

THE EFFICIENCY OF MECHANICAL FILTERS AND AIR CONDITIONERS IN THE REMOVAL OF RAGWEED POLLEN AND FUNGUS SPORES

ROLAND ROOKS, PH.D., RICHARD M. CAPLAN, M.D., AND
RICHARD S. SHAPIRO, M.S., IOWA CITY, IOWA

SCHEPPEGRELL,¹ in 1924, described an air-washing apparatus for the removal of air-borne pollen. In 1925 Leopold and Leopold² studied the effect of air filtration under controlled conditions of environment, temperature, and humidity on bronchial asthma, allergic coryza, and hay fever. Cohen³ noted in 1926 that, when patients with hay fever were placed in a pollen-free room, some relief was given in a few minutes and that after six to eight hours there was complete relief.

Peshkin and Beck⁴ pointed out in 1930 and Rappaport, Nelson, and Welker,⁵ in 1932, that air filtration that removes most of the pollen will relieve symptoms of hay fever and that this method is particularly valuable in those cases not benefited by the usual methods of treatment. Beck,⁶ also in 1932, reported that in almost 80 per cent of properly selected cases patients can find adequate relief through the use of pollen-free air produced by a filter of tested high efficiency. The air filter used was reported as producing 100 per cent pollen-free air. However, details as to tests conducted are lacking. Gay,⁷ in 1933, studied the effect of air filtration and cooling in the treatment of hay fever and pollen asthma. The patients who had ragweed hay fever were free from symptoms in one hour. The patients with pollen asthma had moderate wheezing for the first fifteen hours after admission to the air-conditioned atmosphere. The symptoms were quite mild, however, as compared with the discomfort previous to admission to the air-conditioned atmosphere. The relief given was attributed primarily to air filtration.

Nelson, Rappaport, and Welker,⁸ in 1933, reported experiments conducted on two special air conditioning units. Slides were exposed in the protected ward and outdoors. A comparison of these slide counts indicated an efficiency of 98.2 per cent in terms of air-borne pollen. The conclusions were drawn that no pollen filter on the market at that time could claim 100 per cent efficiency for pollen, but that filters that remove all but traces of pollen will relieve symptoms of hay fever. Cooled filtered air without dehumidification did not give as prompt or as great relief from symptoms of hay fever as uncooled filtered air.

Kahn and Grothaus,⁹ in 1933, reported the successful use of a homemade unit that reduced the air-borne pollen by about 95 to 98 per cent. Vaughan

From the Department of Hygiene and Preventive Medicine, College of Medicine, State University of Iowa.

Received for publication March 28, 1955.

and Cooley¹⁰ used a standard air conditioning unit as a means of removing pollen and spores. Petrolatum-coated slides were exposed in the air-conditioned room, in a control room without air conditioning, and on an outdoor window sill. They found that appreciable numbers of both air-borne pollen and spores were removed by the water of condensation from the air conditioner.

Criep and Green,¹¹ in 1935, apparently were the first to study the use of an electrostatic air cleaner as an aid in the treatment of hay fever and bronchial asthma. The efficiency of this method in a series of experiments was compared with that of a glass wool mechanical filter. Pollen was introduced into the unit under test, and exposed slides were used to determine the efficiency. The average efficiency of the mechanical filter was found to be 96.5 per cent, while that of the electrostatic air cleaner was reported as 100 per cent efficient in removing pollen from the air. Barnes and Rooks,¹² in 1946, by the use of two window type pollen filtering units, were able to set up and maintain through the summer an entire home comparatively free of pollen.

Friedlaender and Friedlaender,¹³ in 1954, studied the effectiveness of a portable electrostatic precipitator in the elimination of environmental allergens and in the control of allergic symptoms. A series of pollen experiments utilizing exposed petrolatum-coated slides to determine efficiency indicated the value of these units in clearing the air of experimentally introduced and naturally occurring pollen. These units, when placed in bedrooms and hospital rooms of selected patients suffering from ragweed hay fever and asthma, produced prompt and sustained relief in most patients. The electrostatic air cleaner also was found very effective in the treatment of certain asthmatic patients allergic to household dusts.

STATEMENT OF PROBLEM

This report is concerned with a study of the efficiency of mechanical filters and air conditioners in the removal of air-borne ragweed pollen and certain fungus spores as determined by a volumetric sampler.

