

THE JOURNAL OF Allergy AND Clinical Immunology

August 1994, part 2 • Volume 94 • Number 2

Air cleaners: A review

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Abstract

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Air cleaners are manufactured by many companies in the United States. Air cleaning devices vary widely in design, methods of operation, cost, and level of efficiency. No universally accepted performance standards are available to compare the capabilities of the available air cleaners. These units are classified as household appliances, not as medical devices. Clinical studies have failed to substantiate a significant impact of air cleaners on patients' symptoms. Air cleaners should be used when it is desirable to further reduce airborne contaminant concentrations that are not eliminated by other environmental control measures. Air cleaners should not be the primary means of improving indoor air quality. (J ALLERGY CLIN IMMUNOL 1994;94:413-6.)

IAQ Indoor air quality

HVAC Heating, ventilation, and air conditioning

HEPA High-efficiency particulate air

EP Electrostatic precipitator

The indoor air of residences and nonindustrial work sites may contain several mostly innocuous, airborne contaminants in extremely low concentrations. The indoor air quality (IAQ) may be compromised by one or more pollutants in concentrations that may adversely affect some occupants. These airborne pollutants consist of particulates, high and low molecular weight allergens, biologic contaminants such as molds and bacteria, volatile organic compounds, gaseous pollutants, and radon and its progeny. Diagnostic evaluation of a building by an industrial hygienist can determine the cause of IAQ problems and potential health risks by applying existing IAQ standards and toxicologic principles.¹ Environmental control strategies are formulated on the basis of the findings of the evaluation.² The first two strategies are contaminant source abatement or containment and correction of deficiencies in the existing mechanical ventilation system by increasing the air exchange rate or by introducing adequate fresh air.³ The first measure eliminates the source or reduces the production rate of an identified pollutant. The manipulations of the heating, ventilation, and air conditioning (HVAC) system diminishes the airborne contaminant concentration by dilutional effect. A third IAQ control strategy (and third in the order of effectiveness) includes use of air cleaning devices to achieve further reduction of pollutants. Air cleaning devices are used adjunctively with other environmental control measures. Air cleaners should not be the primary or only means of improving IAQ.

Air cleaning devices are either incorporated into the mechanical ventilation system or moved from room to room as portable units.^{4 5} The HVAC air cleaning device delivers cleaner air throughout the entire air handling system, ductwork, and rooms. The HVAC fan must be activated for air cleaning to occur, but the fan may only be functioning intermittently to maintain a desired temperature. Inadequate maintenance of the air cleaning device may eventually create problems for the HVAC system by increasing the system to become dirty. Such neglect may ultimately result in inadequate ventilation and biologic contaminant growth.

Low-efficiency air filters are primary used to remove larger particles from the air stream, and more efficient devices are added to the HVAC system for reduction of smaller, respirable particles. HVAC system air cleaner efficiency for particle removal can be assessed by three methods: the weight arrestance test, the atmospheric dust spot test, and the dioctylphthalate method (Military standard 282). These standard manufacturer's tests provide a rating for air cleaning performance during a test period, but a paucity of information is available on the capability of the HVAC type of air cleaners to remove particles from an occupied, indoor environment over time.

Room air cleaners are preferred when continuous, regional air cleaning is desirable. Portable units are marketed by many manufacturers, and persons who desire a healthier indoor environment often select such a cleaning device on the basis of price, personal recommendation, and advertisements. *Consumer Reports* investigators have rated 21 air cleaning devices on the basis of several factors, including clean air delivery rates determined by a chamber test method.⁶ The clean air delivery rate is the product of the unit efficiency and the air flow rate and is a measure of the number of cubic feet per minute of air the unit cleans of a specific material, such as cigarette smoke. The time required for an air cleaner to reduce the particle count in a test chamber by 90% is used to compare air cleaning units.

Portable room air cleaning devices are classified as home appliances. To qualify as medical equipment, the Food and Drug Administration requires performance standards to be established for the efficiency and safety of any equipment labeled as a medical device. Such performance standards have not been developed for air cleaners, and this essential data is unlikely to be forthcoming because of lack of an industrywide consensus and inadequate funding for meaningful research. An array of portable air cleaning devices have been tested and have demonstrated a wide range of removal rates and efficiencies in chamber tests. No air cleaning device is designed to filter or remove every type of airborne contaminant. Activated charcoal filters are included in several models for odor removal, but chamber tests concluded that room air cleaners were ineffective in gas and odor removal. Gaseous and volatile pollutants can be eliminated by industrial air cleaners at great expense.

