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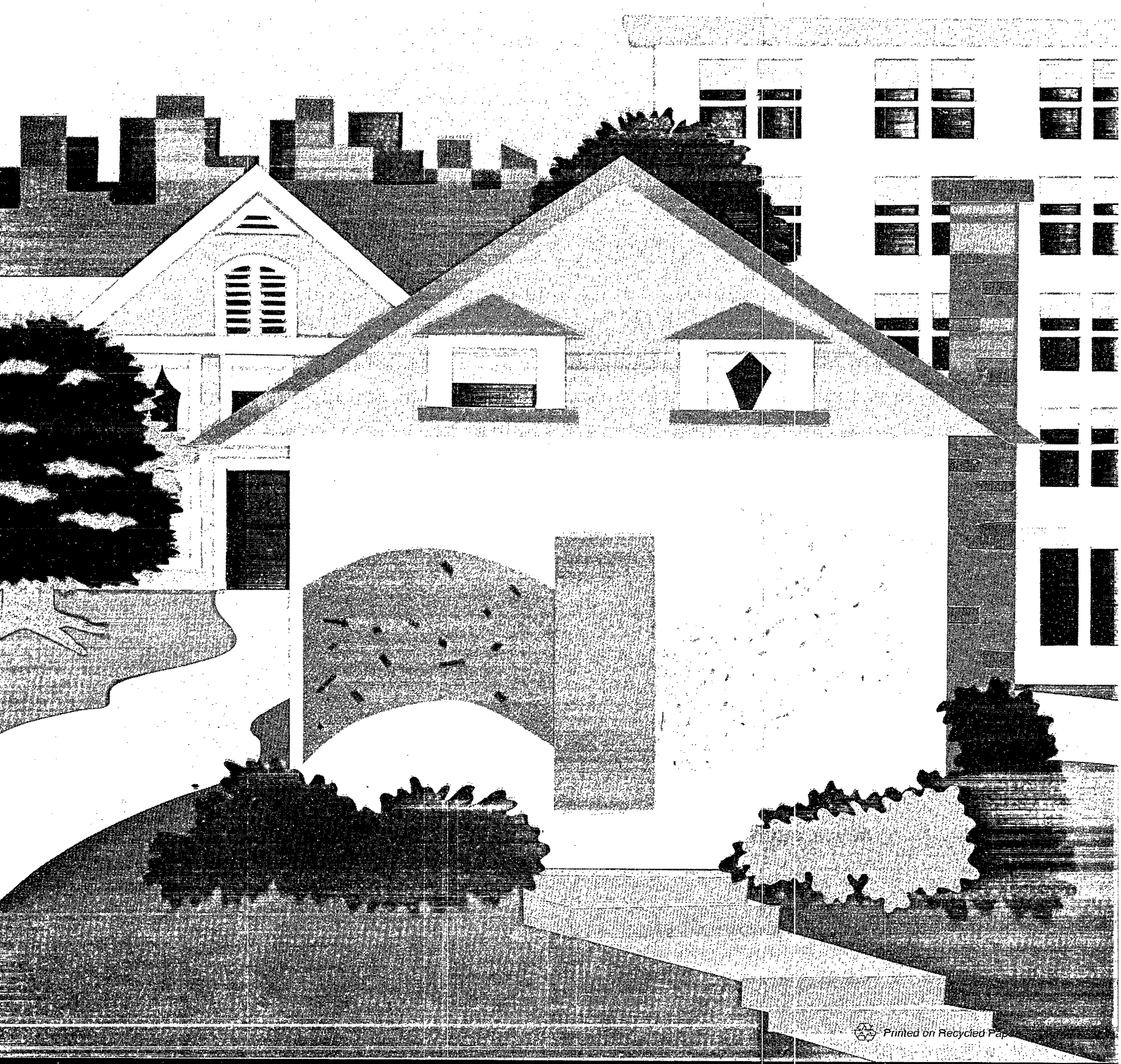
# Residential Air-Cleaning Devices

## A Summary of Available Information



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# Residential Air-Cleaning Devices

## A Summary of Available Information

U.S. Environmental Protection Agency
Indoor Air Division (ANR-445)
Office of Atmospheric and Indoor Air Programs
Office of Air and Radiation
Washington, DC 20460

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## *INTRODUCTION*

Indoor air pollutants are unwanted, sometimes harmful, materials in the air. They range from dusts to chemicals to radon. Air cleaners are devices that attempt to remove such pollutants from the indoor air you breathe.

The typical furnace filter installed in the ductwork of most home heating and/or air-conditioning systems is a simple air cleaner. This basic filtering system may be upgraded by using another filter to trap additional pollutants or by adding additional air-cleaning devices. An alternative to upgrading the in-duct air cleaning system is using individual room, portable air cleaners. Air cleaners generally rely on filtration, or the attraction of charged particles to the air cleaning device itself or to surfaces within the home, for the removal of pollutants. The use of "air cleaning" to remove pollutants from the air in residences is in its infancy; this publication presents the current state of knowledge.

This publication describes the types of air cleaners available to the consumer, provides available information on their general effectiveness in removing indoor air pollutants, discusses some factors to consider in deciding whether to use an air-cleaning unit, and describes existing guidelines that can be used to compare units. It does not discuss the effectiveness of air-cleaning systems installed in the central heating, ventilating, and air-conditioning (HVAC) systems of large buildings, such as apartment, office, or public buildings, nor does it evaluate specific products.

Because many factors need to be considered in determining whether use of an air cleaner is appropriate in a particular setting, the decision whether or not to use an air cleaner is left to the individual. EPA has not taken a position either for or against the use of these devices in the home.

## *WHAT POLLUTANTS ARE OF CONCERN IN INDOOR AIR?*

For the purposes of discussion, we will divide the pollutants into three groups: ***particles, gaseous pollutants***, and ***radon and its progeny***.

