Portable Air Cleaners and Air Changes per Hour

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ASSOCIATION OF HOME APPLIANCE MANUFACTURERS

Leadership ➤ Knowledge ➤ Innovation

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ABOUT THE ASSOCIATION OF HOME APPLIANCE MANUFACTURERS

AHAM represents manufacturers of major, portable and floor care home appliances, and suppliers to the industry. AHAM's membership includes over 150 companies throughout the world. AHAM members employ tens of thousands of people and produce more than 90% of the household appliances that are shipped for sale within the United States. The factory shipment value of these products is more than $50 billion annually. The home appliance industry, through its products and innovation, is essential to consumer lifestyle, health, safety and convenience. Through its technology, employees and productivity, the industry contributes significantly to the US job market and the nation's economic security. Home appliances also are a success story in terms of energy efficiency and environmental protection. The purchase of new appliances often represents the most effective choice a consumer can make to reduce home energy use and costs.

AHAM is also a standards development organization, accredited by the American National Standards Institute (ANSI). The Association authors numerous appliance performance testing standards used by manufacturers, consumer organizations and governmental bodies to rate and compare appliances. AHAM's consumer safety education program has educated millions of consumers on ways to safely use appliances such as portable heaters, clothes dryers, and cooking products. The AHAM Verifide® program provides independent testing by verifying the volume, energy, and in some cases, performance of common household appliances to ensure they will perform according to manufacturers' stated claims.

Introduction

Millions of people around the world rely on air cleaners to improve the air quality in their homes, offices and schools. Physicians often recommend air cleaners to help allergy sufferers reduce symptoms. Air cleaners are increasingly touted by experts as part of a plan to reduce the transmission of airborne illnesses. In areas affected by wildfire smoke, room air cleaners are important appliances to improve indoor air quality. The COVID-19 pandemic triggered a surge in interest in indoor air quality, and consumers should familiarize themselves with two measurements that will allow them to both compare models and verify that manufacturers' claims about air cleaner performance are legitimate. Those measurements are the Clean Air Delivery Rate (CADR) and air changes per hour (ACH). CADR and ACH are established through rigorous science-based testing and are widely accepted metrics for demonstrating how an air cleaner will perform in a given room size. Knowledge of both of these measurements will help consumers choose a model best suited for their situation. This paper focuses on the importance of air changes per hour, which relates to how long it takes for an air cleaner to fully circulate the air in a given room.

Portable Air Cleaners and Air Changes per Hour

CADR

While this paper focuses on air changes per hour, CADR—Clean Air Delivery Rate—is the most important metric for measuring air cleaner performance. As the U.S. Environmental Protection Agency (EPA) states, CADR is a product of the fractional removal efficiency for a particular pollutant and the airflow rate through the air cleaner.[1] CADR is the volume of **clean air** provided by an air cleaner every minute. It is a measurement, proven through rigorous testing, of an air cleaner's ability to remove pollutants.[2] In general, an air cleaner with a higher CADR will be able to remove pollutants from the air at a higher rate than an air cleaner with a lower CADR.

To help consumers to choose an air cleaner suitable for their needs and the room where the air cleaner will be used, ANSI/AHAM AC-1 defines how CADR can be converted into a suggested room size.[3] A higher CADR translates to a larger suggested room size. Certified Clean Air Delivery Rates are stated only by air cleaners that have undergone the AHAM Verifide® testing process, which verifies that manufacturers' claims about the air cleaner's capabilities are legitimate.

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[1] https://www.epa.gov/indoor-air-quality-iaq/introduction-indoor-air-quality

[2] https://ahamverifide.org/wp-content/uploads/2020/06/Air-Cleaner-Performance-FAQs.pdf - Clean Air Delivery Rate (CADR) is a measure of the reduction rate (cleaning speed) of specific particulates by an air purifier or other filtration system in a controlled environment. CADR is measured in cubic feet per minute or in cubic meters per hour. Three particles (engineering tobacco smoke, fine dust and paper mulberry pollen), representing fine, medium and large particles respectively, are cited in AC-1 and used for CADR testing of air cleaners. The higher the CADR numbers, the better the overall ability of the unit to clean your indoor air and the faster the air in the room will be cleaned.

