

# Indoor Air Matters



An in-depth look at the connection between  
indoor air quality and respiratory health

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**Air.** While essential for life, its purity is not assured. Outdoors the insults are obvious – billowing smoke from chimneys, exhaust from automobiles, and the smog settling over cities all reminds us daily that our air quality is being compromised. Indoors the dangers are more insidious and less obvious. This poor indoor air quality is a cause for concern. The impurities found in our homes can build to levels high enough to affect our health, the quality of our lives and the condition of the very homes we live in.

The goals of this white paper are to:

- Educate the reader about indoor air quality (IAQ) with a particular focus on the impact of particulate matter and poor ventilation on respiratory health.
- Provide considerations for consumers looking to purchase an air cleaner (with a particular emphasis in comparing whole-home and portable units).
- Review a recent study comparing several brands of whole-home air cleaners.

I am a practicing internist that has treated patients for a wide variety of medical ailments for over 10 years. Examples of some of the conditions that I treat that are impacted by the environment include: asthma, chronic bronchitis (COPD), allergic rhinitis, sinusitis, and seasonal allergies. In addition to my clinical practice, I serve as the Medical Director for the Center for Patient Safety and Healthcare Quality and as the Deputy Program Director for the Internal Medicine Residency for a large teaching hospital in the Philadelphia area. My professional life is devoted to ensuring that my patients receive care of the highest quality while also training the doctors of tomorrow.

### An Introduction to Indoor Air Quality

Poor indoor air quality is attributable to a variety of factors and stems from multiple sources. The AirAdvice State of Our Indoor Air Report 2007 (1) demonstrated through independent testing of the air of 10,000 American homes from across the country that 96 percent of homes had at least one type of IAQ problem. Pollutants included volatile organic compounds (VOC), carbon

monoxide, radon, environmental tobacco smoke (ETS) and biologicals such as pollen, dander, bacteria and fungus. These pollutants varied little by geography. Particulate matter was the leading cause of poor indoor air – found in 85 percent of homes.

### Overarching Strategy for Indoor Air Quality Improvement

In general there are three main approaches to improve IAQ (2). These three elements include: source control, improved ventilation and air cleaning.

**Source Control:** Source control refers to removing the source of the pollutant from the home. Examples include not smoking indoors and removing unused solvents, such as paint thinners, from the home.

**Ventilation:** New construction techniques that utilize energy efficient windows and doors, extra caulk and weather-stripping, house wraps, sealants and additional insulation all lead to decreased movement of outside air through the home. This lack of ventilation leads to a buildup of stale and dirty air. In fact, according to the EPA (2), the lack of air movement through homes can lead to a buildup of toxic pollutants that can have concentrations up to a hundred times greater inside a home than outside. Therefore, ventilation is key in decreasing pollutants that are generated inside the home. It must be noted that indoor concentration of outdoor particles such as pollen may actually increase when ventilation rates are increased due to the introduction of fresh outdoor air .

**ABBREVIATIONS**

**IAQ:** Indoor air quality

**HVAC:** Heating, ventilation, air conditioning

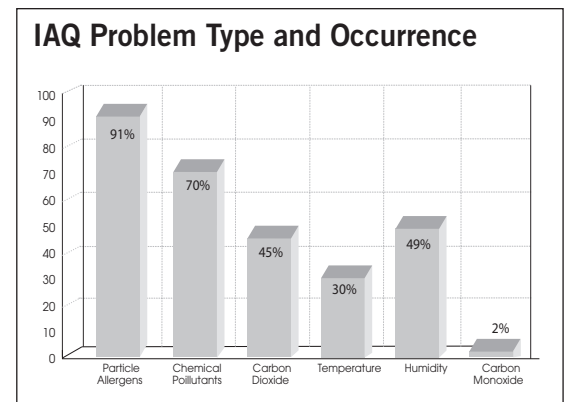
**ETS:** Environmental tobacco smoke

**VOC:** Volatile organic compounds

**EPA:** Environmental Protection Agency

**SIGNS OF POOR IAQ**

- ~ Excess dust
- ~ Stuffy rooms
- ~ Moisture on window panes
- ~ Musty odors
- ~ Family members often sneeze, feel lethargic, or have dry skin