The three types of air cleaners include the following: (1) mechanical filters, which are flat, panel filters to extended surface, pleated filters and high-efficiency particulate air (HEPA) filters; (2) electronic air cleaners, which are electrostatic precipitators or charged-media filters and ion generators; and (3) adsorbents, which are activated charcoal or aluminum and chemisorbs.⁸ Air cleaners range in cost and efficiency. Small tabletop filter models are low in efficiency and inexpensive, whereas HEPA units are costly and are used when a clean environment is necessary. The best portable air cleaners contain HEPA filters or electrostatic precipitators, but a consumer's knowledge about specific air cleaners that would meet their particular needs (depending on the size of the room and the quantity and type of air pollutant) is limited. A highly rated portable unit rather than an HVAC type air cleaner would better serve the needs of persons who would benefit by consistent reduction of airborne, respirable particles.⁹

The very efficient HEPA filter, which is made from a very thin glass fiber woven into a paperlike material, is pleated to increase its surface area and holding capacity and can remove 99.97% of particles as small as 0.3 μm . The HEPA filter, which becomes more efficient with use, has a large dust-holding capacity and is virtually maintenance-free for over 1 year. Airflow resistance increases across the filter as particles accumulate to maximum dust holding capacity at which point the efficiency of the filter begins to decline. Its higher energy costs result from requirements for a powerful fan to generate sufficient airflow through the filter to eventually clean the indoor air, and the HEPA filter replacement is expensive. The electrostatic precipitator (EP) attracts charged airborne particles to a series of oppositely charged plates within the unit. Collection efficiency is a function of the area of the collecting plates, the flow rate, and the strength of the electrical field. The precipitating cell is washable and reusable but requires frequent, periodic cleaning. The airflow remains constant with use but the efficiency declines rapidly as the charged plates become coated with particles. Lower energy requirements and no filter costs (except for a prefilter or an activated charcoal filter in some combination units) make this procedure less expensive than HEPA filtration. EPs have the same basic requirement as the HEPA filter for sufficient airflow to clean the volume of air within a defined indoor space. The ozone emission generated with electric arcing across soiled plates are insufficient to be hazardous. *Consumer Reports* rated the following room air cleaners as excellent or very good in dust and smoke removal rates (cubic feet per minute) in the order listed⁶: Friedrich C90 (EP), Honeywell F59A (EP), Smokemaster P-600 (EP), Enviracaire EV-35A (HEPA) and Austin Air Sierra HPA PFA-80-AC (HEPA). The in-duct air cleaner for the home recommended by *Consumer Reports* is the Honeywell F-50E (EP).

An ad hoc committee of the American Academy of Allergy and Immunology reviewed the published

studies in the medical literature during the previous 60 years.⁸ The inconsistent scientific methods used in many of the studies made an overall analysis of the results difficult. Ten of the 17 studies were unblinded. Twelve of the 17 trials made no assessment of the allergen(s) in the indoor environment. The air cleaners studied included three filters, three air conditioners, five electrostatic precipitators, two HEPA units, and one unit that was a combination of EP and HEPA. Limited numbers of patients were included in these studies, and treatment periods lasted from several weeks to 2 months. Several of the double-blind studies 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 alone. Several double-blind studies of free-standing room air cleaners used by asthmatic subjects sensitive to house dust found that the cleaners failed to reduce their symptoms or increase their peak flow rate significantly. When a laminar flow air cleaning device was placed over the head of a sleeping subject, some decrease in symptoms or medication was consistently demonstrated. The committee concluded that the available data from the 17 clinical trials were inadequate to make any recommendations on the clinical relevance of air cleaning devices for respiratory allergies, except that the use of room air cleaner devices in the absence of the other forms of environmental control was not realistic. If the allergen production rate exceeds the removal rate, even by a high-efficiency air cleaner, the overall beneficial effect would be insignificant.

