Which Air Filter Should I Buy?

Air Filters Part 1 – Introduction – And the First of the Confusions
(draft)

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Selecting an air filter should be easy. Ask some friends, buy what they have, plug it in, and all your problems are gone! If that is what happened for you then you won't be reading this. What is more likely, the air filter you purchased didn't perform as expected.

So, you search the Internet to learn as much as you can about as many products as you can so you can buy the best one.

But you can't find clear, consistent answers to simple questions:

- Why didn't my $900 filter clean the air in the entire house?
- How can a $200 machine claim to be more effective than an $800 one?
- Would a $6000 machine be the best?
- Which air filters will remove mold and mycotoxins?
- Odors and fragrances?
- What about pet dander and pollen?
- Do you need the ones with UV lights to kill germs?
- What about new technologies like PCO and Hydroxl?
- Why don't some need replacement filters?
- Why do you need to know what CFM and ACH mean?
- What is CADR?
- Are there really different types of HEPA filters?

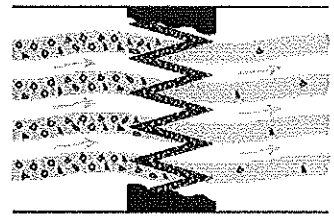
If the answers to these and similar questions were simple then everyone would already own the same equipment from the same company. The answers would be obvious and there would be no need for discussion. But that is far from being the case. Lack of answers creates confusion.

The good news, however, is that despite the complexity and the confusion reliable answers are possible. It will take some work on your part, a little dreaded math – kept to a bare minimum – and a rethinking of the common myths about air filters. This series will take you through the facts – yes there are facts that are undisputed! – and will identify the basics of air cleaning. By the end you also know how to separate the snake oil from the snakes.

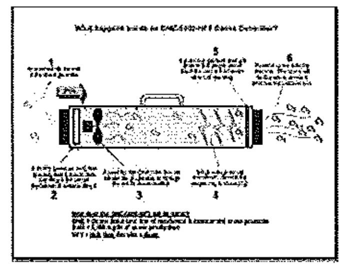
First Confusion
The first confusion is with names. The terms *Air Filter* and *Air Purifier* are used interchangeably. But they are not the same. There is a factual and critical difference not only for how they work and which pollutants each method can (or can't) remove, but also how some can decrease your health or potentially create harm. Buying an air cleaner is serious business that can have considerable risk if the facts are not known and appreciated.

Let's get the names straight first. *Air Cleaners* refers to both air *filters* and air *purifiers*.

- Filters clean by physically *removing* pollutants from the air. There is no exposure to new pollutants.



- Purifiers clean by *adding* something to the air to *alter* the pollutants without removing them. What they add and how they add it is critically important. Some additions work better than others, a few can cause harm.



We are starting with Filters because they are well established with independent facts verified over the decades. Purifiers have newer technologies, are more difficult to understand, and their effectiveness is easily disputed. Therefore, purification will be addressed later.

Second Confusion
The second confusion occurs when the machine you purchased doesn't do what you thought it would do.

- Because not all pollutants are the same and not all filters perform the same, you have to match the type of filter with the type of pollutant.
- No filter can remove pollutants from furniture, walls, floors, or other surfaces – they can only remove what is already in the air that goes through the equipment.
- No single filter can sufficiently clean the air in the entire house – you need to know the biggest room that a particular filter can clean.

Confusion about technology and capabilities is not the formula for success.

The Beginning
To begin our journey out of confusion, we need to start with facts. Both the filters and the purifiers perform according to the factual laws of science. They do not function according to our thoughts, our hopes, opinions, or the claims of those who sell them. They are not magical devices that you can simply place in a room and all the problems are solved. But they can be a powerful ally both at the beginning, until the source of the pollutants can be removed, and at the end if the remedy isn't quite good enough.

The next parts of this series will detail what you need to know to select the right air cleaner for your situation.

- Part 2 – Which pollutants can be removed and how much removal is enough? There are always limitations so how effective do you need yours to be?

- Part 3 – Cleaning an entire room. You need a machine with enough air movement to clean all the air in the room several times each hour. Too small a machine for the size of the room is perhaps The Number One mistake when deciding which machine to buy.
- Part 4 – Comparing products. How do you compare one product to another? The most expensive air cleaner is not always the best, and some of the more expensive ones can actually be the worst. You don't want to pay for a Porsche but get a bicycle.
- Part 5 – Purifiers. This part includes what a purifier is, how they work, how they are different from filters, and when they can be more effective than filters. It also discusses the limitations and potential hazards of the different purifying technologies.
- Part 6 – Exposing the "magic" and the slippery "snake oil." We all have our natural assumptions and beliefs that clever marketing can reinforce. Here is information that can help "vaccinate" you against some of the worst offenders.