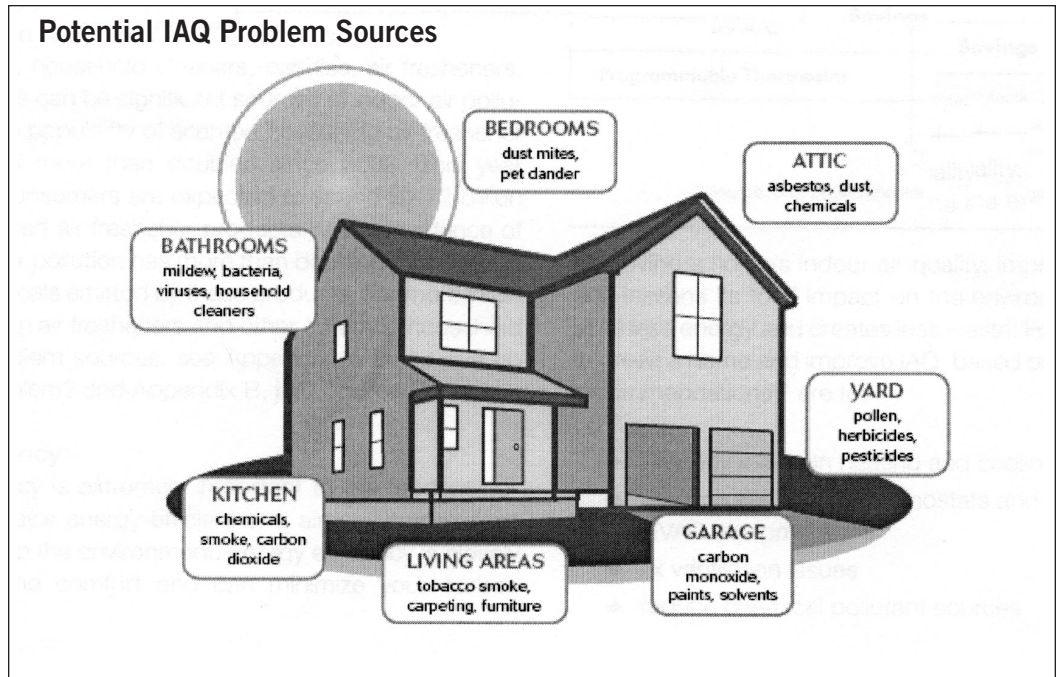
AirAdvice State of Our Indoor Air Report 2007 (1)

**AIR QUALITY CONTROLS**

1. Source control
2. Ventilation
3. Air cleaning

**POLLUTANTS THAT BUILD UP DUE TO VENTILATION**

- ~ Microscopic dirt
- ~ Dust
- ~ Bacteria
- ~ Viruses
- ~ Mold
- ~ Chemicals
- ~ Solvents



AirAdvice State of Our Indoor Air Report 2007 (1)

**Air Cleaning:** When source control and ventilation are employed in improving air quality to desired levels, air cleaning efforts should also be commenced. The effectiveness of air cleaners in improving overall air quality is highly dependent on both the type of air cleaner selected and the nature and the concentration of the pollutant. This white paper will provide the reader with details on how to best integrate and consider these factors when considering the use of air cleaners as part of a multi-pronged strategy for indoor air quality enhancement.

**Health Effects of Excess Particulate Matter**

Poor indoor air quality can cause or contribute to a variety of symptoms and medical issues. While individuals with pre-existing medical problems such as asthma, chronic obstructive pulmonary disease (COPD) and allergies are at most risk from poor indoor air quality, the medical literature demonstrates that even those in a good state of health are negatively affected, and can thus benefit from cleaner air. I highlight asthma as an example of a major health concern directly impacted by air quality.