**Particles** are very small solid or liquid substances that are light enough to float suspended in air (e.g., mists, dust, or pollen). They are composed of diverse materials including inorganic and organic compounds and dormant and living organisms. Of primary concern from a health standpoint are: 1) small, invisible respirable-size particles, with a higher probability of penetrating deep into the lungs, where they may stay a long time and may cause acute or chronic effects, and 2) larger particles, such as some molds, pollen, animal dander, and house dust allergens, which do not penetrate as deeply, but may cause an allergic response.

Respirable-size particles include, but are not limited to, those from cigarette smoke; unvented combustion appliances such as gas stoves and kerosene heaters; viruses, bacteria, and some molds; and fragments of materials which, when whole, would be considered larger than respirable-size particles. Health effects from exposure to respirable-size particles in the air depend on the types and concentrations of particles present, the frequency and duration of exposure, and individual sensitivity. Health effects can range from irritation of the eyes and/or respiratory tissues to more serious effects, such as cancer and decreased lung function. Biological particles, such as animal and insect allergens, viruses, bacteria, and molds, can cause allergic reactions, infectious diseases, and/or can produce toxic products which may be released into the air.

**Gaseous pollutants** include combustion gases and organic chemicals which are not associated with particles. Hundreds of different gaseous pollutants have been detected in indoor air.

Sources of combustion gases (such as carbon monoxide and nitrogen dioxide) include combustion appliances, cigarette smoking, and the infiltration of vehicle exhaust gases from attached garages or the outdoors.

Gaseous organic compounds may enter the air from sources such as cigarette smoking, building materials and furnishings, and the use of products such as paints, adhesives, dyes, solvents, caulks, cleaners, deodorizers, personal hygiene products, waxes, hobby and craft materials, and pesticides. In addition, organic compounds may originate outdoors or through cooking of foods and human, plant, and animal metabolic processes.

Health effects from exposure to gaseous pollutants in the air may vary widely depending on the types and concentrations of the chemicals present, the frequency and duration of exposure, and individual sensitivity. Adverse effects may include irritation of the eyes and/or respiratory tissues; allergic reactions; effects on the respiratory, liver, immune, cardiovascular, reproductive, and/or nervous system; and cancer.

**Radon and its progeny** are radioactive pollutants which originate from natural sources such as rock, soil, groundwater, natural gas, and mineral building materials. These pollutants have the potential to cause lung cancer in humans. The risk of lung cancer increases with the level in the air and the frequency and duration of exposure.

Radon itself is a gas which produces short-lived progeny in the form of particles, some of which become attached to larger particles. Radon progeny may deposit in the lungs and represent the main health hazard from the radon series.

## *HOW DOES AIR CLEANING COMPARE WITH OTHER STRATEGIES FOR REDUCING POLLUTANT CONCENTRATIONS IN INDOOR AIR?*

The three strategies (**in order of effectiveness**) for reducing pollutants in indoor air are ***source control, ventilation,*** and ***air cleaning.***

**Source control** eliminates individual sources of pollutants or reduces their emissions, and is generally the most effective strategy. Some sources, like those that contain asbestos, can be sealed or enclosed; others, like combustion appliances, can be adjusted to decrease the amount of emissions. Unfortunately, not all pollutant sources can be identified and practically eliminated or reduced.

**Ventilation** brings outside air indoors. It can be achieved by opening windows and doors, by turning on local bathroom or kitchen exhaust fans, or, in some situations, by the use of mechanical ventilation systems, with or without heat recovery ventilators (air-to-air heat exchangers). However, there are practical limits to the extent ventilation can be used to reduce airborne pollutants. Costs for heating or cooling incoming air can be significant, and outdoor air itself may contain undesirable levels of contaminants.

**Air cleaning** may serve as an adjunct to source control and ventilation. However, the use of air cleaning devices alone cannot assure adequate air quality, particularly where significant sources are present and ventilation is inadequate.

## *WHAT TYPES OF AIR CLEANERS ARE AVAILABLE ?*

Air cleaners are usually classified by the method employed to remove particles of various sizes from the air. There are three general types of air cleaners* on the market: ***mechanical filters, electronic air cleaners,*** and ***ion generators.***

**Mechanical filters** may be installed in ducts in homes with central heating and/or air-conditioning or may be used in portable devices which contain a fan to force air through the filter. Mechanical filters used for air cleaning are of two major types.

*Flat* or *panel* filters generally consist either of a low packing density of coarse glass fibers, animal hair, vegetable fibers, or synthetic fibers often coated with a viscous substance (e.g., oil) to act as an adhesive for particulate material, or slit and expanded aluminum. (A flat filter in use in many homes is the typical furnace filter installed in central heating and/or air-conditioning systems.) Flat filters may efficiently collect large particles, but remove only a small percentage of respirable-size particles.

Flat filters may also be made of "electret" media, consisting of a permanently-charged plastic film or fiber. Particles in the air are attracted to the charged material.

***Pleated*** or ***extended surface*** filters generally attain greater efficiency for capture of respirable-size particles than flat filters. Their greater surface area allows the use of smaller fibers and an increase in packing density of the filter without a large drop in air flow rate.

**Electronic air cleaners** use an electrical field to trap charged particles. Like mechanical filters, they may be installed in central heating and/or air-conditioning system ducts or may

*Because they may reduce some pollutants present in indoor air through condensation, absorption, and other mechanisms, devices such as air conditioners, humidifiers, and dehumidifiers may technically be considered air cleaners. However, this publication includes only those devices specifically designed and marketed as air cleaners.

be portable units with fans. Electronic air cleaners are usually ***electrostatic precipitators*** or ***charged-media filters***. In electrostatic precipitators, particles are collected on a series of flat plates. In charged-media filter devices, which are less common, the particles are collected on the fibers in a filter. In most electrostatic precipitators and some charged media filters, the particles are deliberately ionized (charged) before the collection process, resulting in a higher collection efficiency.