So, sit back, take a deep breath, and begin an adventure!

Air Filters Part 2 – What Can Air Cleaners Remove, and How Much?
(draft)

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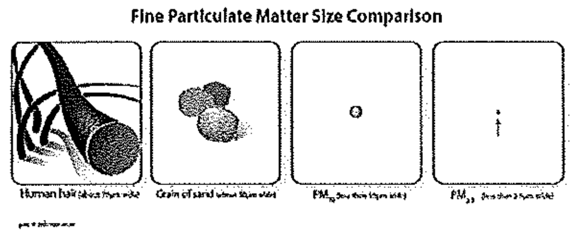
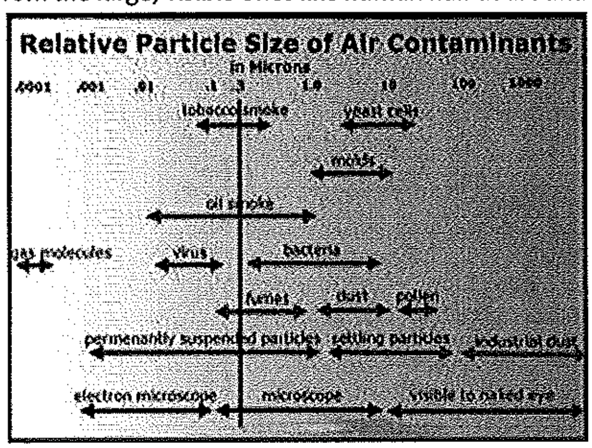
Air filters remove physical particles like dust, dander, pollen, and mold by separating them from the air. It can separate them because particles in the air are much larger than the molecules of air itself. If you force air through a membrane with the right size pores, the air will go right through but the larger particles will be trapped, much like how carpet dirt is captured in a vacuum cleaner bag.



The chart on the right compares the sizes of particles from the large, visible ones like human hair at around 100 microns, to the smallest visible to the naked eye, those that vacuum cleaners easily remove, which are around 10 microns. HEPA air filters are rated at 0.3 microns (the red vertical line). Molecules of air, fragrances, and other chemicals are even smaller down to around 0.0001 microns (3000 times smaller than the rating of a HEPA filter) These molecules can easily flow straight through even a HEPA filter membrane. This is why HEPA and other particles filters can't stop odors, fragrances, and chemicals – only particles. Other methods for chemical removal will be covered later.



Note that some particles – those to the left of the red line – are too small to be removed by filtration. This means that filtration cannot absolutely remove "everything." The output of filtration air cleaners will never be pure air, removed of all particles.

So the question becomes: What size pores are needed to let the air through but stop the bad particles?

Twenty years ago, there was no standardization of filter pore sizes, resulting in a half dozen methods of rating filter membranes, each with different measurements and corresponding claims. HEPA filters were the best but were too expensive. Today HEPA filters are readily available and very affordable.

HEPA is defined by the technical specification which reads "99.97% removal of 0.3 micron diameter particles." If the product doesn't say this, it is not a HEPA. Some manufacturers, however, sell less expensive filters rated at 99%. It sounds like it's close enough. What difference can there between 99.97 and 99.00? There is a huge factual difference! To understand that I have to get a little geeky for a moment, so bear with me on the math.

99.97% means that for every 10,000 particles in the air, 30 get through. They test HEPA filters by actually running 10,000 particles through it. If more than 30 get through its rejected as a HEPA filter.

No more than 30 particles escaping are allowed for each and every cubic foot of air that goes through it!

If air through a HEPA filter moves at the rate of 1 Cubic Foot per Minute (CFM), there will be 30 particles NOT being removed every minute. But filtering air cleaners don't run at 1 CFM. Most run at 150-250 CFM. If we use a nice round number of 200 CFM there will be 6,000 particles that get through each minute. Each and every minute! After 1 hour there will be 360,000 escaping (6,000 x 60 minutes). At the end of each day, there will be nearly 9,000,000 particles not removed from the air.

The impact doesn't stop there. That 9 million is based on air that has 10,000 particles per cubic meter. Typical air has as many as 100,000 particles per cubic meter. The particle count getting through a HEPA filter just jumped from 9,000,000 to at least 90,000,000 a day.

