

Recommendations for the use of residential air-cleaning devices in the treatment of allergic respiratory diseases

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In an attempt to recommend standards for room air-cleaning devices, a committee reviewed (1) the types and performance characteristics of available domestic air-cleaning devices, (2) the available data on concentrations of allergens in the indoor air, and (3) the studies that have examined the health effects of the use of indoor air-cleaning devices. Absence of adequate data on the clinical relevance of indoor ambient allergen levels, as well as the effect of air-cleaning devices on these levels, plus a general lack of health effects by these devices in published double-blind studies precluded any firm recommendations for their use. It was clear, however, that use of room air-cleaning devices in the absence of other forms of environmental control was not reasonable. (J ALLERGY CLIN IMMUNOL 1988;82:661-9.)

In February 1987, an ad hoc committee met at the request of representatives of the Food and Drug Administration and several manufacturers to consider whether standards could be recommended for room air cleaning devices. It was the conclusion of the committee that the data presently available were inadequate to establish the utility of these devices in the prevention or treatment of allergic respiratory disease. Therefore, without a clear definition of the indications for the use of these devices for medical applications, performance standards could not be set. This conclusion was based on a review of the data regarding the performance of room air cleaning devices, independent studies that had documented their relative efficiency, knowledge regarding the prevalence of respirable particles in the indoor air of homes, and published studies of the health effects of air cleaners.

TYPES OF DOMESTIC AIR CLEANING DEVICES

It has been estimated that in 1982, Americans spent \$150 million on room air cleaning devices; the ma-

Abbreviation used

HEPA: High-efficiency particulate air (filter)

jority of this amount was spent for purchases of small tabletop units selling for \$10 to \$40.¹ At present there is no requirement that these devices undergo any testing or that there be any proof that they have a significant effect on levels of indoor allergens, particulate irritants, or gases.

Types of air cleaners

Air cleaning devices (Table I) may be broadly divided into those whose filtering is largely on a mechanical basis and those that use electrical attraction. The physical principles involved in air cleaning by the mechanical filters are (1) inertial impaction and gravitational settling, both most effective for particles $>1\text{ }\mu\text{m}$ and increasingly more effective with increasing particle size, and (2) diffusion due to Brownian movement, particularly effective for particles $<0.01\text{ }\mu\text{m}$ in diameter.¹ Both negative ion generators and electronic air cleaners impart an electrical charge to the particles, which are then attracted to a surface having the opposite charge. Neither mechanical nor electronic filters will effectively remove gases, including odors; these can be removed to some extent by adsorption to activated charcoal or certain chemical crystals.

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TABLE I. Types of domestic air cleaning devices

Mechanical
Panel
Extended surface
HEPA
Electronic
Negative ion generator
Electrostatic precipitator
Hybrid
Charged media filter
Gas and odor adsorbing
Activated charcoal
Chemical adsorbents
Air conditioning

Mechanical filters

The simplest of the mechanical filters are called panel filters. These usually consist of a woven matting of fibers of various compositions. This matting is sometimes coated with oil to increase particle retention. Panel filters are usually installed in small tabletop units with limited airflow. They have approximately 75% efficiency for particles the size of pollens, but for particles the size of tobacco smoke or many mold spores efficiency is too low to be useful.² This combination of low filter efficiency and low airflow means that the usual tabletop unit provides essentially no cleaning when assessed for its impact on the air of the entire room.^{1, 3, 4}

To provide more surface area and allow denser and hence more efficient filter construction, extended surface filters have come into use. The ultimate extension of this concept is the HEPA filter. HEPA filters were developed during World War II by the Atomic Energy Commission to remove radioactive dust from plant exhausts. To be considered a HEPA filter, it must meet very stringent standards: a minimum particle removal efficiency of 99.97% for particles of 0.3 μm diameter, with higher efficiency for both larger and smaller particles, and a maximum pressure drop (when clean) of 1 inch of water when operated at its rated airflow capacity.¹ HEPA filters are constructed of submicronic glass fibers in a matrix of 1 to 4 μm fibers. The principal advantages of HEPA filters are their unexcelled efficiency, which actually increases with use, and their lack of requirement for maintenance.⁵ Filter life in home use is >1 year, and is often reported to be 2 to 5 years.⁵