It is apparent that in the use of a good mechanical filter a sufficient amount of air-borne ragweed pollen can be removed so that air filtration will give relief in a short time to patients suffering from ragweed hay fever, while patients having asthma as a result of a ragweed sensitivity respond much more slowly to filtered air treatment. However, the figures (in per cent) reported representing the efficiency of the unit under test should be questioned.

In all the studies reviewed, petrolatum-coated slides were exposed for from a few minutes up to several days to measure efficiency. The effectiveness of the unit under study was determined for naturally occurring pollen or, in some instances, by experimentally introduced pollen. Slide counts indoors were compared in some studies with slide counts outdoors, but these slide counts are not comparable due to marked differences in sampling conditions. The pollen catch in terms of an exposed slide would depend primarily upon such factors as the settling rate of pollen, the effect produced by air turbulence, and air velocity.

In other instances the slide was exposed directly in the air stream from the test unit, in which case only a fraction of the pollen liberated from or passing through the instrument would be recovered.

The efficiency of air filtration methods, as measured by a suitable volumetric sampler during the actual ragweed pollen season in a high incidence area, should more nearly approximate the actual dosage of pollen to which the individual is exposed when indoors. Because of the importance of hormodendrum and alternaria spores in the production of allergic symptoms, it was decided to include these in the study.

PROCEDURE

The sampler described by Stenborg¹⁴ was selected for this problem because of familiarity with this sampler, its simplicity in operation, and the permanency of records. In a previous study¹⁵ this sampler was reported as having a 76 per cent sampling efficiency in terms of commercially collected ragweed pollen (*Ambrosia trifida*). The sampling efficiency of this instrument for hormodendrum and alternaria spores is not known, but it must be less than for pollen because of their smaller size and because sampling is by impingement to a moving strip of adhesive tape.* All samples, then, in terms of efficiency, represent the minimum exposure of the individual both to ragweed pollen and to hormodendrum and alternaria spores. However, all readings were taken during the height of the ragweed season during the months of August and September and, inasmuch as it has been reported¹⁵ that 56 per cent of the pollen collected over a twenty-four-hour period was collected from 10:00 A.M. to 1:00 P.M., all air samples were taken during this same time interval.

The rate of air flow used in all air samples was 0.5 cubic feet per minute, and 0.5 cubic yard of air was sampled in each instance. This sampling rate approximates the volume of air inspired by an adult during normal activity.

Air samples were taken at the same height indoors and outdoors, in each instance at a height of four feet above the floor or ground. The sampler was centrally located in the test area indoors, but was kept outside any direct air stream from the test unit. Outdoor air samples were taken at the same side of the home or building representing the air intake into the unit and immediately followed the air sample taken indoors.

Four different locations were used; two were protected by commercial window type filtering units supplying only filtered air, manufactured by the same company, and two by standard air conditioning units manufactured by different companies. A total of approximately 100 air samples were taken at these four widely separated locations, and all counting and identification was carried out under high-power magnification.

DISCUSSION AND RESULTS

An inspection of each unit was carried out prior to its operation to be certain that it was installed in such a manner as to minimize air leakage, that the

*Scotch cellophane tape, $\frac{3}{4}$ inch by 300 inches (Minnesota Mining & Mfg. Co., Saint Paul 6, Minnesota).

unit contained a new, clean filter which was properly fitted in the unit, and that there was no unnecessary vibration of the unit which might affect the pollen retention of the filter.

Location No. 1.—Filtered air was supplied to a single room, the bedroom, by installation of a commercial unit* in one of the windows of this room. No special precautions were taken from the standpoint of pollen or spores except that the other windows in this room were kept tightly closed. The door from this room on the second floor was open many times to the rest of the home during operation of the unit.

The patient, a young boy, had a ragweed sensitivity for a number of years, with symptoms of both hay fever and asthma. He was having a great deal of difficulty, especially at night, even though undergoing treatment. His sleep remained undisturbed generally after installation of the unit, although asthmatic symptoms at night were not entirely eliminated.

The mean ragweed dosage, as determined by the volumetric sampler outdoors at this location, was 218 per cubic yard of air. This was reduced by air filtration to a mean dosage indoors of 7 per cubic yard of air, or a reduction of 97 per cent. The maximum dosage of ragweed pollen on any one day was 20 per cubic yard of air, which was reached shortly after installation of the unit. After a few days' operation of the filter, no pollen was detected.

This unit, however, showed only a 53 per cent reduction of *hormodendrum* spores, with a mean dosage of these spores outdoors of 128 per cubic yard of air. The *alternaria* count was rather low in this area, 74 per cubic yard of air outdoors, with a reduction of 92 per cent indoors.