**Ion generators** also use static charges to remove particles from indoor air. These devices come in portable units only. They act by charging the particles in a room, so they are attracted to walls, floors, table tops, draperies, occupants, etc. In some cases, these devices contain a collector to attract the charged particles back to the unit.

( Note: The latter two types of devices may produce ozone, either as a by-product of use or intentionally. Concerns about ozone production are discussed in more depth on page 14.)

Some newer systems on the market are referred to as ***"hybrid" devices***. They contain two or more of the particle removal devices discussed above. For example, one or more types of mechanical filters may be combined with an electrostatic precipitator or an ion generator.

In addition to particle removal devices, air cleaners may also contain adsorbents and/or reactive materials to facilitate removal of gaseous materials from indoor air. Air cleaners which do not contain these types of materials will not remove gaseous pollutants. The potential effectiveness of air cleaners containing these materials in reducing levels of gaseous pollutants in indoor air is discussed on page 8.

## *HOW EFFECTIVE ARE AIR CLEANERS IN REDUCING POLLUTANT CONCENTRATIONS IN INDOOR AIR?*

The effectiveness of air cleaners in removing pollutants from the air depends on both the efficiency of the device itself (e.g., the percentage of the pollutant removed as it goes through the device) and the amount of air handled by the device. For example, a filter may remove 99% of the pollutant in the air that passes through it, but if the air flow rate is only 10 cubic feet per minute (cfm), it will take a long time to process the air in a typical room of 1000 cubic feet.

Although there is no universally accepted method for comparing air-cleaning devices, several investigators of portable air-cleaning units have expressed their results as a "clean air delivery rate" or CADR. The CADR is the product of the unit efficiency and the air flow rate, and is a measure of the number of cfm of air it cleans of a specific material. For example, if an air cleaner has a CADR of 250 for smoke particles, it may reduce smoke particle levels to the same concentration as would be achieved by adding 250 cubic feet of clean (ventilation) air each minute.

The CADR can be used to compare removal rates between different devices and to estimate the removal rate of materials in larger or smaller rooms than those used in the tests.

Knowledge of **both** the CADR and the unit efficiency may be helpful in choosing a device for use in removing pollutants from a specific source. For example, a 45 percent efficient unit operating at a flow rate of 100 cfm has the same CADR as a 90 percent efficient unit operating at 50 cfm. Nevertheless, the 90 percent efficient unit placed near a specific source of pollutants would generally provide lower levels of the pollutant in the space away from the source than the 45 percent efficient unit.

In many cases, especially for in-duct systems and gaseous pollutant removal, only device efficiencies are reported, and the total effectiveness of the device would vary based on room size and air flow rate.

A summary of the results of studies on the effectiveness of air cleaners in removing particles, gaseous pollutants, and radon and its progeny follows.

## *Particle Removal*

The performance of air cleaners in removing particles from indoor air depends not only on the air flow rate through the cleaner and the efficiency of its particle capture mechanism, but also on factors such as:

- The mass of the particles entering the device.
- The characteristics of the particles (e.g., their size).
- The degradation rate of the efficiency of the capture mechanism caused by loading.
- Whether some of the air entering the unit bypasses the internal capture mechanism.
- How well the air leaving the device is mixed with air in the room before reentering the device.

### *In-duct Systems*

Only limited information is available on the performance of whole-house in-duct air-cleaning systems in removing particles. Their efficiency for particle removal can be assessed by three standard methods: the ***weight arrestance test,*** the ***atmospheric dust spot test,*** and the ***DOP method in Military Standard** 282.*

**The weight arrestance test,** described in the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 52-76[1], is generally used to evaluate ***low efficiency filters*** designed to remove the largest and heaviest particles; these filters are commonly used in residential furnaces and/or air-conditioning systems or as upstream filters for other air-cleaning devices. For the test, a standard synthetic dust is fed into the air cleaner and the proportion (by weight) of the dust trapped on the filter is determined.

Because the particles in the standard dust are relatively large, the weight arrestance test is of limited value in assessing the removal of smaller, respirable-size particles from indoor air.

**The atmospheric dust spot test,** also described in ASHRAE Standard 52-76, is usually used to rate ***medium efficiency air cleaners*** (both filters and electronic air cleaners). The removal rate is based on the cleaner's ability to reduce soiling of a clean paper target, an ability dependent on the cleaner removing very fine particles from the air. Exhibit 1 shows typical applications and limitations of filters rated using the ASHRAE Standard 52-76 atmospheric dust spot test[2].

**Military Standard 282**[3] [i.e., the percentage removal of 0.3 micrometer (μm) particles of dioctylphthalate (DOP)] is used to rate ***high efficiency air filters,*** those with efficiencies above about 98 percent. [The term "HEPA" (high efficiency particulate air) filter is commonly encountered in the marketplace. These filters are a subset of high efficiency filters and are typically rated using the DOP method. One standard-setting organization defines a HEPA filter as having a minimum particle collection efficiency of 99.97 percent by this testing method[4].]

Although the above standard tests yield information on the expected efficiency of rated air-cleaning devices in removing particles from the air flowing through them, few studies have been conducted to obtain actual effective removal rates in houses in which the devices were installed. The efficiency of in-duct devices may vary based on the air flow rate and the particulate matter load. Effectiveness may also be decreased if air exiting the heating and/or air-conditioning system is not well-mixed with room air before reentering the system. This can happen if air return and intake vents are too closely spaced within the home. In addition, the type of device chosen should depend not only on its efficiency but also on its dust-holding capacity and its resistance to air flow, two additional factors assessed by ASHRAE Standard 52-76.