Electronic air cleaners

The simplest form of electronic air cleaning is the negative ion generator. Particles in the air are imparted with a negative charge from the unit's coronal dis-

charge. If no collecting plate is provided, particles are then attracted to any positively charged surface—including walls, furniture, and occupants of the room.¹ If a collecting plate is provided, it may diminish surface soiling somewhat, but the lack of directed airflow still presents a major drawback to its efficiency. Electrostatic precipitators can be of the one-stage or the considerably more efficient two-stage design. With the latter, ionization of particles is produced by a coronal discharge from a wire or pointed electrode. The air is then drawn through a series of oppositely charged collecting plates. Collection efficiency is a function of the area of the collecting plates, the flow rate, and the strength of the electrical field.¹ Efficiencies for pollen of nearly 100% and for tobacco smoke-sized particles of 80%² or 90%⁶ have been reported. An advantage in the use of electrostatic precipitators on central heating/cooling units is their low pressure drop, requiring no fan other than that used for normal air recirculation. The major disadvantages of electrostatic precipitators are (1) they are of lower efficiency than the HEPA filter,⁵ (2) they require frequent cleaning (decreasing in efficiency for house dust from 80% to 65% after 16 hours and to 20% after 40 hours,⁵ and for smoke from 99% to 90% after 14 days⁷), and (3) all produce some ozone, although some well-designed and maintained units are said not to generate ozone in amounts sufficient to be considered a hazard.

Hybrid filters

Combining some of the properties of both mechanical and electronic filters are the charged media filters. The charge can be applied from an external high-voltage power supply, but much more frequently a special fibrous material has been imbedded with a permanent electrostatic charge. This type of filter has been termed "electrets."¹ Presumably, it would have a requirement for maintenance similar to the electrostatic precipitator.

Gas and odor removal

Neither HEPA filters nor electrostatic precipitators remove gases or odors. Air cleaning devices are often equipped with an activated charcoal or special chemical filter designed to adsorb these gases from the air.^{8, 9} Few tests have been conducted on these filters to determine their efficiency, and no studies have been undertaken to determine their performance over long periods of time. In one short-term test of these filters for their ability to absorb formaldehyde or nitrous oxide, *New Shelter* magazine found some units capable of absorbing up to 25% of the formaldehyde that had been added to the chamber.⁹ It was estimated that the amount removed in a few hours was equal to that that would accumulate over a few weeks' time in

a closed house. In a study on the ability of a chemical filter to remove odors, a room with a strong guinea pig fecal odor was used.¹⁰ After 16 hours of device operation, the volunteers rated the odor as decreased by 30% over the control period, a statistically highly significant reduction but far from complete.

Air conditioning

Although not technically a method of air cleaning, air conditioning has repeatedly proved to be a very efficient method of reducing indoor pollen¹¹⁻¹⁴ and mold spores^{14,15} and of decreasing the number of house dust mites.¹⁶ The effectiveness of air conditioning in reducing pollen is related to the small amount of outside air drawn into the room (often 10% of the output of chilled air¹⁷). Exclusion of outdoor air and to a lesser degree reduction in indoor humidity accounts for the reduction in mold spores.¹⁵ The reduction in counts of house dust mites is due to the reduction in moisture content of the indoor air.¹⁶