A more recent evaluation in 1990 of a high-flow (300 cu ft/min) portable HEPA air cleaner as a treatment for 32 dust-sensitive patients with perennial allergic rhinitis and asthma was performed using a double-blind, two-month crossover trial.¹⁰ Twenty-three of the patients had other inhalant allergies and 19 patients had animals in the home. Three of these patients were allergic to their pet. Patients in six homes were passively exposed to smoke; three patients were smokers. The age range was 6 to 61 years, 12 were men and 20 were women, and 11 had asthma. Particulate counts were made, but allergen concentrations were not measured. Symptom scores were recorded in a diary. Medication scores were kept by the patient.

No significant clinical improvement was measured by before and after difference in the total symptom/medication scores or individual symptom scores during the placebo or active-filter phase. Although there was an average 70% reduction in particulates greater than 0.3 μm , the specific reduction in the absolute count did not correlate with any clinical response. This evaluation did not provide any additional information about the clinical value of air cleaners.

The amount of allergen suspended in the indoor air from domestic pets and dust mites is relatively small compared with the huge reservoir present in furnishings and carpets.⁹ Both central and room air cleaners would not be expected to have a significant impact on allergen levels in these reservoirs. When an appropriate attempt at environmental control fails to control the patient's symptoms and a substantial load of airborne allergen is believed to still be present an air-cleaning device should be included as an adjunctive measure.

The major cat allergen (*Fel d I*) remains airborne in undisturbed conditions and a significant proportion of it is associated with particles less than 2.5 μm in diameter, which probably accounts for the distinctively rapid onset of symptoms experienced by cat-sensitive patients who enter a home with cat(s). This is in striking contrast to dust mite allergens, which are associated with large particles that fall back into the carpet rapidly. A cat generates large quantities of airborne allergen, and even after the cat has been removed, resuspension of *Fel d I* from the reservoirs in the room maintain airborne concentrations. The air exchange rate affects the amount of allergen measured in

the indoor air with the higher percentage of small allergenic particles in low-ventilated areas. The effect of a HEPA filter air cleaner on total airborne cat allergen (ng/m³) was studied by placing one cat inside a carpeted and then an uncarpeted study room for 70 days. In each experiment the cat was removed and air samplings were performed at the 1-hour steady state period and again after 3 hours of air filtration.¹¹ There was a 56% reduction in total airborne cat allergen in the uncarpeted room compared with only a 7% drop in the carpeted room. The HEPA unit flow rates at 400 m³/hour and at 200 m³/hour were compared in the uncarpeted room; the air removal rate of cat allergen of the high flow was twice that of the low flow (67% vs 33%). A realistic extrapolation of this data is that clinical benefit for cat-sensitive patients cannot be expected unless environmental control measures are enforced.

Carefully controlled studies are needed to define the efficiency and influence of air cleaners on the susceptible patient's health. IAQ problems can be complex. Allergic respiratory diseases caused by the indoor allergens, cat dander, and dust mite allergens are perhaps the best example of a human disorder induced by an IAQ problem. Characterization of the allergens, proposed threshold concentrations, immunoassays to measure allergen content in air and dust samples, and the availability of specific data on the sensitivity of patients defined by skin testing, RAST, and allergen provocation testing make indoor allergens an excellent model for air cleaning device research.¹

Future investigations of air cleaners should use double-blind controlled trials in patients' homes for at least 1 year with a defined, matched patient population. Allergic asthma would be the best disorder to study because accurate objective measurements can be made with spirometry, methacholine, and allergen bronchoprovocation. Use of cat allergen as the standard airborne pollutant in studies of cat-sensitive asthmatic patients could be a favorable way to study the effect of air cleaners on airborne allergen concentrations and resulting effects on patients' symptoms and objective criteria. Specific air cleaning device parameters should be evaluated, such as dust-holding capacity, frequency of filter replacement, clean air delivery rates, and problems with operation of the unit, such as noise or odors. Appropriate statistical analysis of the data and critical review by scientific and medical experts must be conducted to validate the results.

In conclusion, the exact benefit of currently available air cleaning devices will require further investigations. With present-day technology, many of the issues regarding air cleaners as medical devices can be determined.

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- *0091-6749/94 \$3.00 + 0 1/0/56025*

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The role and abatement of fungal allergens in allergic diseases

Journal of Allergy and Clinical Immunology, The

March 2001, part 2 • Volume 107 • Number 3

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