Finally, it should be noted that ASHRAE Standard 52-76 addresses the overall efficiency of removal of a complex mixture of dust. However, removal efficiencies for different size particles may vary widely. Recent studies by EPA, comparing ASHRAE ratings to filter efficiencies for particles by size, have shown that efficiencies for particles in the size range of 0.1 to 1 μm are much lower than the ASHRAE rating[5]. A filter with an ASHRAE dust spot rating of 95 percent only removed 50-60 percent of particles in the 0.1 to 1 μm size range. Many of the respirable-size particles in indoor air (e.g., cigarette smoke) appear to be in this size range.

In contrast to the ASHRAE Standard 52-76 ratings, efficiencies derived by the DOP method in Military Standard 282 are expected to be more representative of capture efficiencies for respirable-size particles.

### *Portable Units*

Studies have been performed on portable air cleaners assessing particle removal from the air in room-size test chambers or extensively weatherized or unventilated rooms. All of the tests addressed removal of cigarette smoke particles[6-14]; some limited testing with larger

**Exhibit 1. Filter Applications for In-duct Systems Based on ASHRAE Atmospheric Dust Spot Test**

**AIR CLEANER EFFICIENCY RATING [1]**

| 10% | 20% | 40% | 60% | 80% | 90% |
|---|---|---|---|---|---|
| Used in window air conditioners and heating systems.<br><br>Useful on lint.<br><br>Somewhat useful on ragweed pollen.<br><br>Not very useful on smoke and staining particles. | Used in air conditioners, domestic heating, and central air systems.<br><br>Fairly useful on ragweed pollen.<br><br>Not very useful on smoke and staining particles. | Used in heating and air conditioning systems, and as prefilters to high efficiency cleaners.<br><br>Useful on finer airborne dust and pollen.<br><br>Reduce smudge and stain materially.<br><br>Slightly useful on non-tobacco smoke particles.<br><br>Not very useful on tobacco smoke particles. | Use same as 40%, but better protection.<br><br>Useful on all pollens, the majority of particles causing smudge and stain, and coal and oil smoke particles.<br><br>Partially useful on tobacco smoke particles. | Generally used in hospitals and controlled areas.<br><br>Very useful on particles causing smudge and stain, and coal and oil smoke particles.<br><br>Quite useful on tobacco smoke particles. | Use same as 80%, but better protection.<br><br>Excellent protection against all smoke particles. |

[1] Efficiency rating by ASHRAE Standard 52-76 atmospheric dust spot test.

Adapted from Reference 2.

particles (fine automotive test dust, airborne cat allergen, and pollen) was also performed[9,12,14]. The test methods used by each group of investigators varied.

The studies show varying degrees of effectiveness of portable air cleaners in removing particles from indoor air. In general, units containing either electrostatic precipitators, negative ion generators, or pleated filters, and hybrid units containing combinations of these mechanisms, are more effective than flat filter units in removing cigarette smoke particles. Effectiveness within these classes varies widely, however.

Again, important factors, in addition to the efficiency of the device itself are the air flow rate; the particle characteristics; the degradation of efficiency with particulate loading; the bypass of air around the collection mechanisms used; and the size of the room.

In addition, for negative ion generators, the placement of the device and the air circulation in the room affect performance. For removal of larger dust particles, negative ion generators, without additional particle capture mechanisms (e.g., filters), may perform poorly.

The general trend in the market over the past few years has been toward larger, more powerful console-sized models. In recent tests[12], the CADRs for 6 table-top units ranged from about 50 to 100 cfm for smoke particles, whereas the CADRs for the 21 console units ranged from about 50 to 250 cfm. (However, as discussed on page 14, reemission of chemicals from particles trapped by these devices is of concern.)

In general, placement of any portable device may affect its performance. If there is a specific, identifiable source of pollutants, the unit should be placed so that its intake is near that source. If there is no specific source, the air cleaner should be placed to force cleaned air into occupied areas. In addition, the air cleaner should be located where the inlet and outlet are not blocked by walls, furniture, or other obstructions.

Effectiveness of a unit may also be decreased if air exiting the air cleaner outlet is not adequately mixed with room air before reentering the device.

The use of a single portable unit would not be expected to be effective in large buildings (e.g., apartments or office buildings) with central heating, ventilating, and air-conditioning (HVAC) systems. Portable units are designed to filter the air in a limited area (e.g., up to several connected rooms without obstructions to air flow). Air circulated within central HVAC systems may have large effective volumes (e.g., several floors of a building). To clean air in these situations requires the use of either multiple portable units or in-duct systems designed for the building by HVAC engineers.

*Removal of Gaseous Pollutants*

Some air cleaners are designed to remove gaseous pollutants as well as particles. However, studies on the effectiveness of portable or residential in-duct air cleaners in removing gaseous pollutants are limited.

Sorption on solid sorbents is the most frequently used process for removing such contaminants from indoor air. The performance of solid sorbents is dependent on several factors, including:

- The air flow rate through the sorbent.
- The concentration of the pollutants.

- The presence of other gases or vapors (e.g., humidity).
- The physical and chemical characteristics of both the pollutants and the sorbent (e.g., weight, polarity, size, and shape).
- The configuration of the sorbent in the device.
- The quantity of sorbent used and the sorbent bed depth.

Because the rate of sorption (i.e., the efficiency) decreases with the amount of pollutant captured, gaseous pollutant air cleaners are generally rated in terms of the sorption capacity (i.e., the total amount of the chemical that can be captured) and penetration time (i.e., the amount of time before capacity is reached)[15].

### *Activated Carbon*

Activated carbon will adsorb some pollutants even in humid environments[15,16] such as those found indoors. However, it does not efficiently adsorb certain pollutants such as volatile, low molecular weight gases[16,17].

Sometimes, relatively small quantities of activated carbon will reduce odors in a residence to imperceptible levels. However, because many chemicals produce health effects at levels below those where odors are perceived, removal of odors alone is not an indicator of a healthful environment.