STUDIES OF AIR CLEANING EFFICIENCY

Tests of the efficiency of air cleaning devices have varied, from studies of single units in individual homes to comparisons of different units in test facilities, with use of one particle source (usually cigarette smoke)^{1, 4, 18, 19} or several particle sources of varying sizes.²⁰ The most complete testing has been performed at the Illinois Institute of Technology Research Institute, where, under contract with the Association of Home Appliance Manufacturers, testing is performed separately with cigarette smoke, Arizona road dust, and paper mulberry pollen to provide a wide spectrum of particle sizes.²⁰ At this research facility, as well as at the Lawrence Berkley Laboratory,¹ the efficiency of the filtering devices is expressed in terms of "clean air delivery rate," calculated on the extent that the rate of removal of particles by the cleaning device exceeds that occurring due to natural fallout. This is a more meaningful measure than that offered by some other testing laboratories,¹⁸ because it allows calculation of the number of air changes that could be produced for any size room. Usually, the minimum number of air changes considered to have any impact on a moderate contamination problem is one per hour.⁵ This is very little when one considers that before the recent emphasis on energy conservation, several air exchanges per hour occurred in the average home because of ingress of outside air.¹⁹ It must be understood that one air exchange per hour does not result in complete cleaning of the air every hour due to the mixing that occurs unavoidably between cleaned and dirty air.²¹

A few examples of single tests may be useful to obtain an idea of what can be accomplished with indoor air cleaning devices. An electrostatic precipitator

was installed in the central heating/cooling system of a five-bedroom home.²² It provided three air exchanges per hour, with a rated efficiency of 90% and an observed efficiency ranging from 80% to 86% for different-sized particles. The filter was operated from 10 AM to 4 PM on alternate weekdays, with the other days serving as controls. Particle counts of all sizes were significantly lower when the filter was in operation. However, when one cigar was smoked at lunchtime, particle counts rose 100-fold and any observable effect of the filter was lost for an hour, with counts still being elevated 2 hours later. Similarly, on days when a cleaning person came and vacuuming was performed, counts rose up to 100-fold and remained elevated without any decline during the lunch hour, when no cleaning activity was taking place.

The effect of a HEPA filter in parallel with the heating/cooling system was studied in an energy-efficient home housing two cats.²³ Two air changes per hour were accomplished by the filtering system, compared with 0.5 changes per hour occurring through penetration of outdoor air. Continuous operation reduced the airborne load of cat allergen to 38% on the main floor and 4% in the basement.

A commercial air cleaning device fitted with a HEPA filter was compared with an electronic air cleaning device.⁵ The units were operated for alternating 4-hour periods over 4 days in a room without artificially generated dust. The HEPA unit, which produced 5½ air changes per hour, reduced the ambient particle level from nearly a million to 6000 per cubic foot in 30 minutes. The electronic air cleaner required 1 hour to reduce the level to 34,000 particles/cu ft. Furthermore, it was observed that the efficiency of the HEPA filter did not decline during the 4 days, whereas the electronic unit rapidly decreased in efficiency.

INDOOR ALLERGEN AND IRRITANT CONCENTRATIONS

The quantity of allergen in the air of the indoor environment is related to the rate of introduction of that allergen from outdoors, as in the case of pollen and some mold spores, or production within the house, as in the case of other species of mold spores and allergens derived from animals and insects. A second variable is the rate the allergen settles from the air. Depending on the size of the particle with which these antigens are associated, rate of spontaneous settling will vary greatly; generally, the amount of antigen associated with surfaces either due to direct deposition or to settling will far exceed that in the air.

Pollen allergens

Most pollen is >15 µm in diameter and settles rapidly from still air. The rate of settling for a 20 µm

particle has been calculated to be 2.4 ft/min.²¹ This rate has been confirmed in actual observations of ragweed pollen showing almost complete clearing from still air within 5 minutes.²⁴ It is because of this rapid settling indoors and isolation from outdoor sources allowed by air conditioning, when it is present, that low indoor counts are observed even in the absence of air-filtering devices. There is evidence, at least during the ragweed season, that there are ragweed allergens carried on particles and perhaps vapors far smaller than pollen grains.^{25, 26} These may arise from other ragweed plant parts, particularly the inflorescence,²⁵ or by leaching of allergens from the pollen grains after they have been released and fallen on other surfaces.²⁶ Thus far, the occurrence of these allergenic particles and aerosols has been assessed only in the outdoor air, and their importance in indoor air is not known.