There are two very important points to be made: 1. This is (one reason) why many report that HEPAs don't work. Or that they don't remove specific substances such as mycotoxins. They actually do remove them, but not totally! Not absolutely. Never completely. 2. The rating above, and which each manufacturer reports, is for when the fan is on the high speed all the time. Turn the fan down and all bets are off!

HEPA filters remove particles but not molecules from each cubic foot of air that goes into, through, and back out of the machine. How many CFM is "good enough" to clean the air in an entire room? It's not quite what many believe it to be and that is Part 3.

What about molecules of fragrance, building materials, cleaning products? The discussion above has been about particles. Removal of odors, fragrance, and chemical molecules is very different from removal of particles because those molecules are the same size as the air molecules. They, like the air, go right through the HEPA filters. The pores of the filter could be made small enough to block the chemicals, but then the air would also be blocked. No air flow, no removal of anything.

This is where charcoal (or similar) is needed. The chemical molecules cling to the charcoal instead of being blocked like the particles are. The best reduction for molecules is about 30%, a far cry from the 99.97% for particles in HEPA. And we saw what the 0.03% meant. Imagine what a 70% escape is like! Technology has developed awesome sounding products, but whose performance is still being debated, and that is in Part 5.

Air Filters Part 3 – Which Ones Can Clean an Entire Room?
(draft)

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Now that we know how effectively we can clean each cubic foot of air as it moves through the filter, how do we clean all the cubic feet of air in an entire room? It's not quite what many believe it to be.

First, a "good enough" air purifier has less to do with the brand or type and more to do with its ability to clean all the air in the room faster than new dust and contamination are entering it. This is true with HEPA for dust, and with charcoal (or equivalent) for odors and chemicals.

The rate of cleaning a room is determined primarily by the number of Air Changes per Hour (ACH). To understand this better we need to discuss some numbers and some simple math.

Studies show that a minimum of 8-10 ACH is usually needed to reach and maintain 80% reduction of particles. This is for HEPA with a 99.97% removal rate at 0.3 microns. An even higher ACH is needed for chemicals because their best removal rate is only about a 33% reduction for each air change.

One air change per hour (1 ACH) means the total volume of air in the room goes through the machine in one hour. For instance, a 10 x 15 room has an area of 150 square feet. To calculate the volume you need to include the height, usually 8 feet. So, 150 x 8 is 1,200 cubic feet of air is this room. One ACH means 1,200 cubic feet went through the filter.

The necessary 10 ACH, therefore, is 12,000 cubic feet per hour through the filter. That's a lot of air but don't despair! There's a conversion between hours and minutes that makes up the difference.

ACH is in hours but air purifiers are rated in minutes – cubic feet per minute, or CFM. Most are rated somewhere between 120 and 250 cubic feet per minute (CFM). We will simplify this to a nice round 200 CFM.

To compare the Hours of ACH with the Minutes of CFM we need to first convert CFM to Cubic Feet per Hour. Multiply CFM by 60 minutes to get CFH. So, for example, a 200 CFM machine moves 12,000 CFH (200 x 60 minutes). Which is exactly what you need to get 10 ACH for your 10x15 room!

Isn't math wonderful! Now for the shortcut.

Estimating other room sizes from this baseline is easy. Double the room size and you get one half the ACH (5 ACH instead of 10 in this example). And cutting the room size in half will double the ACH (20 ACH instead of 10).

Here's another way to estimate based on the CFM of the machine for the same room size. If 200 CFM gets you 10 ACH (in our example of a 10x15 room) then 400 CFM is 20 ACH. Double one and you double the other. Conversely, a 100 CFM machine will do 5 ACH because cutting one in half cuts the other in half also.

You can play with these numbers to fit your room size and the CFM of your machine. Close enough is good enough. You don't need to be precise.

These are estimates because some rooms get added contaminants faster, and others slower. Some people need more than 80% removal of particles while others can get by with less.

And, of course, if the doors to the room are open then you are no longer cleaning the volume of air in just that room, but all the air in (perhaps!) the rest of the house. Finally, the ratings for CFM are with the fan on High. If you turn down the fan speed – which most people do because of the noise – you reduce both the CFM and the ACH. Not a good idea!

Buying and turning on an air purifier does not automatically read your mind and do precisely what you expect or need it to do. It does not perform magic, obey your wishes, or meet your expectations and hopes. It obeys the math. Which is why you need to know the math.

Now that we know how to rate air filters and how that tells us what we need to clean an entire room, we are ready to compare different air filters. How can you factually tell the difference between air filters made by different companies? Is more expensive always better? How can a less expensive filter outperform a more expensive one? That's Part 4.

