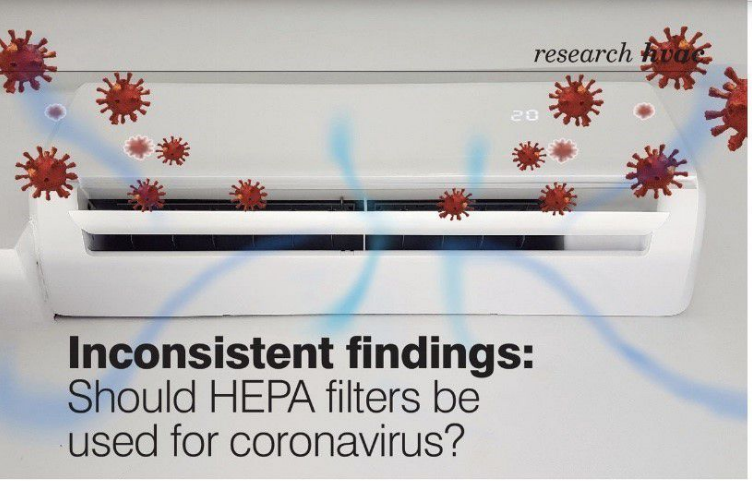


Inconsistent findings: Should HEPA filters be used for coronavirus?

Together with the COVID-19 pandemic, the complexity of the previously presented inconsistencies, leaves its mark on the current rewriting of the science of microbial flow and aerosol by air

Written by Serdar Tuncer

The currently available evidence is strong enough to warrant that the importance of engineering designs that minimise airborne transport of microparticles as well as the benefits of personal protective equipment in limiting the risk of indoor infection spreads.

The gradually accelerating number of buildings is increasing together with population growth and urbanisation. Among these structures, the most effective spread in epidemic situations occurs with the high crowd and human traffic. The vast majority of such structures focus on comfort and savings rather than air biosafety.

Small biological particles such as the COVID-19 virus are considered to act like gas or tiny bubbles that can be suspended in the air and can easily travel between individuals and their environment in the form of an aerosol or small droplet nuclei. Aerosols are too small to descend to the ground rapidly by gravity. Droplet nuclei that sit on the surfaces after evaporation gain momentum with air movements and re-spread into the indoor air (see Figure 1). Likewise, the particles in the droplets trapped in standard surgical masks penetrate the indoor air with exhalation after evaporation in seconds. Therefore, the long-range transmission by aerosol inhalation play an important role in epidemics and increase in parallel with the number of people and uncontrolled air movements independent of social distance.

Submicron particle management becomes more important and priority in terms of hygienic air quality in indoor environments. The knowledge obtained from more than 60 years of experience in cleanroom technologies and having air cleanliness standards will enable an important step to be taken during the epidemics experienced by humanity.

Since high-efficiency particulate air (HEPA) filtration is not used in the traditional ventilation systems, sub-micron particles cannot be cleaned efficiently and are distributed to all spaces by air movements. HEPA filtration is still the most effective technique for reducing the submicron particle number, which does not work as a simple sieve-like behaviour. HEPA filters can trap particles such as viruses smaller than 0.3 µm and light in mass with higher efficiency. Considering the COVID-19 infectivity carried by aerosols occurs within 30 minutes, removing submicron particles from the indoor environment in time is the most important criterion in ensuring hygienic air quality.

Mechanisms of prevention

This article focuses on mechanical ventilation properties and particle filtration efficiency in preventing the transport and dispersion of viral particles in indoor air. Air fluid dynamics is the main technology exploited for efficient filtration by providing proper momentum and direction to the particles. Advanced engineering details and other physical properties that affect cleanroom applications are beyond the scope of this article. A main criterion is the air change per hour (ACH) value where the number of ACH increases, so filtering and dedusting performance increases.

Considering the interest in outbreaks, such as COVID-19, the cleaning time for over 90% of submicron particles to be removed from the room air occurs in less than 30 minutes by applying over 4 ACH rate of HEPA filtrated air.

Most of the existing buildings in the world use a central ventilation system. Although it is difficult to reach an optimum solution retrospectively, it is possible to revise the operating systems. The localisation of indoor air supply and suction grilles in traditional central ventilation systems and their airflow movements are schematised in Figure 2. The ceiling-fed and bottom-suction airflow model is close to cleanroom technology applications for spaces without high ceilings (under 3-4 meters). Air exchange only from the ceiling parts cannot create desired indoor airflow, and a ventilation short circuit occurs between the orifices (Figure 2a). On the other hand, air supply close to the floor will put the respiratory zone at higher risk by creating momentum to droplet nuclei with a high viral concentration on the ground surfaces (Figure 2b). It should be kept in mind that horizontal air currents created at levels close to breathing height may also increase the risk of cross-contamination from person to person.