Mites

The principal allergen of the house dust mite, *Dermatophagoides pteronyssinus*, is associated with fecal pellets >10 μm in diameter.²⁷ The settling rate for particles of this size is estimated to be 0.6 ft/min.²¹ As might be anticipated, particles of this size are largely airborne as a result of domestic cleaning and changing the bedclothes; 15 to 35 minutes thereafter, 96% of the suspended mite allergen has settled out of the air.²⁷ Direct sampling in the air of 16 undisturbed rooms at a rate of 17 L/min for 2 to 8 hours did not reveal detectable quantities (>0.3 ng *Der p* I) of mite antigen, nor could this mite allergen be found when overnight collection at 3.5 L/min was performed at the level of the head of a sleeping person.²⁸

Other studies have detected the presence of mite allergens in the undisturbed air of homes and apartments.²⁵ Although comparison of different types of allergens is hazardous, the quantity of mite allergen in the air (2661 pg/m³) was markedly lower than the quantity of cat allergen in houses with one to three cats (53,333 pg/m³) or the amount of guinea pig allergen in houses with one to three guinea pigs (306,500 pg/m³). Sampling data are thus consistent with a tendency for most mite allergen to settle from the air, which raises a question as to whether significant amounts are in the air except during domestic activities.

Animal allergens

As suggested by the data mentioned above,²⁵ it appears likely that allergens derived from domestic animals remain airborne to a greater extent than those from mites and pollen grains. Sampling of an apartment where cats had resided revealed that 81% of the *Fel d* I allergen (Cat 1) was associated with particles >10 μm in diameter.²⁹ After simulated domestic ac-

tivities, however, a notable quantity of allergen was present in the air associated with very small particles (<0.05 μm) that remained airborne with little reduction 2 hours later.^{23, 25}

Rat urinary proteins have been found to be associated with particles in the 5 to 10 μm range. Mouse urine proteins were found in appreciable quantities in the air of inner-city apartments.^{25, 27}

Molds

Although during the warmer months indoor mold sampling is often dominated by outdoor fungi,³⁰ the principal fungal spores of indoor origin have consistently been *Penicillium*, *Aspergillus*, and yeasts.³⁰⁻³² All of these produce small spores that might be expected to remain airborne for considerable periods. Sampling in homes in Michigan during the winter revealed isolation rates as high as 14,000 spores/m³, with 15 of 80 samples having >1000 isolates/m³.³⁰ Asthma has been provoked with inhalation of both *Penicillium* and *Aspergillus* spores in quantities that might be inhaled as a result of indoor exposure over a 24-hour period.³³

Cockroach

Unlike the house dust mite, the allergens of cockroach appear to be contained primarily in the body and shed skin rather than in the feces.³⁴ In a study of aeroallergens in 20 inner-city apartments, the quantity of cockroach allergen detected in the air was 29,450 pg/m³.²³

Summary

Allergens can be found in the indoor air. It appears that the rate of spontaneous clearing of the air by settling is higher for pollen and mite allergen, and significantly less for mammalian allergens and perhaps mold spores and cockroach. Although these allergens are to be found in the air, this should not obscure the fact that the airborne load may be very small compared with that on surfaces. For example, a spread on which cats had slept regularly was extracted and yielded 20,000 U of *Fel d* I antigen, a quantity equal to 74 times the amount that could be obtained from washing a cat.³⁵ Clearly, with quantities such as this on the surfaces that are readily dispersed by activity, the small amount of allergen available to be removed from the air may be insignificant.

Airborne irritants

In addition to allergens, the air of homes may contain a number of substances that may cause or aggravate respiratory symptoms on a nonimmunologic basis. The most important of these, if present, is tobacco

TABLE II. Effect of air cleaners on seasonal allergic disease

Study	Type of device	Allergen assessment	Blinding	Results
Cohen ³⁹ (1927)	Filter	No	No	Patients improved
Vaughan and Cooley ¹² (1933)	AC	Yes	No	1 of 2 improved
Gay ⁴⁰ (1933)	AC	No	No	Patients "relieved"
Nelson et al. ^{41,42} (1932-1933)	Filter	Yes	No	SAR improved; BA partial improvement
Trasoff and Blumstein ¹³ (1936)	AC	No	No	9 of 10 BA improved
Criep and Green ⁴³ (1936)	ESP	Yes	No	75% improved
Friedlaender and Friedlaender ²⁴ (1954)	ESP	Yes	No	75% excellent result
Scherr and Peck ⁴⁴ (1977)	HEPA	No	Yes	Strong trend toward decreased nocturnal symptoms
Kooistra et al. ⁴⁵ (1978)	HEPA	Yes	Yes	14% decrease in nocturnal symptoms