[3] https://ahamverifide.org/wp-content/uploads/2020/06/Air-Cleaner-Performance-FAQs.pdf - The maximum suggested room size of an air cleaner can be calculated by knowing the CADR from the smallest particle or smoke test. The Room Size is determined by mathematical modeling the steady state and is based on the CADR baseline requirement to remove 80% of cigarette smoke particles between 0.1 and 1.0 micrometer on a steady-state (continuous) basis. This gives the consumer a way to relate CADR to the square feet or square meters of a room. Room Size (ft_2) = CADR (Smoke) x 1.55; Room Size (m_2) = CADR (Smoke) x 1.55 x 0.093.

The air cleaner's CADR, and its accompanying suggested room size, are two of the factors used to determine the air cleaner's air changes per hour (ACH). Air cleaners that carry the AHAM Verifide® Mark have a suggested room size based on 4.8 air changes per hour, which is the minimum equivalent air exchange necessary for an air cleaner to keep up with unfiltered air entering the room. AHAM recently updated its label to state that the AHAM suggested room size is based on 4.8 ACH.

Air Changes per Hour

Air changes per hour (ACH) is a term typically used in determining outdoor air flow into buildings. Air exchange is tied to refreshing oxygen content and NOT measuring cleaned air. Minimum ACH levels are required in construction to prevent oxygen starvation for interior spaces. However, due to the COVID-19 pandemic, there has been more interest in clean air changes provided by an air cleaner. Some references state filtered air can be considered in terms of equivalent air changes per hour (ACHe) and added to the ACH from outdoor air.[4]

Why is ACH Important?

People spend up to 90 percent of their time indoors and having clean indoor air to breathe is essential.

For consumers, ACH is a way to tell how often the air in their room is circulated. A higher number of air changes presents more opportunities for pollutants to be removed. Modern homes are built to minimize energy losses and maximize energy efficiency. While this may be beneficial for electricity costs, it reduces the rate at which allergens and pollutants are removed from homes. The EPA estimates indoor air pollutant levels are two to five times higher than outdoor pollutant levels.[5] High levels of pollutants and allergens can trigger asthmatic and allergic reactions.

How ACH is Calculated

The ACH calculation is based on an air cleaner's ability to reduce the concentration of pollutants in a room appropriate for the air cleaner's size by 80%. The calculation is based on one air change per hour, with a recirculation fan providing complete mixing of air in the room.[6] More importantly, the air cleaner

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[4] https://jamanetwork.com/journals/jama/fullarticle/2779062?guestAccessKey=c2d6071f-60f1-45fa-bfea-e55ecc565fbe&utm_source=silverchair&utm_campaign=jama_network&utm_content=covid_weekly_highlights&utm_medium=email
Filtered air can therefore be considered in terms of equivalent air changes per hour (ACHe). Increasing air changes per hour and air filtration is a simplified but important concept that could be deployed to help reduce risk from within-room, far-field airborne transmission of SARS-CoV-2 and other respiratory infectious diseases. Healthy building controls like higher ventilation and enhanced filtration are a fundamental, but often overlooked, part of risk reduction strategies that could have benefit beyond the current pandemic.

[5] https://www.epa.gov/iaq-schools/why-indoor-air-quality-important-schools#:~:text=EPA%20studies%20of%20human%20exposure,percent%20of%20their%20time%20indoors EPA studies of human exposure to air pollutants indicate that indoor levels of pollutants may be two to five times — and occasionally more than 100 times — higher than outdoor levels.

