Frequency of Air Changes per Hour – A Key Consideration in Selecting Air Purification Systems

a report by

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The average person breathes in approximately 16,000 quarts of air per day. Each quart of air contains some 70,000 visible and invisible particles, which equates to a total intake of over a billion particles per day. When it is then considered that Environmental Protection Agency studies show that indoor air within a standard environment may be as much as 100 times more polluted than outside air, it is no wonder that the need for indoor air purification systems is becoming such an important topic. The necessity of air cleaning solutions is especially critical in healthcare environments, where higher concentrations of harmful or infectious micro-organisms are being emitted into the air.

When considering air purification systems, it is typical to evaluate the filter media, product efficiency claims, and the size and portability of the unit. What is less often considered, and yet is quite possibly the single most important factor in the success of any system, is the frequency of air changes per hour (ACH) that the system can create. The rate of ACH determines the rate at which the total volume of air in the room is cleaned by an air purification system, which is a major factor in the degree of air cleaning that can be achieved.

The Importance of ACH

There is no question that filter media selection is critical to the purification process, and also plays a role in determining a system's ability to create air changes, but it is also important to understand that without air changes indoor air cannot truly be cleaned. An air purification system can only clean air that enters the system, and the filtered air only remains clean as long as no new contaminants are introduced into the environment. Given these conditions, it becomes clear that the greatest benefit is achieved when the air in the room is being changed or processed more frequently, as clean air is then able to continually dilute the concentration of unwanted particles in the air. In essence, air changes create a compounding efficiency effect. After operating an air purifier in an undisturbed environment for a period of time, the total air volume in the room will be replenished with clean air, which eventually allows all of the air in the room to be cleaned to the efficiency level of the air purification system.

While there are few instances where air purification will be implemented in this manner, it does become clear that in environments where new airborne contaminants are frequently added, such as medical facilities, there is a need for increased frequency of air changes. Given two systems with equivalent filter effectiveness, the unit with a higher ACH rating will improve the air quality of a room in much less time, which is important, when considering how a large proportion of nosocomial infections are spread. Micro-organisms such as mycobacterium tuberculosis, measles virus (i.e. rubella), and small pox virus (i.e. variola major) are released into the air as individual droplets via oral or nasal secretions from infected individuals. These infectious airborne disease particles become suspended in the air, where they dry and become attached to other airborne material creating much larger particles called droplet nuclei that are between one and five microns in size. These larger infectious particles can then remain in the air for much longer than the individual micro-organism droplets. The good news is that with proper air circulation and filtration these larger particles can be removed from the air by air purification systems. By increasing the frequency in which an air purification system changes the air in a given environment, it is possible to decrease the concentration level of the most common airborne infectious disease particles in a given space, which helps to protect the health of the staff, visitors and patients of medical facilities.

Figure 1 depicts the types of particles that can be cleaned from the air utilising air purification systems. Most high efficiency particulate arresting (HEPA)-rated systems can remove particles 0.3 microns or larger, although system airflow and efficiency ratings vary.

Defining ACH

Now that the critical importance of air changes to the reduction of airborne particulate has been established, the focus moves to defining and creating indoor air circulation. ACH is defined as, "A value representing the number of times each hour that an enclosure's total volume of air is exchanged with fresh or filtered air."[1] This is not to say that an air change represents

Figure 1: Particle Size Chart

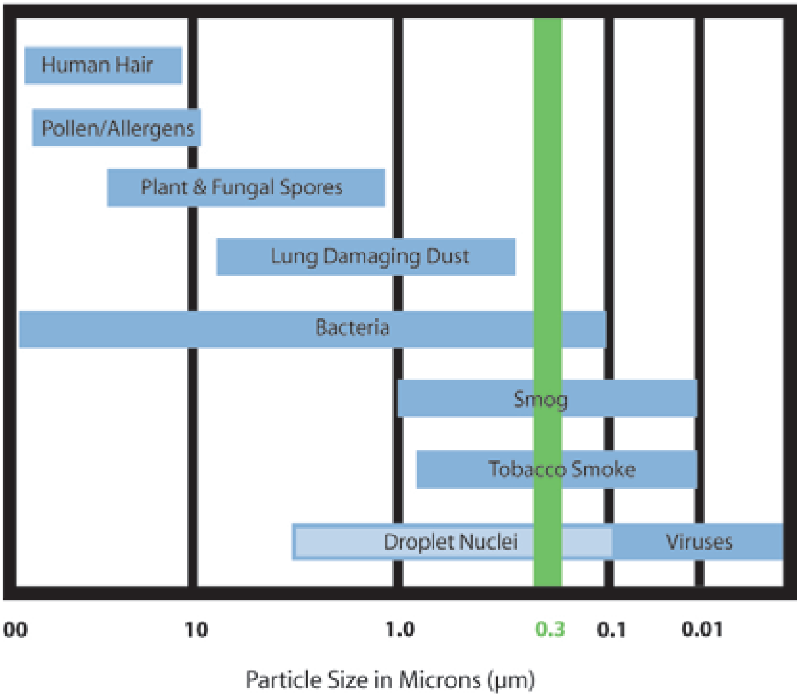

Table 1: Recommended Minimum Total Air Changes per Hour

Area	ASHRAE Handbook (1999) Min. Total Air Changes per Hour
Operating Rooms (recirculating air system)	25
Delivery Rooms (recirculating air system)	25
Recovery Rooms	6
Nursery Suite	12
ICU	6
Patient Rooms	4
Medical Procedure/Treatment Rooms	6
Autopsy Rooms	12
Physical Therapy	6
Positive Isolation Rooms	15
Negative Isolation Rooms	6

Source: Pawangkarat, Chakrapan. "Airborne Infection Control for Hospitals"
http://www.thaihvac.com/

removal of all unwanted particles from the air. Instead, an air change represents a complete recycling of the air in a given space through some form of filtration or ventilation, the efficiency of which is determined by the method used to cycle the air.