AC = air conditioning; SAR = seasonal allergic rhinitis; BA = bronchial asthma; ESP = electrostatic precipitator.

smoke. A number of studies have addressed the health of children residing in homes in which parents smoke.³⁶ Most of these studies have indicated an increase in respiratory illness and symptoms and a decrease in pulmonary function in those children whose mothers smoke, with a less significant impact from paternal smoking. Similar but much less consistent effects have been reported for children residing in homes in which gas is used for cooking.³⁷

Other indoor pollutants include formaldehyde outgassing from insulation, building materials such as plywood and particle board, and furnishings; CO, NO, and NO₂ from unvented gas heating and cooking appliances; particulates and fumes from wood and kerosene heating; and a broad spectrum of airborne chemicals arising from cleaning and personal care items (particularly those dispensed by aerosol) and adhesives, paints, and varnishes used throughout the house.³⁸

A naturally occurring indoor air pollutant of considerable concern in some areas is radon gas and its decay products. Radon gas arises from the earth's crust and building materials made from the earth's crust. It is produced by the decay of radium. The gas enters houses through basement drains and foundation cracks and accumulates in houses with low air exchange rates. The decay products become attached to fine particles in the air, by which means they can be inspired. The concern with radon exposure is not asthma but rather that it may increase the risk of lung cancer.^{1, 38}

Summary

There occur in some houses significant quantities of nonallergenic indoor air pollutants. Some, such as

cigarette smoke and adsorbed radon decay products, are particulate and are susceptible to removal by electronic or mechanical air cleaning. Others are gases and would be removed only by activated charcoal or special chemical filters. Except for tobacco smoke, the health effects are largely unassessed and the effectiveness of air filtering devices is untested.

STUDIES OF HEALTH EFFECTS OF AIR CLEANING DEVICES

The studies of health effects that have been demonstrated for home air cleaning devices can be best considered separately for pollens and other seasonal exposures (Table II) and for house dust or other perennial allergens (Table III). In each table, the data are given for the type of air cleaning device, whether a measurement was made of its effect on indoor allergen levels, whether the study was open or blinded, and the subjective or objective assessment of the results.

The unblinded studies often involved several days of residence in the treated environment and used methods that are recognized to reduce pollen levels in the air. Indeed, in those studies in which pollen testing was performed, it was regularly demonstrated that the rooms with either filtered or air-conditioned air contained lower pollen counts than rooms not fitted with these devices. Although it is reasonable to assume that this reduction in pollen counts would be reflected in fewer symptoms, the extent to which this was true cannot be ascertained without the inclusion of a control group.

Two studies were conducted in a double-blind manner. In the study by Scherr and Peck,⁴⁴ one or two air cleaners equipped with HEPA filters were placed in

TABLE III. Effect of air cleaners on perennial allergic disease allergens

Study	Device	Allergen assessment	Blinded	Results
VanLeeuwen ⁴⁶ (1924)	Filter	No	No	Patients improved
Criep and Green ⁴³ (1936)	ESP	No	No	Improvement in hospital
Friedlaender and Friedlaender ²⁴ (1954)	ESP	No	No	8 of 18 improved
Zwemer and Karibo ⁶ (1973)	LF	No	Yes	Strong trend toward improvement
Villaveces et al. ⁴⁷ (1977)	LF	No	Yes	Symptoms decreased ($p < 0.05$)
Verrall et al. ⁴⁸ (1988)	LF	No	Yes	Significantly less medication
Mitchell and Elliott ⁴⁹ (1980)	ESP	No	Yes	No difference
Bowler et al. ⁵⁰ (1985)	ESP and HEPA	No	Yes	No difference