Air Filters Part 4 – Comparing Air Cleaners – The Biggest Bang for the Buck
(draft)

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First a distinction about HEPA filters. We often refer to the entire air cleaning machine as a "HEPA filter." Actually, it is a HEPA-filtered air cleaner. It is an air cleaner that has a HEPA filter installed inside it. Only the filter membrane, the part the air goes through and where the dust accumulates, is a HEPA filter.

While this seems trivial and overly nerdy, the difference can have major consequences when comparing air filters. Because while all HEPA filters perform the same, not all air cleaners with HEPA filters perform the same.

All companies making HEPA-filtered air cleaners get the actual HEPA filter from the same manufacturers of HEPA membranes. They don't make their own. Therefore, all HEPA filters that meet the technical requirements to be called a HEPA filter, will perform the same. In other words, they remove 99.97% at 0.3 microns.

That is what a HEPA filter is. Any other designation such as 99%, 90% or 50% is not a HEPA filter. Neither is HEPA-like, HEPA-style, Hospital grade-HEPA or similar descriptions. HEPA is HEPA. All HEPA filters have the same performance.

However, not all HEPA-filtered air cleaners perform the same. There will be differences in how big the HEPA filter is, how fast the air is forced through it, whether the shape is round or square, and even how thick it is. The shape of the air cleaner itself can have an effect, as can whether the air comes in the bottom and out the top, or in the top and out the bottom. So with these differences (and more) how can they be compared in a meaningful way?

The answer is the Clean Air Delivery Rate – CADR. The Association of Home Appliance Manufacturers – AHAM – developed an ANSI accredited evaluation program to compare the effectiveness of filter air cleaners. Not just the filter, but the entire assembly of housing, motor, and the HEPA filter.

Different machines with a similar CADR number will perform the same. What this means is if there is a price difference between two air cleaners with the same CADR, buy the less expensive one. It will clean the air just as well as the more expensive one.

Specifics about CADR and AHAM, along with a list of certified air cleaners, can be found at:
http://ahamverifide.org/search-for-products/room-air-cleaners/

In my experience, there are three broad ranges of CADR numbers. 300-400 is about the best. 80-120 or so is usually acceptable. Below 50 is not very effective at all. At least not for any room bigger than a small closet. So why pay $800 when you can get the same CADR for $200?

But not all air cleaners are HEPA-filtered. How do they compare? Do they do an even better job? Can they provide benefits that HEPA can't?

Unfortunately, there is no rating system for non-HEPA comparable to the CADR for HEPA. Also, many of the newer technologies have not been independently tested. So, we have to rely on the manufacturer's own marketing claims. (More on that in Part 5).

But in the meantime, there are some facts which can be discussed and compared with a few general conclusions to guide us.

First, as we learned in previous parts of this series, HEPA doesn't remove chemicals and odors. Even when charcoal or other adsorbents are used along with HEPA, the removal rate of chemical molecules is estimated to be somewhere between about 15% and 35%. The actual rate depends on the type of adsorbent compared to the chemicals in the air, how much adsorbent there is, the air speed through the adsorbent, and a handful of other factors. Yet, removal of chemicals, odors, and fragrances is as important as removal of particles. There needs to be an effective and reliable way to remove them.

Non-HEPA technologies were developed to fix this shortcoming. For example, electrostatic air cleaners don't have a fan to move air into and through the electrostatic plates. Air movement is by ambient convection only. Based on earlier Parts of this air cleaner series, it is easy to understand that their effectiveness will be limited to the near vicinity of the machine. My estimated guess for CADR would be 20, or even less. Even for a very tiny space. By not moving air with a fan, it simply can't get even 1 Air Change per Hour. More like 1 Air Change per Day.

Other non-HEPA technologies have a fan but for technical reasons the CFM is not in the range of 200, but more like 30-50 CFM. (more about that also, in Part 5).

Based on the previous discussion of how many CFM are needed to get 10 ACH, we can calculate the size of the room that 30 CFM (cubic feet per minute) can result in 80% reduction – assuming their efficiency is equivalent to the 99.97% at 0.3 microns like the HEPA. (Note: It doesn't!) But let's pretend for the sake of better understanding low volume air cleaners. Let's also pretend that we like math!

So what size room will a 30 CFM machine deliver 1 ACH? Well, 30 CFM = 1,800 CFH which is 1 ACH. A 30 CFM machine will deliver 1 ACH in an 1,800 cubic foot room.

It will deliver 10 ACH in a room one tenth that size. In other words, a 180 cubic foot room.