Location No. 2.—A small apartment was supplied filtered air by a unit and filter larger than that installed in location No. 1, but manufactured by the same company. Precautions were taken at this location prior to the ragweed season to reduce the pollen count as low as possible indoors by a thorough housecleaning to remove accumulated pollen from previous seasons and by the use of storm windows.

A nurse experienced seasonal ragweed hay fever. She was given a great deal of relief by air filtration shortly after coming in from outdoors and also upon awaking in the morning when ordinarily her symptoms would be most severe.

The mean dosage of ragweed pollen outdoors at this location was 195 per cubic yard of air, while indoors it was 7 per cubic yard of air. The maximum dosage at any time indoors was 16 per cubic yard of air, which was reached on just one day. The over-all reduction indoors during the height of the ragweed pollen season amounted to 97 per cent.

*Filter, described as an "air mat" filter consisting of six-ply mat material produced from spruce pulp and treated with a colorless, odorless oil, matting encased in a cardboard frame, two-inch convolutions with separators between to increase the surface area, filter size 17 by 9 by 2 inches.

The mean dosage of hormodendrum spores was 820 per cubic yard of air, with a reduction of 91 per cent by air filtration. The mean dosage of alternaria spores was 149 per cubic yard of air, with a reduction of 88 per cent by air filtration.

Additional readings taken in another apartment of the same size, but on the second floor of this building with no air filtration and no precautions taken from the standpoint of windows and doors, indicated a pollen and spore count approximately one-half that of the outdoor count.

Location No. 3.—A standard air conditioning unit* was installed in a five-room one-story home. Windows were kept tightly closed, but no additional precautions were taken except that prior to the pollen season there was a thorough housecleaning. This unit was operated during the first part of the summer on recirculation of indoor air, but in the latter portion on circulation of outdoor air through the unit. It was hoped that the reduction of ragweed pollen and spores by these two operating characteristics of air conditioning units could be determined under the conditions just described. In recirculation of indoor air there should be a higher natural leakage, as there is no positive pressure within the home. In circulation of outdoor air, although there may be less natural leakage because of some positive pressure, the efficiency would depend to a greater extent on the filter used by the unit and on the degree to which pollen and spores might be removed by the condensation of moisture on the cooling coils.

The owner of this residence has experienced hay fever due to a ragweed sensitivity during the past fifteen years and has had asthmatic symptoms, especially at night, during the past five years. Symptoms of hay fever subsided shortly after returning home in the evening and, although some asthmatic symptoms did occur at night, they were much milder compared with previous seasons.

With a mean dosage of ragweed pollen outdoors of 70 per cubic yard of air, by recirculation of indoor air this was decreased by 98 per cent. At no time did the ragweed pollen count indoors exceed 4 per cubic yard of air. A comparison of indoor and outdoor spore counts showed a reduction of 86 per cent for alternaria and 89 per cent for hormodendrum.

In circulation of outdoor air through this unit there was a reduction of 81 per cent for ragweed, 60 per cent for alternaria, and 77 per cent for hormodendrum. The ragweed pollen dosage indoors reached a maximum of 24 per cubic yard of air, which was the one night that asthmatic symptoms occurred of sufficient severity to interfere with sleep. The mean dosage of ragweed pollen indoors was 18 per cubic yard of air.

A comparison of the figures obtained using recirculation of indoor air with circulation of outside air indicates how much less effective these units are in the control of both ragweed pollen and spores by operation on "fresh air."

*Filter, a permanent filter constructed of coarse mesh screening into which is sprayed a special filter oil supplied with the unit. Filter size 20 by 9 by $\frac{1}{2}$ inches.

Location No. 4.—A small room for gastroscopy in the hospital was air conditioned for comfort of personnel. No precautions as to pollen or spores were taken in this location. Again, in tests on this unit,* the air in this room was first recirculated followed by additional readings on circulation of outside air through the unit.

The mean ragweed pollen dosage indoors in recirculation of indoor air was 7 per cubic yard of air, with a total reduction of 94 per cent. These readings were taken during an outdoor ragweed pollen count of 116 per cubic yard of air. The mean hormodendrum count per cubic yard of air outdoors was 1,088; that of alternaria was 300, and the reduction by recirculation was 94 per cent for hormodendrum and 93 per cent for alternaria.

Although the outdoor count for both ragweed and spores was much lower during circulation of outdoor air, the reduction again was much less—86 per cent for ragweed pollen, 78 per cent for alternaria and 80 per cent for hormodendrum spores.