ESP = electrostatic precipitator; LF = laminar flow.

boxcars serving as sleeping quarters for children at an asthma camp. Machines with filters or no filters were used on alternating months in each of two consecutive years. Sixty-eight campers were studied the first year and 62 were included the second year. For each year there was a "strong trend" for fewer nighttime symptoms with the active filter, but each year the results fell just short of significant ($p = 0.07$). The trend of daytime peak flow measurements was stated to be identical to the symptom scores. In a study by Kooistra et al.,⁴⁵ a central HEPA filter was used in the central air conditioning system of the homes of 20 subjects with seasonal allergic rhinitis during the ragweed season in Madison, Wis. Filters were used for 1 month and removed for another month in a random crossover design. Air conditioning alone reduced the pollen count by 94.5%; the reduction of 97.5% with the filter was not significantly different. There was no significant difference in daytime symptom scores, but the nocturnal symptom scores were reduced by 14% during the period of filter use. This was a statistically highly significant difference ($p = 0.0007$), but the authors noted that the slight reduction in symptoms appeared to be clinically undetectable when compared with the effects of air conditioning alone.

The concept of a "miasma-free" room was introduced by the pioneer Dutch allergist van Leeuwen, who created a room for which air was drawn from 50 feet above the rooftops, then cooled and filtered. Patients with asthma would remain in the room at night, pursuing their normal activities during the day.⁴⁶ Subsequent studies have concentrated on patients allergic to house dust by history and skin testing. In none of these studies was there an attempt to measure the

effect of air cleaning equipment on the aeroallergen load. In fact, there has been no demonstration of the presence of a significant burden of potentially respirable allergen-containing particles in proximity to the patients' heads while the patients were in bed. Given this lack of documentation of potential benefit, it is difficult to credit studies that do not include a suitable control. Of those with suitable controls, two could show no benefit from the use of air-cleaning devices. Mitchell and Elliott⁴⁹ used either an active or dummy electrostatic air cleaner in the bedroom of 10 children who had nocturnal wheezing, positive skin reactivity to dust or mites, and moderate to severe asthma. The devices were in operation from 3 hours before bedtime through the night for 4 weeks of active treatment and 4 weeks of control. There was no significant effect on thrice-daily measurement of peak expiratory flow rate or the patients' requirement for supplemental inhaled bronchodilator. In a single-blind, crossover study, Bowler et al.⁵⁰ compared four 2-week periods in which patients with a strong history of symptoms on exposure to house dust and positive skin tests to house dust mites were sequentially treated with a dummy air cleaner, environmental control measures for house dust mites, an electrostatic air cleaner, and an air-cleaning device fitted with an HEPA filter. Neither symptom scores nor twice-daily peak expiratory flow rate measurements differed significantly among the four treatment periods.

Different results were obtained in those studies with laminar flow of HEPA-filtered air over the head of the sleeping patient. In a study by Zwemer and Koribo,⁶ a HEPA filter laminar flow device provided a 24-inch zone of clean air extending out from the headboard of the bed. Twelve children, positive on skin testing

to house dust, provided evaluable data that revealed nonsignificant trends toward symptomatic improvement. In their 4-week crossover study with the active filter, there was a report of excellent improvement in seven subjects and good improvement in four, which only one patient reporting only fair improvement. Nights of uninterrupted sleep were 140 with the filter and 45 without. Scores for nocturnal wheezing and coughing were reduced from 480 without filter to 113 with the filter in place. No objective measurements were made. Villaveces et al.⁴⁷ used a similar principle to study a group of children with positive skin tests to house dust. However, their laminar flow unit was portable and was aimed at the patients' pillows from a distance of 3 feet. In a crossover study with 2 weeks each of active and dummy filter, they recorded a significant ($p < 0.05$) reduction in symptoms with use of the active unit; however, morning peak flows were not significantly different during the active treatment and control periods. In looking for variables that might correlate with improvement, they found that children who were sleeping on mattresses not sealed with an impervious mattress cover showed significantly greater improvement than those with covered mattresses. Further support for the usefulness of a laminar flow headboard was provided by a recent study in which 13 children with asthma considered to be predominantly or exclusively allergic to house dust mite were treated with this device. Two placebo and two active periods were used, each of which lasted for 3 weeks. The authors observed no difference in symptom scores, although the children used significantly ($p < 0.02$) less medication during the periods of active treatment.⁴⁸