[6] https://ahamverifide.org/wp-content/uploads/2020/06/Air-Cleaner-Performance-FAQs.pdf - For AC-1, test chambers use a ceiling fan mounted in the center of the ceiling to stir or mix the pollutants before testing. In the AC-1 test, this fan is shut off during the

continues to keep the pollutant concentration at this level even with an influx of polluted air from ventilation, household activities etc.[7] For the air cleaner to be able to keep up with unfiltered air entering a room with the suggested room size, the air cleaner must deliver an amount of clean air (CADR) sufficient to deliver clean air in the room 4.84 times per hour.

$$\text{ACH} = \frac{\text{Smoke CADR} \times 60 \text{ minutes}}{\text{8ft ceiling height} \times \text{Suggested room size}}$$

$$\text{Installing in the suggested room size calculation ACH} = \text{Smoke CADR} \times \frac{60}{8 \times \text{Smoke CADR} \times 1.55} = 4.84 \text{ /h}$$

AHAM rounds the 4.84 down to 4.8. The suggested room size stated on the seal of an AHAM Verifide® air cleaner is always based on the air cleaner's ability to clean and circulate the air in the room 4.8 times per hour.

If the air cleaner will be used in a room larger than the suggested room size, the number of air changes per hour will be less than 4.8, and the pollutant concentration in the indoor air will be higher. The opposite applies if an air cleaner is used in a room smaller than the suggested room size where the actual air cleanings and circulation per hour will be greater than 4.8. An air cleaner with a higher CADR will be able to remove pollutants from the air at a higher rate than an air cleaner with a lower CADR. The number of air changes an air cleaner can deliver based on its smoke CADR is determined through the following formula.

$$\text{ACH/ACHe in room} = \frac{\text{Smoke CADR} \times 60}{V}$$

where, V = Room volume (cubic feet or ft^3) of planned location of the air cleaner.
ACH/ACHe = Number of Clean Air Circulations/Filtered Air Changes per Hour

Also, the air cleaner performance can be looked at from the room size perspective when keeping air changes constant. The following equation shows how large a room the product can be placed in based on the desired number of air changes and the Certified CADR rating:

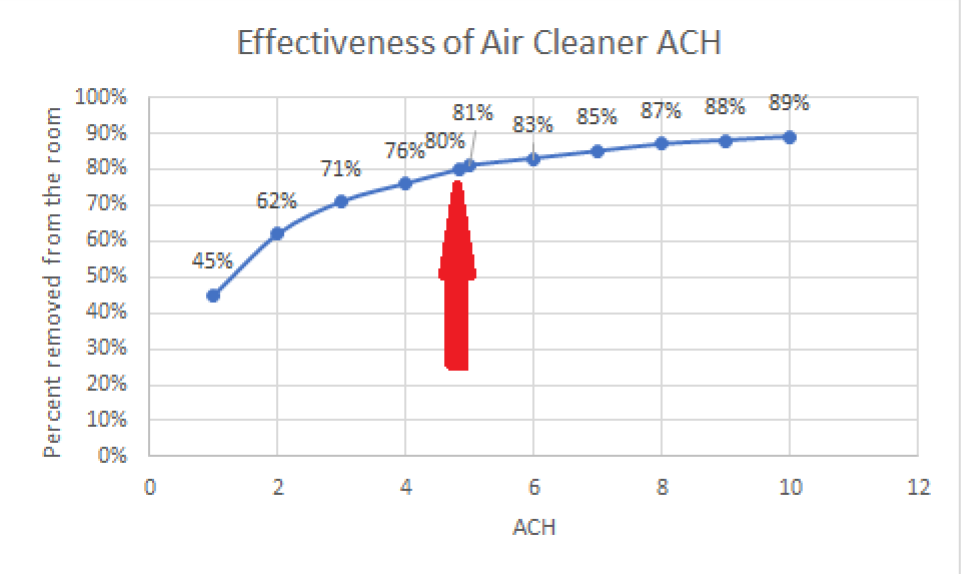
$$\text{Room Size} = \frac{\text{Certified Smoke CADR} \times 60}{\text{ACH} * \text{8 Feet ceiling}}$$

test. A continuously operating recirculation fan assures uniform mixing of the contaminants during the entire set of tests. The recirculation fan is mounted out of the air stream against a wall to reduce the chance of contaminants gathering in a corner. The recirculation fan runs for all tests whether the air cleaner is operating or not. This recirculation fan does not contribute to the measured performance of the air cleaner but creates a fair and comparable environment for small, medium and large air cleaners so that consumers can equally compare the results of all air cleaners.