SUMMARY

A total of approximately 100 air samples was taken by a volumetric sampler at four widely separated locations to determine the efficiency of certain mechanical filters and air conditioners in the removal of ragweed pollen and hormodendrum and alternaria spores. All these air samples were taken during the height of the ragweed season and, because of the marked diurnal variation of ragweed pollen, all readings were taken between 11:00 A.M. and 1:00 P.M.

These volumetric readings indicate that mechanical filters are available which, by filtration, will reduce the incidence of ragweed pollen indoors to a mean dosage of 7 per cubic yard of air. The outdoor count was approximately 200 per cubic yard of air at the two locations studied. Although these filters are remarkably effective in the removal of air-borne ragweed pollen, they are much less so in the removal of air-borne hormodendrum and alternaria spores.

Similar air samples show that air conditioning units, when operated on recirculation of indoor air, will markedly lower the incidence of ragweed pollen indoors, comparing favorably in the results produced with mechanical filters. However, when the two units tested were operated on circulation of outside air, they were found to be much less effective in the removal of both ragweed pollen and fungus spores.

Complete dependence cannot be placed on either mechanical filters or air conditioning units for the control of air-borne hormodendrum and alternaria spores.

REFERENCES

1. Scheppegegrell, W.: Comfort for Hay Fever Subjects at Home, *M. J. & Record* **120**: 4, 1924.
2. Leopold, Simon S., and Leopold, Charles: Bronchial Asthma and Allied Allergic Disorders, Preliminary Report of a Study Under Controlled Conditions of Environment, Temperature and Humidity, *J. A. M. A.* **84**: 731, 1925.
3. Cohen, Milton B.: A Pollen Filter, Preliminary Report of the Treatment of Hay Fever in Rooms Made Pollen Free by a New Filter, *M. J. & Record* **123**: 322, 1926.

*Filter; a disposable filter described as a new type glass cloth filter, size 23 by 12 by $\frac{1}{4}$ inches.

4. Peshkin, M. M., and Beck, Isabel: A New and Simplified Air Filter in the Treatment of Hay Fever and Pollen Asthma, *J. Lab. & Clin. Med.* **15**: 643, 1930.
5. Rappaport, B. Z., Nelson, Tell, and Welker, W. H.: Effect of Air-Filtration in Hay Fever and Pollen Asthma, *J. A. M. A.* **98**: 1861, 1932.
6. Beck, Isabel: The Treatment of Hay Fever and Pollen Asthma With Pollen Free Air, *M. J. & Record* **136**: 90, 1932.
7. Gay, Leslie N.: The Treatment of Hay Fever and Pollen Asthma by Air-Conditioned Atmospheres, *J. A. M. A.* **100**: 1382, 1933.
8. Nelson, Tell, Rappaport, B. Z., and Welker, William H.: The Effect of Air Filtration in Hay Fever and Pollen Asthma, *J. A. M. A.* **100**: 1385, 1933.
9. Kahn, I. S., and Grothaus, Emma M.: The Antigen-Free Room in the Detection and Control of Cutaneous Anergy in Pollen Bronchial Asthma, *J. ALLERGY* **5**: 45, 1933.
10. Vaughan, Warren T., and Cooley, Laurence E.: Air-Conditioning as a Means of Removing Pollen and Other Particulate Matter and of Relieving Pollinosis, *J. ALLERGY* **5**: 37, 1933.
11. Crip, Leo H., and Green, M. A.: Air Cleaning as an Aid in the Treatment of Hay Fever and Bronchial Asthma, *J. ALLERGY* **7**: 120, 1935.
12. Barnes, M. E., and Rooks, Roland: A Pollen Refuge at Home: A Case Report, *J. Iowa M. Soc.* **36**: 190, 1946.
13. Friedlaender, Sidney, and Friedlaender, Alex S.: Effectiveness of a Portable Electrostatic Precipitator in Elimination of Environmental Allergens and Control of Allergic Symptoms, *Ann. Allergy* **12**: 419, 1954.
14. Stenborg, R. L., and Hall, Lawrence B.: A Continuous Recording Particle Sampler, Mimeographed Notes, CDC Center, Technical Development Services, Public Health Services, Federal Security Agency, Atlanta 5, Georgia.
15. Smith, Ronald D., and Rooks, Roland: The Diurnal Variation of Air-Borne Ragweed Pollen as Determined by a Continuous Recording Particle Sampler and Implications of the Study, *J. ALLERGY* **25**: 36, 1954.