Tests of gaseous pollutant removal by activated carbon have generally been performed using only high concentrations of pollutants, so little information is available on the effectiveness of carbon in removing chemicals present at the low (part per billion, or ppb) concentrations normally found in indoor air. Recent tests performed at EPA measured the adsorption isotherms for three volatile organic chemicals (VOCs) in the 100 to 200 ppb concentration range using three samples of activated carbon. Estimates of the bed depth needed to remove the compounds were made assuming a 150 ppb concentration in the air, an exit concentration of 50 ppb, and a flow rate of 100 cfm across a 2' X 2' filter. The results of the study suggest that these chemicals would quickly penetrate the 6-inch deep carbon filters currently marketed for odor control in in-duct systems[18]. Therefore, the useful lifetime of these filters in removing many indoor air pollutants may be short.

The ability of carbon to reemit pollutants it has trapped from indoor air is also of concern. The National Institute of Standards and Technology (NIST), formerly the National Bureau of Standards (NBS), is currently developing a standard method to be used in evaluating the effectiveness of media used for gaseous pollutant removal[19]. They have reported the results of a study using activated carbon, in which the concentration of toluene in the air flowing into the carbon was varied during the test (from 150 to 0 to 340 to 26 to 0 ppm). The experiment simulates the variations in pollutant levels which would be expected in indoor air situations. They found that toluene initially adsorbed by the media was slowly reemitted each time the pollutant level entering the media dropped. The amount of toluene emitted by the media during the 45-hour experiment was approximately equal to that adsorbed.

### *Special Sorbents*

Special sorbents have been developed to remove specific gaseous pollutants such as formaldehyde[15,20]. Many of these are chemisorbents, impregnated with chemically active materials, such as potassium permanganate or copper oxide, which will react with one or a limited number of different reactive gaseous pollutants.

Several studies have focused on the removal of formaldehyde in homes using such chemisorbents. These data suggest that large quantities of sorbent and high air flow rates may be required to effectively reduce formaldehyde levels[20].

In addition, because chemisorbents are specific for one or a limited number of reactive pollutants, they should not be expected to efficiently reduce pollutants for which they are not specifically designed.

### *Tests of Portable Units*

Testing has been performed recently on gaseous pollutant removal by several portable air cleaners containing activated carbon and/or additional specialized sorbents[10,11,13,21]. The CADRs calculated for "hydrocarbons" or individual VOCs (excluding formaldehyde) in these studies were generally low, ranging from 0 to 30 cfm. None of four units tested for the removal of dichloromethane removed any of this compound. Lower molecular weight gases, including nitrogen oxides, sulfur dioxide, formaldehyde, hydrogen cyanide, and ammonia, were generally removed at greater rates than the higher molecular weight organic compounds. Nitrogen dioxide removal for eight units where CADR values were reported ranged from 3 to about 94 cfm[11,13,21]. CADRs were available for only two units for each of the remaining lower molecular weight gases; the highest CADRs reported were for nitrous oxide and formaldehyde (approximately 120 cfm in one unit).

In general, units containing specialized sorbents performed better in the removal of gaseous pollutants than those containing activated carbon alone. However, as suggested by the above results, removal rates varied widely between units. In addition, widely differing removal rates were found for the pollutants tested in the same unit; some models that removed larger quantities of one pollutant did not remove much of another.

Several factors were **not** assessed in the tests of the portable units, making evaluations of the effectiveness of these devices in indoor air environments incomplete. For example, because these tests did not determine the sorption capacity or penetration rates for the air cleaners, it is not known how long the filters would remain effective. Preliminary tests were performed on one air cleaner to assess long-term efficiency in removing $NO_2$ (260 ppb) and six VOCs. The VOCs chosen were representative of six classes of VOCs found in indoor air, and the concentrations and relative proportions of the six VOCs were selected to reflect those reported for their respective classes in indoor air. Following testing in a test chamber to determine the initial removal efficiencies for these compounds, the air cleaner was operated intermittently in a home over a two-and-a-half-month period. Follow-up testing in the test chamber showed a decrease in efficiency of 50 percent or more for each chemical after 160 hours of use (i.e., 15 percent of the manufacturer's recommended filter lifetime)[21].

Another factor that was not assessed was the effect of additional chemicals in the air (e.g., water) during the removal process. Since indoor air is a complex mixture of chemicals, tests on one or a mixture of several pollutants may not adequately represent removal rates in indoor environments.

***In summary,*** data are too limited at present to assess the overall effectiveness of air-cleaning devices in removing gaseous pollutant mixtures. Although some of the devices which are designed to remove gaseous pollutants may be effective in removing specific pollutants from indoor air, none are expected to adequately remove all of the gaseous pollutants present in the typical indoor air environment. In addition, information is limited on the useful lifetime of these systems.

### *Removal of Radon and its Progeny*

Air cleaning is generally not the preferred approach to reducing health risks associated with radon. When source control techniques are not possible, or do not result in acceptable radon levels, air-cleaning techniques are available to reduce levels of radon gas and its progeny. Studies on the effectiveness of air cleaners in removing these pollutants have focused on either removing radon gas itself or removing the short-lived progeny produced by radon.

Some limited research on the effectiveness of carbon in removing radon gas itself from indoor air suggests that extremely large quantities of carbon would be required. However, some radon removal units which are specifically designed to regenerate the carbon media that they contain can increase the range of situations (area and radon concentration to be treated) where this technique is applicable.

Since the health hazard from radon is associated with the radon progeny, rather than radon gas itself, the effectiveness of air cleaners in removing radon progeny has also been assessed. Although some radon progeny are removed by filtration or electrostatic precipitation, the types of radon progeny not removed from the air may be of relatively greater concern from a health standpoint. In addition, radon gas concentrations are unaffected, and can continue to be a source of radon progeny in areas of the structure that are not effectively treated by the air cleaner. Because uncertainty exists concerning the effectiveness of air cleaners in reducing the health risks associated with radon, EPA neither currently endorses nor discourages their use as a method of reducing radon progeny in indoor air[22].