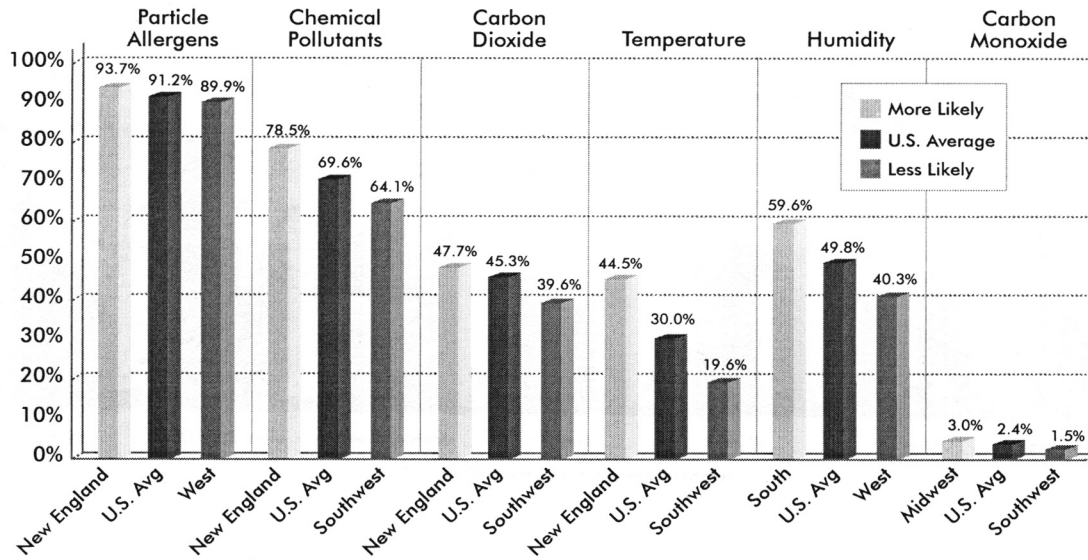
**Asthma:** Over 22 million Americans have the inflammatory lung condition known as asthma (3). Asthma is the most common serious chronic disease of childhood, affecting over seven million children and accounting for hundreds of thousands of hospital admissions and millions of physician visits.

For susceptible children, exposure to dust mites increases the chances for development of asthma. For those already living with asthma, attacks can be triggered by exposure to dust mites and a wide variety of other indoor and outdoor air pollutants. A key element of asthma management is control of the home environment with the intent of reducing exposure to triggers. The checklist found at [http://www.epa.gov/asthma/pdfs/home\\_environment\\_checklist.pdf](http://www.epa.gov/asthma/pdfs/home_environment_checklist.pdf) offers tips for modifying the home environment to decrease the risk for asthma attacks. After environmental control is achieved, the focus should shift towards improving ventilation and enhancing air purification. Studies have demonstrated that these environmental efforts may decrease the need for certain asthma medications (4) and decrease the risk of an attack (5).

**Other:** Many other conditions are affected by, or are due to, environmental exposures. Examples of these are included in the following table:

PERCENTAGE OF SELECTED CONDITIONS ATTRIBUTED TO ENVIRONMENTAL FACTORS (6)	
Asthma	30%
Cardiovascular disease	7.5%
Cancer	5%
Lead poisoning	100%
Birth defects	2.5%
Neurobehavioral	10%

## IAQ Prevalence by U.S. Region: Multiple (4+) IAQ Problems



AirAdvice State of Our Indoor Air Report 2007 (1)

The medical literature supports the strategy of source control, improved ventilation and air purification. Selected studies that support the benefit of air purification on human health are summarized in the following table:

TITLE	SUMMARY / CONCLUSION
Effect of Air Filtration on Asthma (7)	Review of 10 articles found that among patients with allergies and asthma, air filter use was associated with fewer symptoms and better sleep.
Clearing the Air: Asthma and Indoor Air Exposures (9)	Suggestive evidence exists that particle air cleaning is associated with a reduction in asthma symptoms - particularly with particles smaller than two micrometers, such as ETS particles and airborne cat allergen.
Air filtration devices in the control of indoor allergens (8)	Air cleaners can help reduce the levels of allergens produced by cats and dogs.
Clinical effects of air filters in homes of asthmatic adults sensitized and exposed to pet allergens (10)	Air cleaners used in the homes of asthmatics led to improved asthma scores and resulted in changes in medical management.
Resman (11)	Benefit of air cleaners was observed in patients with allergic rhinitis who were exposed to ETS, dust mites and dander.
Bascom (12)	Non-smokers had less symptoms after exposure to ETS in rooms that had air cleaners running.

While air cleaners can affect the levels of certain pollutants, they are less effective in reducing the levels of others. The following table summarizes the health effects of common indoor air pollutants and whether or not air cleaners have been shown to decrease those risks.

