductivity was recorded for a period of 4 days, during which the remaining experimental conditions in the test chamber were as follows: temperature 22.4° C ± 0.9° C, relative humidity 60 per cent ± 3 per cent, barometric pressure 755 mmHg ± 1 mmHg, and electric field strength 0 $V \cdot m^{-1}$. In addition, the days were characterized by stable fair-weather conditions.

The result of the registration is shown in Fig. 3, which discloses a daily variation with a maximum in the early morning hours and a plateau of low value in the afternoon and the evening. The values and variations found correspond to what is stated in the literature to be normal fair-weather conditions (14). A preliminary series of experiments was performed to demonstrate the variation around the desired value of the climatic parameters, and to evaluate the accuracy of the pollen measurements.

First an attempt was made to establish a standard climate, in which we tried to maintain the following parametrical values: temperature 20° C, relative humidity 66 per cent, electric field strength 0 $V \cdot m^{-1}$ and low constant electric conductivity, *i.e.* $< 1 \cdot 10^{-14}\ \Omega^{-1} \cdot m^{-1}$.

As mentioned above the first three parameters may be controlled, while the value of the last parameter was obtained by performing the experiments at a time when the conductivity was supposed to lie around the desired value.

The experimental procedure is as follows: after careful cleaning of the test chamber, partly mechanically and partly by heavy ventilation through the air filter, a varying number of mg pinus montana pollen is placed in the metal cup under the ceiling. Slides are mounted in the 13 covered dishes shown in Fig. 2. The temperature and relative humidity are adjusted by means of the air-conditioner. The conductivity is measured in the chamber until a constant value at the desired level is ob-

tained, the ceiling and floor are earthed. When the desired values are obtained, any external influence on the test chamber is stopped for 2–5 minutes. The pollen is emptied from the cup into the air simultaneously with 15 seconds ventilation which mixes the pollen with the air of the room. After waiting for another ten seconds, to prevent pollen collection during heavy turbulence the lids covering the slides are opened, and kept open for 20 minutes. After closing them relative humidity, temperature and conductivity are re-measured.

TABLE 1

Mean Values of Climatic Observations with Calculated Standard Deviation.

	Temperatur	Relativ Humidity	Electric field	Conductivity	
				Positiv	Negativ
	°C	%	volt/cm	10^{-14} m^{-1} Ω^{-1}	
Wanted	20.0	66	0	<1.00	<1.00
		A			
Obser.	20.02	66.1	0	0.51	0.54
s.d. n = 14	0.28	1.62	0	0.34	0.39
		B			
Obser	20.17	67.6	0	0.54	0.58
s.d. n = 12	0.27	1.11	0	0.24	0.26

The climatic factors have been varying—the mean values and standard deviations from the experiment are given in Table 1. The temperature has varied ± 0.5° C from the selected temperature. The relative humidity has varied ± 3.1 per cent from the selected value. In both cases it is a matter of normal distribtution. The conductivity disclosed greater variations with a mean lambda pos. of $0.51 \cdot 10^{-14}$ m^{-1} Ω^{-1}, the corresponding value for lambda neg. is $0.54 \cdot 10^{-14}$ m^{-1} Ω^{-1}. As the test chamber must be regarded as a Faraday's cage, and as ceiling as well as floor are earthed the field strength is 0 volt/m.