Summary

Double-blind studies of air cleaning have demonstrated that the addition of a central air cleaner to an air conditioning system can produce a small, often clinically insignificant, further reduction in pollen load and symptoms compared with the major effect of the air conditioning system itself. Limited double-blind studies of free-standing room air cleaners in subjects sensitive to house dust failed to demonstrate any significant reduction in symptoms or improvement in peak flow rate. However, when cleaned air has been incorporated into a laminar flow device directing the air over the head of the sleeping subject, some decrease in symptoms or medication use has been consistently demonstrated. It should be noted, however, that in the study in which this variable was examined, improvement was particularly evident in those patients not practicing the standard environmental control measure of covering the mattress with an impermeable cover.

RECOMMENDATIONS

Different allergens are associated with particles of different sizes that vary in their tendency to remain airborne. Thus pollen grains and house dust mite feces predictably fall from still air within a few minutes, whereas allergens derived from animals and mold spores may remain airborne to a greater degree, although even they settle significantly from the air.

The amount of allergen in the air, even from domestic animals, is relatively small compared with the huge reservoir existing in the furnishings and carpets of the home.

There is no information on the threshold dose of any indoor allergen required to produce symptoms. Furthermore, the relative importance of continuous low-grade exposure as opposed to intermittent exposure to heavy concentrations of allergens is unknown. It is possible the latter is more apt to increase non-specific bronchial hyperreactivity.

The most predictable health benefit will be achieved by eliminating the source of the allergen from the home—be it a pet or a heavily mite-infested sofa—or by environmental control measures designed to decrease the exposure to mite allergen.^{51, 52} Important measures, when feasible, are to increase ventilation with outdoor air and, where appropriate, to reduce humidity, a measure that decreases both mite^{16, 53} and mold¹⁵ growth.

The available data suggest that the role for free-standing indoor air cleaners is limited. Published reports indicate that most of the prevention of exposure to outdoor allergens during warm months can be obtained by use of air conditioning, with only marginal additional benefit from a central air cleaner. Studies of room-cleaning devices have not produced significant clinical improvement, except with the use of a laminar flow of highly cleaned air over the subject's head during sleep. Significantly, in one study, similar results appeared to be achievable by encasing the mattress in an impermeable covering. This reinforces the feeling that avoidance measures and reduction in the reservoir of allergen should be used first, and air-cleaning devices should be considered only if symptoms remain severe despite other avoidance measures and there is reason to believe that a significant load of airborne allergens is present.

If the decision is made to use an air cleaner, which type should be obtained? It is clear that the ordinary panel filter unit, often producing a scent, with very low cleaning efficiency is difficult to recommend. Because the designation of a filter as HEPA ensures a high degree of efficiency, it should be sought if a mechanical filter is to be used. Electronic air cleaners are initially somewhat less effective and can rapidly decline in efficiency unless regularly maintained.

There does not appear to be any obvious advantage to counterbalance these definite disadvantages of the electronic air cleaners when compared with HEPA filter units. In addition, units of mixed pedigree are available.

The best way to compare units is to obtain air output figures, preferably from an independent testing laboratory. With this information, rates of clean air change per hour can be calculated for the area to be serviced. For units in which electrical attraction is used in the collection process, some documentation of the rate of decline in efficiency with use will provide insight into the frequency with which maintenance procedures will be necessary.

In summary, the available data on the use of residential air cleaning devices has been reviewed. Absence of adequate data on the clinical relevance of indoor ambient allergen levels and the effect of air cleaning devices on these levels precludes any firm recommendations for their use. It is clear, however, that the use of air cleaning devices in the absence of other forms of environmental control is not sensible.

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