How big is a 180 cubic foot room? If it has a typical ceiling height of 8 feet, then 180 divided by 8 gives us 22 square feet. That's a 4'x5' room. About the size of a medium closet. Most bedrooms, for a comparison, are 10x15 or 150 square feet, nearly 7 times larger! As we learned in Part 2, that means the ACH in the bedroom is 7 times less. Not very impressive.

Another shortcoming, especially with some equipment from former MLM sales companies, was the cost. These 30-50 CFM machines cost as much as $800 for a device that didn't clean a room as well as a lousy $100 HEPA. People were paying for a Porche but getting a bicycle. Plus, many used a technology that created ozone, which is a pollutant that can sometimes cause lung damage. It other words, that type of air "cleaner" claimed they could clean by polluting.

Other technologies are continuing to be developed which also continue to create many of the same issues. The claims, however, state otherwise. That is Part 5.

Air Filters Part 5 – Alternatives to HEPA
(draft)

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When HEPA became the dominant standard for air cleaners, the public became aware that they didn't remove "everything." Odors, fragrances, and chemicals were seemingly unaffected. Manufacturers observed the market and began developing purifying alternatives to the filtration of HEPA. A brief history will help to better understand the benefits and limitations of todays most modern air purifiers, and how history can repeat itself.

The first new technology designed to purify (rather than filter) the air generated ozone to "burn" chemicals by oxidation. It just so happened that ozone would also oxidize dust, mold, and pet dander. This promised to be a fantastic combination of purifying odors, fragrances, chemicals, plus particles all at once! And ozone generating air purifiers didn't have expensive HEPA filters that needed costly replacements.

But ozone generating air purifiers had a fatal flaw – the ozone was a strong respiratory irritant with the potential for damaging the membranes of the cells in the lungs. It had also been identified as a major component of atmospheric smog, with the result of a spike in emergency room visits on days of high ozone levels.

As the public began to turn against O3 (ozone) the Multi-Level Marketing (MLM) organizations took up the challenge. Their marketing became very creative with a variety of incredible claims. They claimed that it wasn't actually O3 that was purifying the air. Rather, it was the higher level activation of oxygen such as O4, O5, O7, O9, and so on. This "activated oxygen," not the minor amount of O3, was what was actually doing the purifying.

Instead of using the name of ozone they created a new name, "ions." While all descriptions were true, and nothing contradicted known scientific facts, the fallacy was with the application in the real world. So instead of technical jargon, MLM and others began using descriptive terms like naturally generated air, which is why pine forests and mountain breezes smell so fresh and clean. Lightening created lots of ions, which is why the air is so clear after a thunderstorm and why we feel so invigorated. One company even described their product as "a thunderstorm in a box." What could be more natural than Mother Nature's own method for clearing the air? You get the idea.

But the simple fact was that ozone was still the dominant force, aggressively reactive to most things it came into contact with. Including our lungs. Ozone by any other name, it seems, is still ozone.

Then came the law suits. In one famous trial, the jury determined that only 1 out of over 300 claims of effectiveness and safety was true. Search for "Alpine and FTC" on the Internet for all the gory details.

Manufacturers moved the action of the ozone from outside the purifier cabinet to inside the cabinet. Instead of blowing ozone into the room, a strong UV light would shine on the HEPA filter. That way trapped bacteria would be killed and the UV would also degrade some of the VOCs. This technology helped but only a little. But the UV would also degrade the HEPA filter, plastic parts, and the gaskets. Effectiveness was reduced by the 200 CFM air flow. There wasn't enough time for the UV to act on most of the pollutants, especially the chemicals known as VOCs – Volatile Organic Compounds. Something else was needed.

A rather brilliant technology brings us up to date. If UV shines onto a metal surface coated with a catalyst instead of on the HEPA filter, the "purification" process is intensified, accelerated, and becomes more efficient. The catalyst used is titanium dioxide (TiO_2) and the process is called Photocatalytic Oxidation – PCO. Although it still created ozone, the most effective ingredient were the Hydroxyls. UV shining on the TiO_2-coated surface would break apart the humidity molecules in the air – H_2O – into pairs of charged OH ions. These were much more aggressive than O_3, O_4, and even O_9!

There were still difficulties, however, both technical and exposure related.

Because Hydroxyl molecules are incredibly aggressive they have a short life span. Instead of persisting for several hours like ozone can, hydroxyls persist for only a tiny fraction of a second. While this keeps them inside the purifier, out of the room, and especially out of our lungs, the pollutants in the air have to move slowly through the area where the UV is shining on the catalyst surface.