Because air cleaners do not work for all pollutants, they can be part of the solution, but should never be considered as the only necessary intervention in improving air quality.

POLLUTANT (AFFECTED BY AIR CLEANERS)	HEALTH EFFECTS	REMEDIATION
<b>Particles</b>	Eye, nose, and throat irritation; respiratory	<ol style="list-style-type: none"> <li>1. Vent all furnaces to outdoors; keep doors to rest of house open when using unvented space heaters.</li> <li>2. Choose properly sized woodstoves, certified to meet EPA emission standards; make certain that doors on all woodstoves fit tightly.</li> <li>3. Inspect, clean, and tune-up central heating system (furnace, flues, chimneys) annually. Repair leaks promptly.</li> <li>4. Change filters on central heating and cooling systems and air cleaners according to manufacturer's directions.</li> </ol> <p><b>5. Install air cleaners.</b></p>
<b>Environmental tobacco smoke</b>	Eye, nose, and throat irritation; headaches; lung cancer; may contribute to heart disease. Specifically for children, increased risk of lower respiratory tract infections, ear infections; increased severity and frequency of asthma episodes.	<ol style="list-style-type: none"> <li>1. Decrease indoor smoking.</li> <li>2. Increase ventilation.</li> </ol> <p><b>3. Install air cleaners.</b></p>
<b>Biologicals</b> (viruses, bacteria, mold, pollen)	Eye, nose, and throat irritation; shortness of breath; dizziness; lethargy; fever; digestive problems. Can cause asthma; fever; influenza and other infectious diseases.	<ol style="list-style-type: none"> <li>1. Appropriately use and maintain humidifiers / dehumidifiers.</li> <li>2. Vent kitchens, bathrooms and clothes driers outdoors.</li> <li>3. Clean and dry or remove water-damaged carpets.</li> </ol> <p><b>4. Install air cleaners.</b></p>

NOT AFFECTED BY AIR CLEANERS	HEALTH EFFECTS	REMEDIATION
<b>Radon</b>	No immediate effects; long term risk of cancer	1. Radon elimination and mitigation system.
<b>Carbon monoxide</b>	At low concentrations, fatigue in healthy people and chest pain in people with heart disease. At higher concentrations, impaired vision and coordination; headaches; dizziness; confusion; nausea. Can cause flu-like symptoms that clear up after leaving home. Fatal at very high concentrations.	<ol style="list-style-type: none"> <li>1. Keep gas appliances properly adjusted.</li> <li>2. Consider purchasing a vented space heater when replacing an unvented one.</li> <li>3. Use proper fuel in kerosene heaters.</li> <li>4. Install and use an exhaust fan vented to outdoors over gas stoves.</li> <li>5. Open flues when fireplaces are in use.</li> <li>6. Choose properly sized woodstoves that are certified to meet EPA emission standards. Make certain that doors on all woodstoves fit tightly.</li> <li>7. Have a trained professional inspect, clean, and tune-up central heating system (furnaces, flues, and chimneys) annually. Repair any leaks promptly.</li> <li>8. Do not leave the car idle inside the garage.</li> </ol>
<b>Organic gases</b> (from paint strippers, solvents, aerosols, fuel, etc.)	Eye, nose, and throat irritation; headaches, loss of coordination, nausea; damage to liver, kidney, and central nervous system. Some organics can cause cancer in animals; some are suspected or known to cause cancer in humans.	<ol style="list-style-type: none"> <li>1. Throw away unused or little used containers.</li> <li>2. Ensure adequate ventilation during use.</li> <li>3. Follow manufacturer directions.</li> <li>4. Never mix products.</li> </ol>

As referenced in the previous charts, air cleaners are emerging as an important tool in the fight against many types of indoor pollutants. The health benefits have been demonstrated in the medical literature. However, in order for the consumer to realize the maximum potential gains when utilizing an air cleaner, understanding the capabilities and limitations of the various available types becomes of paramount importance.

### **Air Cleaners: The Basics (13,14,15)**

There are many different types of air cleaners on the market today. The two major types are whole-home and portable units.