## *WILL AIR CLEANING REDUCE HEALTH EFFECTS FROM INDOOR AIR POLLUTANTS?*

As previously discussed, no air-cleaning system is available that will effectively remove all pollutants from indoor air. As such, the use of air cleaners should only be considered when the use of other methods to reduce indoor air pollutants (e.g., controlling specific sources of pollutants or increasing the supply of outdoor air) are not successful in reducing pollutants to acceptable levels.

Under the right conditions, some air-cleaning systems can effectively remove certain particles, although the particles must be suspended in the air as discussed below. Some of the air cleaners containing sorbents may also remove a portion of the gaseous pollutants in indoor air, and may help eliminate some of the hazards from these pollutants, at least on a temporary basis. However, air-cleaning systems are not expected to totally eliminate all of the hazards from gaseous pollutants. In addition, gaseous pollutant removal systems may have a limited lifetime before replacement of the sorbent is necessary. It should also be noted that although some air-cleaning devices may be effective at reducing tobacco smoke particles, many of the gaseous pollutants from tobacco smoke are not expected to be effectively eliminated. In addition, gases may be reemitted from tobacco smoke particles trapped by the air cleaner[17].

The typical air cleaner which does not contain a specialized carbon regenerating device would appear to be ineffective in removing radon gas and, because many questions exist concerning the relative health risks of radon decay products, there are insufficient data to quantify the impact of air cleaning on reducing the risks of lung cancer caused by radon progeny.

There is currently some controversy about how effectively air cleaners alleviate allergic reactions produced by larger particles such as pollen, house dust allergens, some molds, and animal dander. In February 1987, an ad hoc committee convened at the request of the Food and Drug Administration and several manufacturers of air-cleaning devices met to determine whether standards could be recommended for portable air cleaners and concluded that "the data presently available are inadequate to establish the utility of these devices in the prevention and treatment of allergic respiratory disease."[23]

Pollen and house dust allergens settle out rapidly from the air if not disturbed and suspended in the air again. Because only a small proportion of these allergens is generally suspended in the air, air cleaners may be relatively ineffective in their removal.

Although other allergen particles, such as animal dander, do not settle as rapidly as pollen and house dust allergens, the amount of allergen associated with surfaces either due to direct deposition or to settling will generally far exceed that in air. However, because larger quantities of these allergens may remain in air, air cleaning may be more effective in reducing these particles under some circumstances[23]. On the other hand, use of an air cleaner may disturb allergen which has settled on surfaces, resulting in a decrease in overall allergen removal from the air[14].

Published reports reviewed by the ad hoc committee were limited in scope, but indicated that the exposure to allergens originating outdoors during the warm months (i.e., pollen and some molds) can best be prevented by the use of an air conditioner, with only minimal additional benefit from an air cleaner. The effectiveness of air conditioning in reducing these pollutants was related to the exclusion of outdoor air (often 10 percent of the output of chilled air) and, in the case of molds, also to a reduction in humidity.

With subjects sensitive to house dust allergen, the use of impermeable coverings on the mattresses appeared to be as effective as the use of a laminar flow air-cleaning system above the bed. Based on these results, the committee felt that "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."[23]

## *WHAT ADDITIONAL FACTORS SHOULD BE CONSIDERED IN DECIDING WHETHER TO USE AN AIR CLEANER?*

Several factors other than the ability of air-cleaning devices to reduce airborne pollutant concentrations should be considered when making decisions about using air cleaners. These include:

### *Installation, Use, and Need for Maintenance*

The air-cleaning unit may have certain installation requirements that must be met, such as an adequate and accessible power supply or the need for access during use, repairs, or maintenance.

After installation, operating and maintenance procedures specified by the manufacturer need to be followed to assure adequate performance from the air cleaner. Filters and sorbents must be cleaned or replaced and plates or charged media of electronic air cleaners must be cleaned, sometimes frequently. To avoid electrical and mechanical hazards, the purchaser should ascertain that the unit is listed with Underwriters Laboratories (UL) or another recognized independent safety testing laboratory.

In addition, during cleaning an effort needs to be made to ensure pollutants do not get reemitted back into the air. For example, when filters are removed, excessive movements or air currents should be avoided to prevent redistribution of particles into the air.

### *Cost*

Cost may also be a consideration. Major costs include the initial purchase of the unit, maintenance costs (i.e., cleaning and/or replacement of filters and other parts), and operating costs (e.g., costs for electricity).

In general, the most effective units (e.g., those with high air flow rates and efficient particle capture systems) are also the most costly. Maintenance costs vary depending on the device, and should be considered before choosing a particular unit. In comparison to purchase and maintenance costs, operating costs for portable units (e.g., costs for electricity) are negligible[12].

### *Production or Redispersal of Pollutants*

Another consideration is whether some units will produce new pollutants or redisperse old ones. The potential for ion generators and electronic air cleaners to produce ozone, a lung irritant, may be of concern, particularly if electronic air cleaners are not properly installed and maintained[7,15,16]. This requires further study. At least two manufacturers of portable units advertise that their products produce ozone to facilitate removal of harmful gases, but the levels produced by these devices and the possible health effects are not known. Measurable levels of ozone were produced by one portable and two in-duct electrostatic precipitators in tests by EPA[5], and the Agency is conducting research to determine if the concentrations produced by the in-duct air cleaners are potentially harmful.

The production of fine particulate material by electronic air cleaners has also been reported[8,11,24]. Also, filters and other particulate control devices may remove particles from air and then may reemit gases and odors from the collected particles[17], and materials used in the construction of air cleaners may themselves emit chemicals to indoor air (e.g., formaldehyde may be emitted if particleboard is used in the air cleaner housing[21]).