Blowing air through a hydroxyl machine at 250 CFM, or even 100 CFM, like for a HEPA filter, didn't give the hydroxyls time to sufficiently breakdown the particles and molecules. The result was a combination ranging from no effectiveness to a partial breakdown of uncontrollable and unpredictable substances. Some of which proved to be more hazardous that either the ozone or the original chemicals. Plus, they could persist for as long as several hours. More than enough time to escape out of the purifier cabinet and into the room for people to inhale.

The primary fix is to slow down the air flow through the machine – 30 CFM or thereabouts instead of 200 CFM or more was a good balance.

Now, think back to Part 4 where we calculated the CFM required to get 10 Air Changes per Hour (ACH) for an 80 percent reduction in particles. And think about how charcoal could only achieve about a 30 percent reduction of chemicals. The math showed 10 ACH was possible at 30 CFM but for only a 3x3x8 foot room. The size of a small closet!

Yet some companies claim their 30 CFM device is effective in a 600 square foot room. The math says it will take 2.7 hours for just 1 air change. To get 10 air changes requires 27 hours. That is nowhere close to 10 air changes in one hour for effective HEPA filtration.

Something different must be occurring for these devices to have any significant effect in typical rooms of a house!

There are claims that proprietary or patented processes achieve these amazing results. But so far, I've seen no credible, independent evidence to support those claims. The evidence offered so far is in-house rather than independent. A few continue with verbal assurances of independent testing and just never get around to showing the studies. I've even seen "studies" offered as proof where the numbers certainly look good, but what they measured was not the same as what they claimed.

One of the most convincing has their legitimate, independent data front-and-center on their Web page. It looks impressive because it takes a measured pollutant to zero. But upon closer examination we see that it takes more than 2 hours to get to zero. Not in a house. And not in a room. But in a 30 cubic foot test chamber in the lab. 30 cubic feet is roughly 3x3x3 – that's half the size of the small closet in the example above! Anecdotal reports range from it works great, to complaints of respiratory irritation.

There's still a lot to learn about the new technologies that are non-HEPA. Manufacturers would help all concerned by emulating the HEPA filter companies and develop a credible, trustworthy measurement of effectiveness, plus a comparative rating analogous to CADR. Because they add substances to the air rather than remove, there needs to be an indicator for acceptable reactivity (risk) to people.

In the meantime, my professional advice is to stick to a decent, basic HEPA filter without expensive bells-and-whistles with a CADR of at least 200. Buy one that includes 3-5 pounds of charcoal or equivalent for reducing odors, fragrances, and chemicals.

If manufacturers or others disagree with anything I've written, please send me the independent studies that validate your claims. Give us a ray of hope! In the meantime, here are two independent sources of information. Check it out and let's start a conversation. Maybe I'm wrong. But whether I am or not we all need to know the facts.

https://www.epa.gov/indoor-air-quality-iaq/residential-air-cleaners-second-edition-summary-available-information
https://www.sciencedaily.com/releases/2015/07/150715130835.htm

Air Filters Part 6 – The Mangled Words of Marketing Claims
(draft)

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Perhaps the major confusion about air cleaners, air filters, and air purifiers regardless of which name is used are the way claims are made by manufacturers and frequently (mis)understood by customers. In fact, many experts sometimes miss the subtleties of marketing language. This final part of the series will illustrate several examples.

Four of the major confusions include:

- When I look for the CADR of products, I find different kinds of CADR. Which one is true?
- Different machines with the same CFM report different room sizes.
- How can a technology that produces ozone not report ozone?
- It appears there are several different versions or grades of HEPA, some with better performance than others. How do I know which one is true?

First, let me state that I realize that math, semantics, and geeky technical talk is aggravating and hard to comprehend. Nobody wants to spend their time parsing subtle semantics and technical jargon that only the experts can comprehend. Just tell me what to do. Just tell me what to buy.

However, when the numbers, words, and specifications that are the basis for deciding what to buy are corrupted, then the facts cannot be illuminated without digging into the troublesome details. And our reluctance to put product claims under the microscope of careful analysis is what the purveyors of confusion count on. Dazzle them with bull, just as long as they buy.

CADR

CADR is used to compare one product from another. If one unit is more expensive than another with the same CADR, buy the cheapest one because it will perform as well as the expensive one. The official Clean Air Delivery Rate for air cleaners is determined by the ANSI-accredited standard developed by AHAM – the Association of Home Appliance Manufacturers www.aham.org. Although they are an industry association, the CADR was developed under the strict rules of inclusion of all interested parties and transparency of procedures by the American National Standards Institute – ANSI. For more information go to: www.ansi.org.