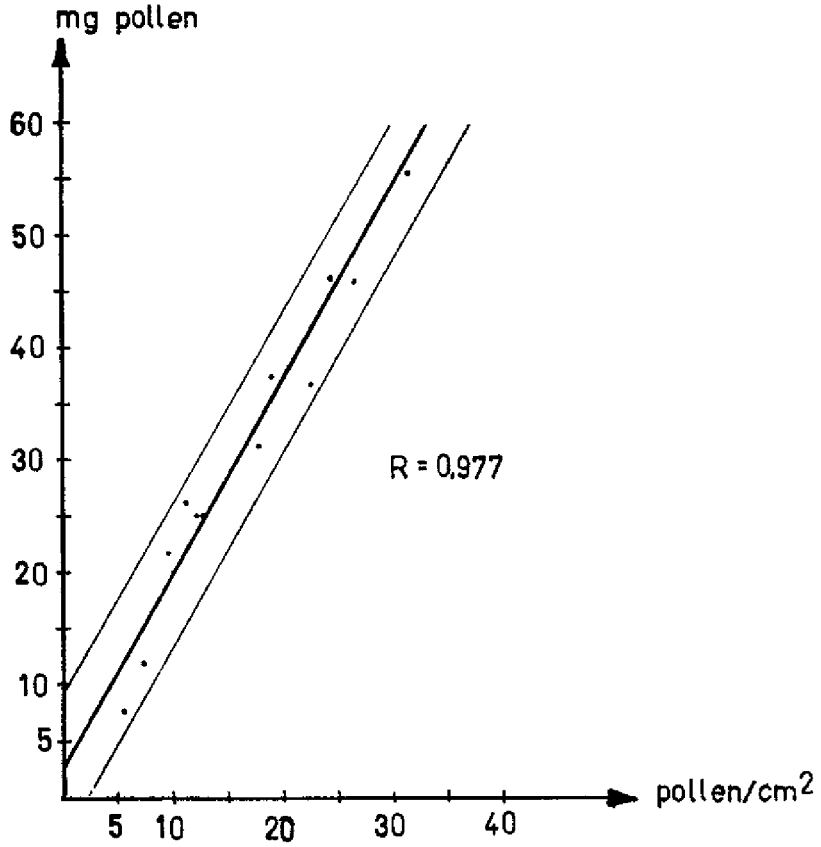


Fig. 4.
The correlation between the number of mg. pinus montana pollen mixed in the test chamber and counted number of pollen/cm² on the floor, as well as the 95 per cent range of the results.

Calculations of the results of the pollen measurements from 12 experiments show a correlation coefficient of 0.97 between the number of mg pollen placed in the room and pollen grains/cm² on the floor.

The equation for the line best expressing the regression between the experimental results is $Y = 1.65\,X + 3.6$. The standard deviation around this line is 3.01. The intersection

of the ordinate does not differ significantly from 0 (see Fig. 4).

From the slope of the regression line it is calculated that 1 mg pollen gives 0.606 grains per cm^2 floor, or with a floorage of 56700 cm^2, that 1 mg pollen correspond to 34400 grains per mg.

The pollen used—*pinus montana*—have in a Calberlas' solution a diameter of ca. 50 $\mu = 5 \times 10^{-6}$m and a density of 450 kg/m^3. If the diameter is called d, and the density p, the number of grains per kg may be written

$$N = \frac{6}{\pi \cdot d^3 \cdot p}$$

when using figures $N = 3.39\ 10^{10}$, which gives 33900 grains per mg. This figure differs only about 1.5 per cent from the experimental one.

With regard to the pollen distribution on the slides placed on the floor, an observed mean value is found of 7.84 per cent of the total amount of pollen/cm^2 slide, against an expected value of 7.69 per cent. The standard deviation is 2.43 per cent, a rather high value. At the examination of each slide with a mean distribution, none of the slides have more than twice the standard deviation from the observed or expected mean value. Thus in a series of experiments pollen is evenly distributed on the floor.

On the basis of the above results it seems reasonable to conclude that the experimental arrangement illustrated can be used with a sufficient degree of accuracy.

In a new series of experiments the velocity of fall and the shape of curve of this velocity is determined experimentally. With the standard climate described above as a basis, the slides on the floor are exposed to falling pollen for varying periods.

Table 1 and Fig. 5 show the results of the experiment. An "S"-shaped curve is found with a maximum collection after 70 seconds. The values obtained at 70 secs. corresponds com-