### *Inability to Remove Some Odors*

A number of air cleaners tested were found to reduce the levels of cigarette smoke particles in the air. However, the odor of cigarette smoke remained because many of the devices do not contain effective systems to remove the gaseous products of cigarette smoke and because the gaseous products may be adsorbed and later reemitted by articles in the home[8,9]. To overcome this, some devices scent the air to mask odors, which may lead the occupants of the home to believe that the odor-causing pollutants have been removed.

### *Possible Effects of Particle Charging*

Another factor with respect to ion generators, particularly those that do not trap some of the charged particles, is the effect of particle charging on deposition in the respiratory tract. Experiments have shown a linear increase in particle deposition with charge; therefore, the use of ion generators may not reduce the dose of particles to the lung[8].

### *Soiling of Walls and Other Surfaces*

Ion generators are generally designed not to remove particles from the air but to deposit them on surfaces around the room. This results in soiling of walls and other surfaces, especially if the particles charged by the apparatus are not collected on a filter[9].

## *Noise*

Noise may be a problem with air cleaners containing a fan[7,9,12]. Some portable units operating at high speed can produce noise equivalent to a small vacuum cleaner[9] or that made by light traffic at 100 ft[7]. Even at low speed, some models produce an annoying hum or whine[12].

# *WHAT GUIDELINES ARE AVAILABLE TO COMPARE AIR CLEANERS?*

With the exception of the DOP method in Military Standard 282[3], used only to rate particle reduction by high efficiency filters, the federal government has not published any guidelines or standards for use in determining how well an air cleaner works in removing pollutants from indoor air. However, standards for rating particle removal by in-duct or portable air cleaners have been published by two private standard-setting trade associations[1,25]. These estimate the efficiency or effectiveness of an air-cleaning device in removing particles from indoor air, and can be used for comparisons among different devices.

Standards for air cleaners now focus only on particle removal. No guidelines or standards are available for use in assessing the comparative ability of air cleaners to remove gaseous pollutants or radon and its progeny, and research is currently inadequate to draw firm conclusions regarding the relative effectiveness of air-cleaning devices in removing such pollutants.

## *Standards for In-Duct Devices*

ASHRAE Standard 52-76[1] and the DOP method in Military Standard 282[3] may be used to estimate the efficiency of in-duct devices in removing particles. Using the ratings of the ASHRAE Standard 52-76 atmospheric dust spot test, Exhibit 1 can give a general indication of the types of particles which should be removed by a specific air cleaner. These standards can generally be used to compare the performance characteristics of one device with another, but cannot by themselves predict the actual effectiveness of a given unit in use in a residence or its useful lifetime. In addition, as discussed on page 6, the efficiency of these air cleaners may vary by air flow rate and particle load, and removal of some small respirable-size particles may actually be lower than assessed by the ASHRAE atmospheric dust spot test.

(Note: In examining information on ASHRAE ratings, be aware of differences in results from the weight arrestance test and the atmospheric dust spot test. For example, a filter with a weight arrestance of 90 percent may have an atmospheric dust spot efficiency below 40 percent. The ASHRAE weight arrestance test is of limited value in assessing the removal of respirable-size particles from indoor air.)

Because higher efficiency pleated filters are much thicker than filters generally used in standard home heating and/or air-conditioning systems, their use results in substantial air resistance, so they cannot be directly incorporated into the standard residential system. Instead, a system must be specially designed with a fan of sufficient power to create the necessary air pressure and with one or more efficient prefilters. Costs for installation of the system, replacement of prefilters and filters, and system operation should be considered before deciding whether to purchase higher efficiency filters. Again, the purchaser should be aware of the difference between high "arrestance" and high "efficiency," as provided by the standard tests.

Further information on standards for in-duct air cleaners can be obtained through a ***local heating/air-conditioning contractor*** or from:

Air-Conditioning and Refrigeration Institute (ARI)
1501 Wilson Blvd., 6th Floor
Arlington, VA 22209

## *Standard for Portable Air Cleaners*

The Association of Home Appliance Manufacturers (AHAM) has developed an American National Standards Institute (ANSI)-approved standard for portable air cleaners (ANSI/AHAM Standard AC-1-1988)[25]. This standard may be useful in estimating the effectiveness of portable air cleaners. Under this standard, room air cleaner effectiveness is rated by a clean air delivery rate (CADR) for each of three particle types in indoor air: tobacco smoke, dust, and pollen.

Only a limited number of air cleaners have been certified under this program at the present time. A complete listing of all current AHAM-certified room air cleaners and their CADRs can be obtained by sending a stamped, self-addressed envelope to AHAM at:

Association of Home Appliance Manufacturers
Air Cleaner Certification Program
20 North Wacker Drive
Chicago, IL 60606

Exhibit 2 shows the percentage of particles removed from indoor air in rooms of various size by rated CADR, as estimated by AHAM. Because CADR values on air cleaners in the market will vary from the five in the exhibit, the figures are to be used only as a guide to a model's performance. The exhibit provides estimates of the percent of particles removed by the air cleaner and the total removal by both the air cleaner and by natural settling.

There are other factors to consider in using the ANSI/AHAM ratings. The CADR values reported are based on reducing particle levels from sources which emit the particles ***intermittently*** rather than continually. If the source is continual, the devices would not be expected to be as effective as suggested by Exhibit 2. In addition, the values represent performance that can be expected during the first 72 hours of use. Subsequent performance may vary depending on conditions of use. Use and care directions should be followed routinely to get adequate performance from the air cleaner.