#### **Whole-home air cleaners**

Whole-home air cleaners are devices that attach to HVAC equipment for the purposes of filtering particles out of the air that is circulated via the duct system throughout the home. There are two main types: Mechanical and Electronic

#### **Mechanical air cleaners**

This air cleaner uses either flat or pleated media made of either synthetic material or glass microfibers. The mechanisms of particulate filtration for mechanical type air cleaners are straining, interception and impingement, and diffusion.

#### **Electronic air cleaners**

There are two main types:

*Electrostatic precipitator:* This air cleaner uses the mechanism of electrostatic attraction to filter particles from the air in two stages. The first stage charges the particles (either negative or positive) as they pass through. The second stage uses charged surfaces (plates or honeycomb structures) to attract and capture the particles. There are no mechanical mechanisms of filtration in an electrostatic precipitator.

*Hybrid:* A hybrid air cleaner also uses two stages for filtration. The first stage charges the particles as they pass through, just like an electrostatic precipitator, but the collector stage is made of filter media. Particles are captured via straining, interception/impingement, and diffusion, as well as by electrostatic attraction.

#### **Portable air cleaners**

Portable air cleaners are devices that treat air in the immediate vicinity of the unit.



## How effective is an air cleaner in removing particles?

The effectiveness of any air cleaner is a function of the efficiency of the device (the percentage of the pollutant removed as air passes through it and the amount of air handled by the device). The industry accepted standard for testing and reporting the particle removal efficiency of commercial and residential air cleaners is the Particle Size Efficiency (PSE) test (ASHRAE Standard 52.2). PSE tests measure the efficiency of the filter to remove particles in distinct particle size ranges. Clean Air Delivery Rate (CADR) applies to portable units only and measures the amount of clean air in cubic feet per minute that an air cleaner delivers to a room. In short, efficiency multiplied by air flow equals the CADR.

*Efficiency:* All air cleaners become less efficient as particle size decreases. Only those air cleaners with the highest efficiency can consistently remove particles of the smallest size (0.3 – 1.0 microns). These small particles are most likely to deposit into the alveoli of the lungs and include particles in tobacco smoke, bacteria and viruses. Any high efficiency air filter is more effective in removing these small particles than are typical 1" filter units (filters that are added in series with the heating and cooling system). For reference see the image:

*Air Flow:* Air must flow through a filter for the capture and removal of particulates to occur. It is for this reason that a continuous fan is recommended for the operation of whole-home air cleaners that attach to the HVAC equipment.

### EFFICIENCY RATINGS

(Percentage of .3-10 micron size particles removed)

Low	20%
Medium	20-50%
High	60-95%

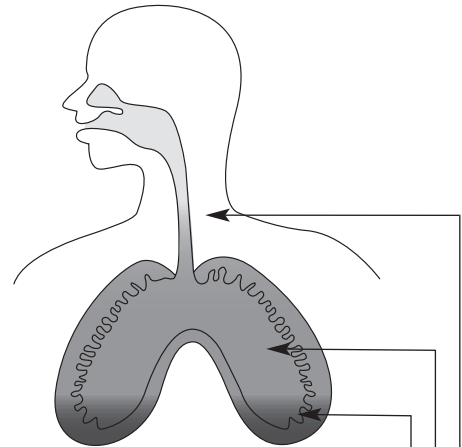
## Why Be Concerned About Particles in the Air?

### SITE OF DEPOSITION

**Upper respiratory tract**  
(nasal passages and pharynx)

**Middle respiratory tract**  
(trachea and bronchi)

**Lower respiratory tract**  
(alveoli)



### SIZE MATTERS

<b>5-30 microns<sup>1</sup></b>	<ul style="list-style-type: none"> <li>• Molds and spores</li> <li>• Pollens</li> <li>• Dust mites</li> <li>• Outdoor air dust</li> </ul>
<b>1-5 microns</b>	<ul style="list-style-type: none"> <li>• Bacteria</li> <li>• Pet dander</li> <li>• Small mold spores</li> <li>• Outdoor air dust</li> </ul>
<b>&lt;1 microns</b>	<ul style="list-style-type: none"> <li>• Tobacco smoke</li> <li>• Small bacteria</li> <li>• Outdoor air dust</li> </ul>

The examples listed are not all inclusive.