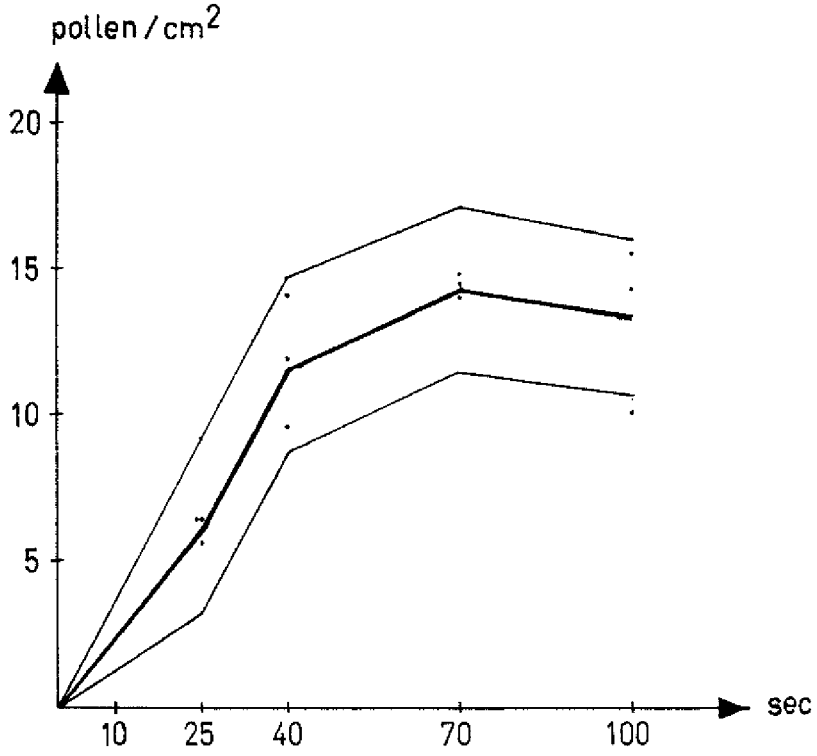


Fig. 5.

The correlation between counted pinus montana pollen/cm² and time of exposure of the slides after the mixing of 27 mg pinus montana pollen in the test chamber.

pletely to the value expected from the results in Fig. 4. In both experiments, as in all the remaining experiments, identical amounts of pinus montana pollen are used.

Partly by using the curve section from 25 to 40 secs. (see Fig. 5) as a tangent for the S-shaped curve, and partly by assuming that the mean length of fall of the pollen equals half the height of the chamber, a velocity of fall is found of 2.8 cm/sec, ranging from 2.3 to 3.6 cm/second, ($\pm$ 2 $\times$ SD, corresponding to 95 per cent range).

In a final series of experiment it was determined whether the variations in the climatic parameters could reduce the

number of pinus montana pollen/cm², collected in 70 seconds in the previously described experimental arrangement.

The examined combinations of climatic parameters and the collected number of pollen/cm² are seen in Fig. 6. As an identical amount of pollen is used as in the preceding experiments, and the way of fall is identical with that in Fig. 5, the average number of pinus montana pollen/cm² as well as the range of this value from the above experiments may be used in this experiment too as reference range.

The combination of high relative humidity and high conductivity is not included, as this combination does not occur in nature.

The high humidity with plenty of water drops in the air affects the conditions for balance of small atmospheric ions, so that the number of these fall to very low values, implying a decrease in the conductivity of the air.

It is seen from Fig. 6 that none of the combinations of climatic factors examined significantly reduces the number of a 70 seconds collection of pollen/cm².

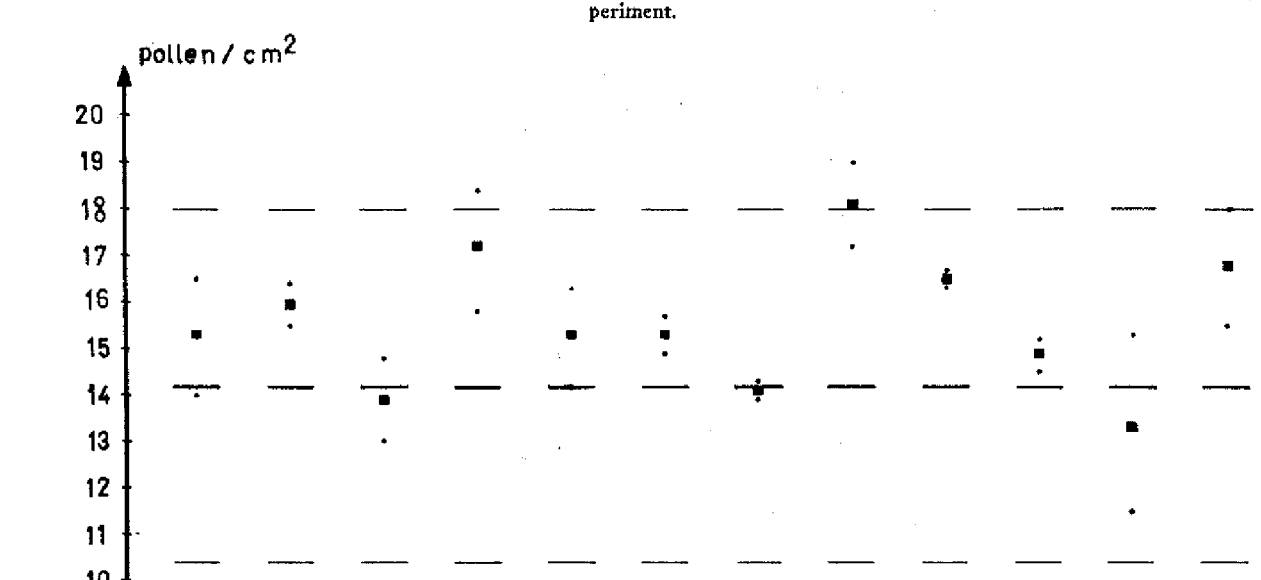
In order to find the specific charge of pinus montana pollen, which may then be compared with that of other species of pol-