**Exhibit 2. Estimated Percentage of Particle Removal for Portable Units by CADR and by Room Size**

| | | PERCENTAGE OF PARTICLES REMOVED: | | | | | |
|---|---|---|---|---|---|---|---|
| | | *Smoke* (20 min) | | *Dust* (20 min) | | *Pollen* (10 min) | |
| **Room Size** | **CADR** | AC[a] | T[b] | AC[a] | T[b] | AC[a] | T[b] |
| **5 X 6** | **10** | 49% | 68% | 49% | 70% | — | — |
| | **40** | 89% | 97% | 88% | 98% | 57% | 93% |
| | **80** | 95% | 100% | 95% | 100% | 75% | 99% |
| **9 X 12** | **40** | 53% | 71% | 52% | 72% | 24% | 78% |
| | **80** | 76% | 89% | 75% | 89% | 40% | 86% |
| | **150** | 89% | 98% | 89% | 98% | 58% | 94% |
| **12 X 18** | **80** | 53% | 71% | 52% | 72% | 24% | 78% |
| | **150** | 74% | 87% | 73% | 88% | 38% | 85% |
| | **300** | 89% | 97% | — | — | — | — |
| | **350** | — | — | 91% | 99% | — | — |
| | **450** | — | — | — | — | 69% | 97% |
| **18 X 24** | **150** | 51% | 70% | 50% | 71% | 23% | 78% |
| | **300** | 73% | 87% | — | — | — | — |
| | **350** | — | — | 77% | 91% | — | — |
| | **450** | — | — | — | — | 50% | 91% |
| **20 X 30** | **300** | 63% | 79% | — | — | — | — |
| | **350** | — | — | 67% | 84% | — | — |
| | **450** | — | — | — | — | 40% | 86% |

[a] Removal by the air-cleaning device

[b] Removal by the air-cleaning device plus natural settling

Note: Estimates ignore the effect of incoming air. For smoke and, to a lesser extent, dust, the more drafty the room, the smaller the CADR required. For pollen, which enters from outdoors, a higher CADR is needed in a drafty room.

Source: Reference 26.

## *SUMMARY*

Three strategies (**in order of effectiveness**) that may be used to reduce indoor air pollutants are source control, ventilation, and air cleaning. Air cleaning may achieve an additional reduction in the levels of certain pollutants when source control and ventilation do not result in acceptable pollutant concentrations. However, air cleaning alone cannot be expected to adequately remove all of the pollutants present in the typical indoor air environment.

Air cleaners are usually classified by the method employed for removing particles of various sizes from the air. There are three general types of air cleaners on the market: mechanical filters, electronic air cleaners, and ion generators. Hybrid units, using two or more of these removal methods, are also available. Air cleaners may be in-duct units (installed in the central heating and/or air-conditioning system) or stand-alone portable units.

The effectiveness of air cleaners in removing pollutants from the air is a function of both the efficiency of the device itself (e.g., the percentage of the pollutant removed as it goes through the device) and the amount of air handled by the device. A product of these two factors (for a given pollutant) is expressed as the unit's clean air delivery rate (CADR).

Portable air cleaners vary in size and effectiveness in pollutant reduction capabilities. They range from relatively ineffective table-top units to larger, more powerful console units. In general, units containing either electrostatic precipitators, negative ion generators, or pleated filters, and hybrid units containing combinations of these mechanisms, are more effective than flat filter units in removing tobacco smoke particles. Effectiveness within these classes varies widely, however. For removal of larger dust particles, negative ion generators, without additional particle capture mechanisms (e.g., filters), may perform poorly.

Pollutants in indoor air may be divided, for convenience, into three groups: particles, gaseous pollutants, and radon and its progeny. Some air cleaners, under the right conditions, can effectively remove small particles which are suspended in air. However, controversy exists as to the efficacy of air cleaners in removing larger particles such as pollen and house dust allergens, which rapidly settle from indoor air. In assessing the potential efficacy of an air cleaner in removing allergens, one should consider the relative contribution of airborne to surface concentrations of the allergens, particularly in the case of pollen and house dust allergens where natural settling may be so rapid that air cleaners contribute little additional effect. Animal dander may settle more slowly although, again, the surface reservoir far exceeds the amount in the air. Furthermore, control of the sources of allergens and, where allergens do not originate outdoors, ventilation should be stressed as the primary means of reducing allergic reactions.

Some of the air cleaners containing sorbents may also remove some of the gaseous pollutants in indoor air. However, no air-cleaning systems are expected to totally eliminate all hazards from gaseous pollutants and these systems may have a limited lifetime before replacement is necessary. In addition, air cleaning may not be effective in reducing the risks of lung cancer due to radon.

In choosing an air cleaner, several factors should be considered. These include:

- The potential effectiveness of the device under the conditions it will be used.
- The need for routine maintenance, including cleaning and replacement of filters and sorbents.
- The estimated capital and maintenance cost.
- The installation requirements (e.g., power, access).
- The manufacturer's recommended operating procedures.
- The possible production or redispersal of pollutants, such as ozone, particles, formaldehyde, and trapped gaseous pollutants.
- The inability of air cleaners designed for particle removal to control gases and some odors, such as those from tobacco smoke.
- Possible health effects from charged particles produced by ion generators.
- Possible soiling of surfaces by charged particles produced by ion generators.
- The noise level at the air flow rates that will be used.

Finally, one Federal standard, addressing only high efficiency air filters, and two standards provided by independent standard-setting trade associations outside the Federal government may be useful as guidelines in choosing an air cleaner for reduction of particles in indoor air. For in-duct systems, the atmospheric dust spot test of ASHRAE Standard 52-76 and the DOP method in Military Standard 282 may be used, respectively, to estimate the performance of medium and high efficiency air cleaners. For portable air cleaning systems, ANSI/AHAM AC-1-1988 may be useful in estimating the effectiveness of the units. Similar standards are not currently available to compare the performance of air cleaners in removing gaseous pollutants or radon and its progeny.

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