CADR has an algorithm that weights the values of different sizes of particles according to whether they can be removed by an air filtration device. For example, pollen particles are not included because they are large enough and heavy enough to settle to the floor long before they could circulate to the intake of the air filter. Smoke particles can be extremely small and may not be captured by a HEPA filter.

However, as the CADR began to successfully compare products the manufacturers began modifying how they rated their products to show a competitive advantage. It is not unusual to see a CADR applied to just one of the many different types and sizes of particles, for example. The way to find the facts about any particular air filtration device is to go the AHAM Web site at http://ahamverifide.org/search-for-products/room-air-cleaners/ for their list of certified products.

CFM
Cubic Feet per Minute is important for different sized rooms. Most companies list the Cubic Feet per Minute (CFM) for their products right on the box. To avoid the aggravation of calculating which room size is most appropriate they simply list the room size. For example, 200 sq feet is a common report.

The confusion occurs because the Air Changes per Hour (ACH) is rarely listed. Remember in Part 3 that 8-10 ACH was needed to remove 80 percent of the particles in a room. So does the CFM of a specific machine achieve 8 ACH or 10 ACH? Or perhaps it is rated at the older level of 6 ACH. Many non-HEPA air filters, and especially air purifiers, don't list ACH at all. They simply state a room size.

More than one product claims the product is appropriate for a 600 square foot room. And customers rely on that number. But when details are considered – which is why the previous Parts went into such detail and did the math – it becomes obvious that the numbers just don't work.

For example, some of the non-HEPA purifiers – those that don't remove pollutants by filtering but introduce a substance into the air to "purify" the air – have a fan speed of 30 CFM. The Part 3 calculations showed that such a device could achieve 10 ACH only in a very small 3x3x8 foot room (72 cubic feet). So how long would it take to achieve 10 ACH in 600 square feet (4,800 cubic feet)? I'll skip the math and simply state that it would take 67 hours, or nearly 3 days. Compare that with a HEPA-type device at 200 CFM needing 4 hours.

Wait a minute! Even a HEPA fails to achieve 10 ACH in a 600 sq ft room? Check the math. This is not opinion, or hope, or belief. Neither is it a claim by anyone. It is the math. If you want 10 ACH in a 600 sq foot room you need a fan speed of 800 CFM. Try to find a HEPA filter with that speed. If you do, see how loud it is when turned on to the highest speed, which is the only speed that will achieve 800 CFM. I guarantee it will be turned to a lower speed within minutes. And that will reduce the ACH to below 10.

With math like this, is it any wonder companies prefer to claim a room size rather than the ACH for a specific sized room?

OZONE
The answer to how technologies that will produce ozone are not reported as producing ozone is simple. Don't report ozone if the tested level created by the unit is below the regulated threshold of 50 ppb. Or, simply claim that ozone is not the "primary" factor in purifying the air, that others substances are responsible.

HEPA
This is an increasing belief that there are different types and grades of HEPA filters. Therefore some are better than others. Despite claims to the contrary there is only one HEPA. It is the filtering membrane that is tested to remove 99.97% at 0.3 micron particle size. Anything else and it isn't a HEPA. They can call it what ever they desire, but a HEPA is a HEPA and a non-HEPA is a non-HEPA. With clear specifics like this, how is the confusion created?

There are many ways. Here are just the significant ones

Some claim their product is a 99% HEPA. Because the difference between 99.00 and 99.97 is so small, who cares? But there are two problems. 1. It cannot be a HEPA filter because it doesn't meet the defined specification of 99.97%. 2. That tiny 0.03% difference can result in over 9 million particles passing through the filter each day. Again, this is not an opinion. It is factual math. Go back to the previous part of this series and you can see the numbers for yourself.

Another way to fudge the definition is to call their product HEPA-like, HEPA-style, or Hospital HEPA. The first two are HEPA by name only. The third is a description that is true if a HEPA is used in a hospital, not because of superior performance. Remember, HEPA is precisely 99.97% at 0.3 microns.

And this leads to the next confusion that was very difficult to identify.