This definition provides an important piece of criteria for evaluating air purification systems. A system must be designed in such a way that it can pull all of the air in the given space through the system in order to create true air changes. The most contaminated air in any room is typically found from ground level to six feet from the floor. The reason for this is that air particles typically follow the path of least resistance, allowing gravity to pull heavy particles downward. In order to intake the most polluted air, the air purification unit is therefore most efficient if placed on the floor. Allowing for this fact, systems should exhaust clean air upward out of the unit so that the air at the upper levels of the room is displaced by the clean air. The unclean air will then move downward into the air circulation path created by the system. This air circulation pattern is the most effective pattern for achieving ACH in a given space. Another reason to have clean air exhausted upward from a portable air purification system that intakes air from floor level is that if the system's intake placement is too close to the area where clean air is exhausted, the clean air can be drawn back into the system for cleaning a second time, which creates a situation where the air purification system repetitively cleans the same air.

Another key criterion for evaluating air purification systems is the cubic feet per minute (CFM) of air that a system can output. The US Department of Health and Human Services Centers for Disease Control and Prevention (CDC) recommends that healthcare facilities, "Select portable HEPA filters that can re-circulate all or nearly all of the room air and provide the equivalent of >12 ACH". *Table 1* lists recommendations for several specific medical facility locations.

The number of ACH that a system can generate is calculated by dividing the CFM that a system can generate by the cubic feet of the space and then multiplying that number by 60 minutes (see *Figure 2*) For example, if an average air purifier has a clean air output of 150 cubic feet per minute and is placed in a room with the dimensions of 12' W x 15' L x 8' H,

Figure 2

$$\text{Number of Air Changes per Hour (ACH)} = \frac{\text{Airflow of Air Cleaner in Cubic Feet per Min. (CFM)} \times \text{60 Min.}}{\text{Cubic Footage of Area } (L \times W \times H)}$$

the unit needs to clean 1,440 cubic feet of air. Utilising the formula, it is determined that the unit will complete six ACH or roughly one air change every 10 minutes. In order to meet the CDC recommendation within this sample space, the system selected has to have a total clean air output of 300 CFM, which could be met by selecting a single unit that can produce 300 CFM or placing two units in the space.

Increasing the Frequency of ACH

Thus far, the basic principles of ACH have been explored; and several simple ways to evaluate air purification systems in terms of the ability to circulate the air in a given space have been discussed. What is of more interest are the ways in which air purification systems can be designed to create greater airflow and thereby increase the frequency of ACH that a single unit can provide. There are a number of design factors that determine the CFM and ACH a system can output. The most important factor is the selection and placement of filters within the system. As stated previously, the CDC recommends the use of HEPA filtration in medical environments in order to clean the air.

HEPA filtration technology was designed during World War II (WWII) by the Atomic Energy Commission to remove and capture radioactive dust particles in order to protect the human respiratory system. HEPA filters are rated to remove up to 99.97% of all particles 0.3 microns in size or larger, which encompasses most non-viral airborne particles. HEPA filter media also has important efficiency properties that are critical to successful air purification solutions. Not only is the filter media efficient at cleaning the air that passes through the filter, but it is designed in such a way that as particles are captured on the surface of the filter the cleaning efficiency of the filter actually increases before eventually decreasing as the filter becomes filled with particulates.

There is also a new type of filter media called high airflow particulate arresting (HAPA™) that further improves on HEPA technology and can help systems achieve increased air circulation. Like its WWII-era predecessor, HAPA is also rated to remove up to 99.97% of all particles 0.3 microns in size or larger. This filter media is constructed of a totally synthetic melt blown fibre material that is more durable than traditional HEPA filters. It has also shown greater depth loading capacity[2] than HEPA-rated filter material, which means that more particles can collect on the filter surface before the efficiency of the filter begins to decrease. Most importantly, HAPA is less restrictive to airflow than HEPA, which means that systems utilising HAPA filter media are capable of achieving higher CFM output than systems utilising HEPA filtration.

Once the filter media is selected, the placement of the filters, both in terms of filter order and spacing within the system, must be considered as both factors contribute to the level of CFM that a unit can produce. There is no way to define the correct design of an air purification system, but evaluating the way in which airflow is created and restricted by the filter media is one way to better understand the ACH and the efficiency that can be achieved with the unit. The one known truth about filter placement is that the presence of pre-filters within air purification systems is critical to protecting the efficiency of the system. By removing larger particles from the air before the air is cycled through the HEPA or HAPA filter media, higher airflow levels can be maintained for longer periods of time.

Selecting the Right Air Purification System

Creating a clean and safe indoor environment is a complex task. Selecting the correct air purification system is an integral part of this task, and requires a complete understanding of both the environment and the required results. The CDC recommends that healthcare facilities, "Situate portable HEPA units with the advice of facility engineers to ensure that all room air is filtered". Regardless of the process followed to evaluate an air purification system, one thing is clear. Creating ACH is the key to providing a clean air environment. Systems that can provide the recommended frequency of ACH for a medical facility will exponentially improve the quality of the air that is shared by the facility's patients, visitors and staff. ■

1. *www.energyvortex.com*
2. *based on recent testing completed by the manufacturer.*