TABLE 2

The Specific Charge of some Species of Pollen During Varying Experimental Conditions. For further Explanation see Text.

A	n	mV	mg	mV/mg	s.d.
Phleum Pratense	5	—23.66	9.1	—2.61	2.19
Pinus Montana	5	—38.96	6.9	—5.79	5.22
B					
Betula Pendula	3	—16.61	5.8	—2.86	
Pinus Montana	3	+ 7.50	2.0	+3.74	
Phleum Prathense	3	+17.56	6.7	+2.63	
Cynosurus Chris.	3	+14.44	14.9	+0.97	
Chreysantemum	3	— 9.76	5.7	—1.71	
Solidago Virga	3	—13.94	3.7	—3.77	

Observed number of pinus montana pollen/cm² floor 70 seconds after mixing of 27 mg pollen in the test chamber. Expected value and 95 per cent range according to results in Fig. 4. Statement of the combination of the climatic factor in each individual experiment.



len, a series of experiments was made using the measuring technique previously described.

For this experiment some of the pollen was collected natuarlly and stored in a large glass bottle and some was bought in slender glass tubes from an allergological laboratory.

The comparison with the pollen collected naturally is illustrated in Table 2 A. In these experiments an attempt has been made to analyse pollen in contact only with identical species, *i.e.* samples drawn from the centre of the spacious glass bottles. In the subsequent experiment, given in Table 2 B, pollen was analysed which was probably in contact with many things.

The most characteristic feature about these experiments is the wide range of results and the varying polarity of pollen kept in different ways.

DISCUSSION

This series of experiment must be seen against the background of the contradictory literature dealing with the influence of small atmospheric ions on respiratory allergics. If the electric climate does not affect the patients directly, which may be supposed from the literature (1–29–44), the effect of small ions, demonstrated by some workers (2–18) may be explained by an effect of the electric climate on the allergens. This effect may be the result, partly of a change in the concentration in the air of the allergen responsible for the disease, partly of a change in the electric properties of the allergen, and through this a change in the allergen properties. The first of these theoretical possibilities has been tested in the present paper.

The working hypothesis is inspired by Milligan's experiments with the influence of electric fields on oil globules. A negative field may keep a small particle with positive specific charge suspended. Small atmospheric ions around this kind of particle would either be attracted or repulsed by the charge of the particle, by which the specific charge is affected, influencing the ability to be suspended in the electric field.

It is emphasized that the particle used in the experiment is an allergen occurring in nature. Furthermore the electric parameters used are varied within ranges normal to the climate of the country.

The selected allergen is pinus montana pollen, one of the most common species of pollen. It is not a very powerful allergen, but what makes it suitable for this series of experiment is its shape, size and density. Pinus montana pollen is winged, which makes it slower falling than pollen of a more spheroid geometry, and its size and density condition its suitability for examinations of changes in the velocity of fall.

With regard to climatic parameters the relative humidity is partly kept constant at a value around 66 per cent, partly at low value and partly at almost 100 per cent saturation. Throughout all the experiments the temperature remained 20° C.

As demonstrated in Fig. 3, the conductivity shows daily fluctuation between a value for λ of ca. $0.25 \cdot 10^{-14}$ m^{-1} Ω^{-1} as the lowest and ca. $3.0 \cdot 10^{-14}$ m^{-1} Ω^{-1} as the highest value. In the experiments it was chosen to examine at low values, where $\lambda < 1.0 \cdot 10^{-14}$ m^{-1} Ω^{-1} and at high values $\lambda > 2.0 \cdot 10^{-14}$ m^{-1} Ω^{-1}.