[7] https://ahamverifide.org/wp-content/uploads/2020/06/Air-Cleaner-Performance-FAQs.pdf - The suggested Room Size for an air cleaner is based upon the CADR obtained for reducing engineered cigarette smoke concentrations (See Annex E of the standard). The Room Size is based upon the ability of the air cleaner in smoke CADR to reduce the concentration of particles by 80 % in a room at steady state to a new steady-state when the air cleaner is operating. This includes contributions from room sources and infiltration of air from outside as well as other rooms connected to the one where the air cleaner is in use.

Suggested Room Size

The suggested room size for an air cleaner is based upon the CADR obtained for reducing engineered cigarette smoke concentrations. The room size is based upon the ability of the air cleaner to reduce the concentration of smoke particles by 80% in a room to a new steady-state when the air cleaner is operating. This includes contributions from room sources and infiltration of air from the outside as well as from other rooms connected to the one where the air cleaner is in use. The following chart demonstrates that the effectiveness of an air cleaner could vary between 40% of the particles removed at one air change per hour and up to 89% of the particles removed at 10 air changes per hour. This relationship between cleaning rate in CADR and room size to clean to the 80% level has been verified by scientists at the National Institute of Standards and Technology (NIST) and recognized as reasonable by the U.S. Federal Trade Commission.



Air cleaner ACH	% removed
1	45%
2	62%
3	71%
4	76%
4.84	80%
5	81%
6	83%
7	85%
8	87%
9	88%
10	89%

When comparing air cleaners a consumer should consider the number of air cleaner air changes per hour for the room that the air cleaner can provide. An ACH/ACHe of at least 4.8 is recommended for the room size where the air cleaner is to be placed or the air cleaner might not be able to actually lower the pollutant concentration adequately. Harvard University and The University of Colorado-Boulder have created a spreadsheet[8] to help with this analysis which is available in this link. Please note that the ratings in the link are **total** air changes[9], which include the ACH provided by the HVAC in addition to the ACH/ACHe from the portable air cleaner.

[8] https://docs.google.com/spreadsheets/d/1NEhk1IEdbEi_b3wa6gI_zNs8uBJjlSS-86d4b7bW098/edit#gid=1882881703

[9] An ACH rating of 6 is ideal for ventilation as identified in a 5-Step Guide to Checking Ventilation Rates in Classrooms, Harvard T.H. Chan School of Public Health, https://schools.forhealth.org/wp-

Wildfires Have Changed the Rules (slightly)

Due to the level of pollutants that can be found in wildfire smoke and that it is above the normal polluted air in a city and in a home, AHAM has changed the recommendation for room size. For a wildfire, the recommendation changed from room size (sq ft.) = 1.55 times smoke CADR to Room Size = Smoke CADR. This means:

1. The load seen by the air cleaner is reduced by 35% (1-1/1.55). This will provide additional life on the filter which is critical with the wildfire smoke.
2. This revision will raise the % removal from 80% to 86% in the room size. This is a 7.5% increase in removal but more importantly moves the air cleaner air exchange rate from 4.8 ACHe to 7.5 ACHe. This is just over a 50% increase in the equivalent air change rate.

Conclusion

When focusing on Indoor Air Quality (IAQ), consumers comparing air cleaners need to consider CADR/ACH together - the number of air changes per hour and clean air delivery rate suitable for the room. Of the two, CADR tips the scale of importance in air cleaner metrics, as it is used to derive other measurements – recommended room size or air changes per hour based on a fixed room size. Every AHAM Certified Air Cleaner that is used in a room of its suggested room size will deliver 4.8 air changes per hour. Frequent air changes will remove harmful particulates from the room. As the number of air changes per hour increase/become more frequent, the more harmful particulates that are removed.

content/uploads/sites/19/2020/08/Harvard-Healthy-Buildings-program-How-to-assess-classroom-ventilation-08-28-2020.pdf