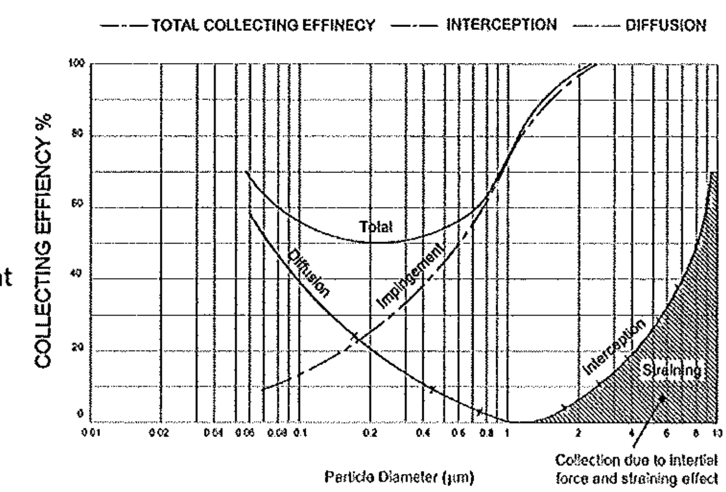
I've seen specifications that claim a filter is better than HEPA because it removes particles as small as 0.001 microns rather than just 0.3 microns. That's 300 times better. Right?

Here's the trick, and it's based on the poor marketing of HEPA. The 0.3 microns for a HEPA filter is not the lower limit, it is not the smallest particle that can be removed at the rate of 99.97%. It is actually the Maximum Penetrating Particle Size – MPPS. Meaning, particles both larger and smaller than 0.3 microns are captured at *better than* 99.97%. In fact, HEPA has been measured at near 99.99% to as small as 0.1 microns. It's just that around 0.3 microns the rate drops from 99.99% to its worst rate of 99.97%.

Why is this important? Because claims of a HEPA better than a regular HEPA are not true when the numbers and the definitions are not honest.

Because the concept of MPPS, rather than smallest size, is difficult to understand, bear with me for a moment to explain why. As the pores of the filter membrane get smaller and smaller the aerodynamic forces affecting the smaller and smaller particles changes. I'm enlarging the chart below so its big enough to see the details.

The larger particles above 1 micron are removed by a physical straining, like straining the dirt off the vegetables with water through a strainer. Some of the smaller particles can also accidently hit the fibers of the filter and stick through Impingement. It is effective for a different range of sizes. A third force is diffusion. This is the one that responsible for the removal of the smallest particles.



The key is where the Impingement drops off just as the Diffusion increases. It is that range from slightly below to slightly above 0.3 microns that is the least effective. All other sizes are more effective.

You don't have to be an Einstein or to understand the physics or the aerodynamics to appreciate what the chart shows. It shows the FACTS of how a HEPA functions. It reveals the false impressions that some HEPA filters are better than others. This is not my opinion or the opinion of others. It is measurable fact.

One final comment on comparing HEPA claims. Some specifications claim 99.5% removal of particles as small as 0.001 microns. This is near the size of chemicals. So, if these small particles are stopped why isn't the air also stopped? Here is where the wording gets even trickier.

The difference is with the words "at" and "as small as." HEPA specifies the removal "at" 0.3 microns. This statement will be true only when 99.97% or more of the 0.3 micron particles are captured. The words "99.95% as small as" is not for a specific particle size but for a range of unidentified sizes. It could be from 0.001 to as large as 10.00 microns, or 100 microns, or any maximum size desired. As long as the removal of the *total* achieves 99.95% the claim will be true. But it says nothing about the removal of any particle size, least of all those at 0.001 microns.

This "trick" was perfected 15-20 years ago before HEPA became the standard of comparison. It's another attempt to create the appearance of a competitive advantage. While it may increase sales, it does not increase effectiveness of HEPA filters. It does not create a reduction of reactivity of people.

But I'm saving the best trick for last. And it, too, goes back at least 20 years with vacuum cleaner bags. About the time HEPA filters and HEPA filtered vacuums were becoming affordable, I started receiving phone calls from clients saying they didn't need to spend $1000 to $2000 for a HEPA vac. They had a $5 bag that was better than HEPA. Their bag removed 0.1 particles rather than 0.3 particles like HEPA did.

The claim, printed on each bag was in two sentences:

> "Removes all common dust, dander, and pollen."
> "Removes particles as small as 0.1 microns."

There are two separate sentences, each with its own meaning. The "all" in the first sentence is true because the pore size of the vac bag was 5.0 microns and the stated particles are mostly larger than 10 microns. It's not difficult to remove "all." But the "all" does not refer to the second sentence. The second sentence stands alone. It does not say "all," but rather "as small as."

What would make the second sentence true? If even a single 0.1 micron particle was accidently stopped, the statement would be true. And surely, at some point, at least one would get stuck on the bag. But stopping just one is a huge difference from "all" or "99.97%."

To illustrate this point further, I can make the argument that an open window or open door could also remove particles "as small as 0.1 microns." All that has to happen is for one, single, individual particle of 0.1 microns to accidently get stuck on the door frame or the window glass. But it still does not compare at all to a vacuum cleaner bag or a HEPA air cleaner.