By ion generators considerably higher value may be acquired for λ, but these artificial changes in the electric climate were not examined.

The direction and size of the electric field varied from +25 V/cm over 0 V/cm, to —25 V/cm positively from above and downwards. The mean field corresponds to the magnitude in normal fair-weather, the large fields are small to medium compared with the fields occurring during thunderstorms. The direction of the field varies remarkably during the passage of a thunderstorm (5).

The final parameter in the evaluation of the sedimentational ability of pollen under varying electric conditions is the specific charge of pollen. We have failed to find observations on this charge of pollen in the literature, whereas some studies exist on the charge of fungus spores.

In 1909 A. H. *Reginal Buller* (3) found that some spores

had a specific charge, and most of them positive. Scarcely 50 years later *H. P. Gregory* (1) confirmed this finding, demonstrating that spores of relatively close affinity may have different polarity, and that spores of the same fungus may have numerically larger or smaller specific charge.

Despite a slightly primitive technique, the results of the author's own experiments show that a population of pollen grains has a mean specific charge. To a large degree this mean specific charge depends on the materials with which the pollen has been in contact. This is the only conclusion of the experiments in Table 2.

The charge possessed by the individual pollen grains in its natural state suspended in the air, is probably produced by fusion of small or medium atmospheric ions. The specific charge of the individual pollen grain has not yet been measured, and nothing is known of spontaneous or induced variations of this charge. If this information were available the influence on the electric field by suspending pollen might be calculated. As this is not the case, however, it is necessary—in order to elucidate these conditions—to investigate the sedimenational ability in constant fields of a pollen population, which is likely to have a wide range round a mean charge.

In order to investigate the validity of the measuring method used some preliminary experiments were performed, where the velocity of fall of the pollen as well as the number of pollen grains per mg were determined. These figures are compared with the information in the literature.

In these experiments the velocity of fall is found to be 2.8 cm/sec with a range of 2.3 to 3.6 cm/sec. By a different technique *Durham* (8) found a velocity of fall for pinus pollen of 2.49 cm/sec. By comparison *Knoll* (18) found a velocity of 2.5 cm/sec.

According to Stoke's law the theoretical velocity of fall is 3.5 cm/sec.

$$v = \frac{2\,r^2 \cdot P \cdot G}{9\,\beta}$$

(P = the density of pollen, β = viscosity of the air, G = acceleration due to gravity, r = radius of pollen).

Variations between the velocities of fall found by experiments and the theoretical velocity are due to the fact that pinus pollen are not spherical, but float somewhat better due to their shape.

From Fig. 4 the number of pollen grains/mg was found to be 34.400 against a calculated number of 33.900 grains/mg, a deviation of ca. 1.5 per cent.

From these two comparisons, as well as from the range of the experimental results in Fig. 4 and Table 1, the collecting technique and sedimentation analysis are found to be sufficiently accurate to be employed in experiments on the sedimentation of pollen in varying climatic combinations.

The investigation aims at demonstrating a reduced velocity of fall, which means higher pollen concentration in the inspired air and hence clinical symptoms in allergic patients. However, an increased velocity of fall will not be demonstrated by this experimental procedure.

As seen from Fig. 6 the velocity of fall in pinus montana pollen is not reduced in the combinations of climatic parameters examined.

This result indicates that the specific charge of pollen is so small compared with the size of the fields used in the experiments that gravity is the dominant factor in the fall of the pollen in non-tubulent air. No change can be measured in the degree of sedimentation, caused by small atmospheric ions, just as in 70 seconds the relative humidity cannot change the density of pollen so much that changes in the sedimentation degree may be measured.

SUMMARY

In order to discover whether the electric climate and relativ humidity of the air may affect the concentrations of airborne allergens, the velocity of fall for pinus montana pollen is examined under a varying but naturally occurring electric climate, together with changes in the relative humidity of the air.

No reduced velocity of fall, and thus no increased air concentration can be demonstrated of pinus montana pollen in the climatic combinations examined. As pollen possesses a—though highly variable—specific charge, very large fields might affect the velocity of fall, but such fields are only found momentarily in nature, and are of no practical importance to the allergic's daily exposure to allergens.

The specific charge of pollen as well as investigation into the reaction of allergics to differently charged pollen are future areas of research within climatologic allergology.

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