<sup>1</sup> The diameter of a human hair is approximately 100 microns

Where a particle is likely to deposit in the respiratory system depends primarily on the size of the particle. How the body reacts to the particle once it reaches its destination varies from person to person. There could be no reaction at all, or a simple cough, or the reaction may be an asthma attack or worse.

## Selecting an Air Cleaner

The first decision that most consumers face is whether to purchase a portable or whole-home air cleaner. The following table compares both types of technologies:

PORTABLE	WHOLE-HOME
Treat air only in the immediate vicinity of the unit.	Treat the air in every room of the home.
Separate units are required for each room.	Single unit cleans air throughout the home.
Often are noisy and obtrusive in living areas.	Are installed out of sight into the heating and cooling system working invisibly, silently and automatically.
May not be as energy efficient due to the need for multiple units.	Energy efficient. Can improve the efficiency of the central heating and cooling system by as much as 25 percent by trapping and removing harmful dust, dirt, dander, hair and other substances that settle on the equipment.
Require more frequent cleaning and maintenance. Need to have their filters changed every one to three months.	Are engineered to last as long as the entire HVAC system. Filters require changing every one to two years, depending on the manufacturer and model.

### WHAT ABOUT OZONE?

Ozone is an unstable oxygen molecule that is a pollutant most commonly found in outdoor air. Exposure to high levels of ozone can be harmful to health and can lead to symptoms such as cough and sore throat and can worsen asthma and other lung conditions. Sources of indoor ozone include photocopiers and laser printers. Some indoor air cleaners are designed to generate ozone as their primary means of 'cleaning the air'. These machines have been proven to be ineffective and due to the buildup of high levels of ozone are not recommended. Leading consumer and government publications have come out against these products (16.) Whole-home air cleaners such as those sold by Aprilaire do not utilize ozone to clean the air.



Enhanced and superior air quality is only one of the many benefits that whole-home air cleaners have over the portable units. The additional benefits of efficiency, decreased maintenance requirements, and improved longevity of other expensive heating and cooling elements make the whole-home air cleaner the most attractive option for the educated consumer.

### Aprilaire Whole-Home Air Cleaners



Indoor air cleaners and filters are a vital part of the solution for poor indoor air quality. These cleaners remove the particulate matter that remain airborne after source control and improved ventilation have failed. As referenced, there are two types of air cleaners on the market: mechanical air cleaners

and electronic air cleaners. Aprilaire electronic air cleaners work through hybrid design, combining mechanical filtering with electrostatic precipitation of particles.

An example of Aprilaire's superior performance can be found in a recent independent study conducted by LMS Technologies, Inc. This study found that Aprilaire whole-home air cleaners outperformed competitors in the important efficiency testing. The Aprilaire Model 5000 provides the best long-term efficiency, and the six month efficiency exceeded all others by as much as 27 percent on small particles and up to 54 percent on larger particles. In addition, of all models tested, the Aprilaire 5000 had the longest life for its filter.

#### **There are many benefits to the Aprilaire design.**

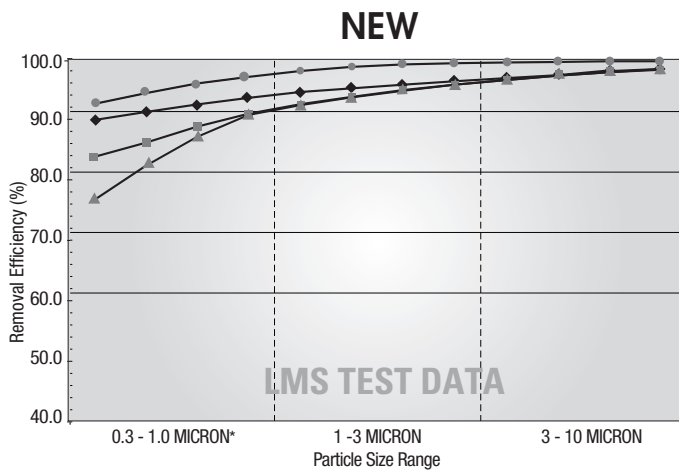
##### **Some of these include:**

- Traps up to 99.9 percent of airborne pollen, mold and spore-sized particles.
- Eliminates up to 98 percent of airborne bacteria-sized particles.
- Removes 94 percent of respirable dust, dust which the EPA reports can trigger asthma.
- Captures up to 99.5 percent of airborne particles the size of tobacco smoke.
- Removes up to 80 percent of airborne virus-sized particles—something no other air cleaner in the industry can do.
- Unlike competitive electronic air cleaners there is never a need for the frequent and time-consuming cleaning or washing of collector cells.
- Requires less maintenance than portable units. Aprilaire units need to have their filters changed every one to two years.

## Air Cleaning Performance

**Efficiency Performance:** Homeowners purchase air cleaners to remove particulate (dust, smoke, allergens, spores...) from the air. The most important measure of an air cleaner's performance is the percentage of particles removed from the air, or removal efficiency. The charts below illustrate how well the four leading air cleaners perform over time as they load with particulate. You will see that some air cleaners perform very differently when they are brand new and when they load with particles over time.

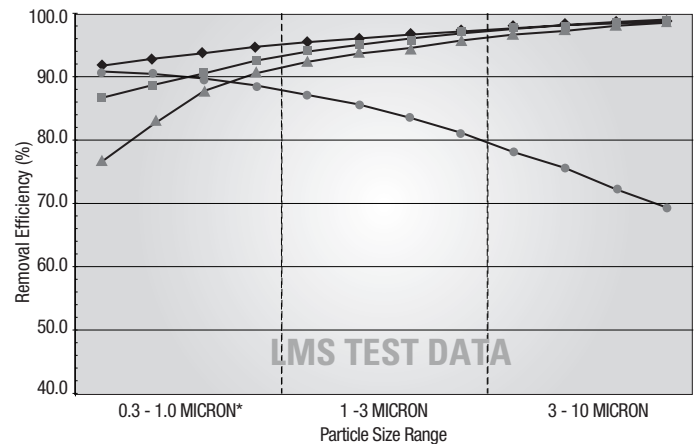
◆ Aprilaire 5000    ■ Carrier Infinity    ● Trane Clean Effects    ▲ Honeywell F300



When a new air cleaner is removed from the box and installed, the removal performance is shown in this graph. This performance is often what is reported when some manufacturers publish efficiency numbers. This condition is least important when comparing air cleaners, because it only happens for a very limited time period.

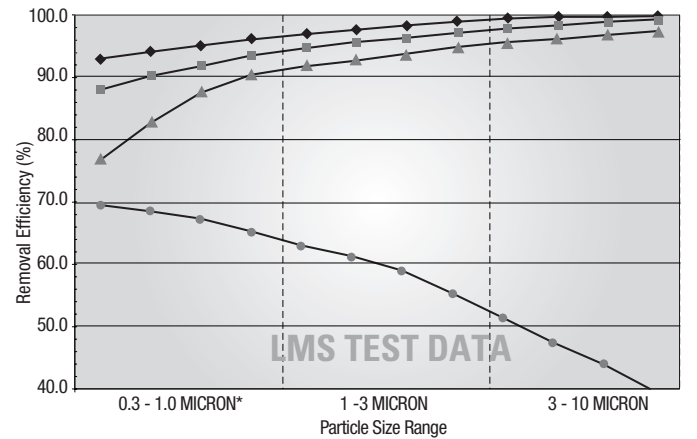
\* Homeowners purchase electronic air cleaners because of their ability to remove the smallest particles (.3-1.0). The Aprilaire Model 5000 outperforms all other products in this important size range.

## 2 MONTHS



Once in service the air cleaners will have removed particulate from the air and performance starts to change. The two month test provides a better real-world gauge of efficiency in a residential home. Several models see improvement in performance, while the Trane CleanEffects has a dramatic decrease in performance. This test demonstrates that publishing performance only when new does not give the consumer enough information to make the best buying decision.

## 6 MONTHS



This test illustrates performance of air cleaners prior to when most models need some type of maintenance. The Trane product continues to lose performance, capturing less than 50% of particles larger than 4.0 microns. The Aprilaire product remains the best performing product, capturing over 99% of all particles over 2.2 microns (5 times smaller than what is visible by the naked eye).

## Conclusion

I hope this whitepaper assists the reader in better understanding the health benefits of purer indoor air as well as the differences between whole-home air cleaning technologies and their superiority over portable units. Clearly, Aprilaire whole-home air cleaners are the right choice for the educated consumer.

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