In large spaces, gas and fine particles accumulated on the ceiling are removed more efficiently with ceiling level exhausts. The application of hybrid air flow techniques may be required for those architectures by applying computational fluid dynamics (CFD) calculations. Since engineering solutions for large and high-volume areas go beyond the scope of this article, the comments are limited to rooms with a ceiling height of less than 3-4 metres. Unless the airflow patterns in the spaces are arranged by the techniques suggested above, only HEPA filter implementation to the central air supply unit is an approach that cannot achieve the desired efficiency. When it is limited to spaces with low ceiling height, the particles are pushed downwards with the positive pressure created by the clean air created in the ceiling part and are swept away by negative pressure created in the floor part with the help of air suctions. These are the ideal indoor particle sweeping techniques (Figure 2c & 2d). Using specially designed air outlet diffusers, it is also possible to sweep the entire ceiling area and prevent the air vortexes formed in the corners (Figure 2d).

After providing a proper indoor airflow pattern, central ventilation system can meet hygienic air criteria in two ways. The HEPA filter to be placed at the outlet of the main air handling unit (AHU) or to the air supply outlet of each room. In both methods, existing AHU will not meet the power and air volume needs due to increased filter resistance and air leakages through long-distance air ducts. An additional AHU or capacity increase will be needed. Also, proper operation of the central system requires an advanced central control unit.

The local ventilation system operates independently with a group of parts consisting of fan- motor, air recirculation duct and filter, (FFU system) suitable for every interior. With the help of built-in designs, there will be no need for indoor ducting revisions. Before fresh air is supplied through ceiling-mounted HEPA fan units, recirculated air and conditioned air are mixed. This is flexible enough to provide engineering and architectural suitability for every location to adapt. Also, FFU systems have the availability of individual or integrated control and alarm systems.

The revision of indoor air ducts and suction vents required for both ventilation systems may not show a significant difference in total investment costs. The additional central air plant costs will be comparable to the number of FFUs suitable for the building's volume and rooms. Assuming that both solution methods meet the hygienic air performance criteria in this way, only maintenance and operating performance remain.

SOME SCENARIOS ENCOUNTERED DURING THE OPERATION WITH HEPA FILTRATION AND CORRECT AIRFLOW MODEL
Air Handling Unit (AHU) engine failure: Central system must keep a spare unit in such cases. Otherwise, the whole building becomes unusable. The fault only affects the room where the local system is located, and its correction is easier and cheaper than the central system.
Insufficient air supply or filter clogging: All building ventilation will be adversely affected in central systems. Since the local system works individually and has a filter compensation mechanism, they only allow intervention in the necessary rooms with the activation of the alarm.
Room pressuring needs: It may be necessary to prevent particle leakage into surrounding rooms by keeping the contaminated environments under negative pressure. Applying positive pressure in staff rooms can increase facility staff safety against unknown originated aerosols. In the central system, it is possible to create a pressure difference between air dampers and rooms. However, it is more difficult to automate and manage than easily compatible FFU systems that can control a smaller array of zones.
Avoiding unnecessary ventilation of rooms: Closing the ventilation of unused spaces or operating them in night/eco mode provides easier and unnecessary operating costs in FFU systems with the superiority of regional control.
New interior additions: The central system requires duct and culvert reconstruction. In such cases, the existing AHU may not meet the additional capacity requirement. A flexible and modular FFU system provides on-site solutions using only the necessary equipment for the new space.
Leaks in air ducts: Whether the HEPA filter is at the outlet of AHU or the indoor endpoint, since the distance that the air will travel will be much longer, more leaks will occur in the air duct. FFU systems have negative plenum designs where any leakage trapped in the plenum without reaching into the environment.
Energy consumption performance: All of the above-mentioned items increase the operating, maintenance, repair costs and the higher air volume need of AHU brings additional costs. Besides the air quality, local operating FFU systems need less air rate in providing temperature and humidity control.
Total operating cost: The high cost of HEPA filtered air conditioning compared to standard building ventilation can reach a very high overall total. The difference in energy consumption between the two systems increases up to 40%. When the additional maintenance and repair costs of the central systems are added to this, the loss as much as the facility's entire construction and mechanical installation cost arises over the years.

Figure 1: Demonstration of infective particle sources and spread of aerosolised submicron particles by indoor air movements

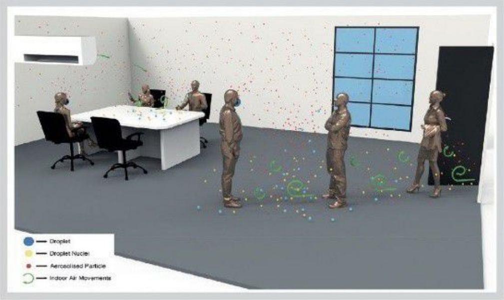
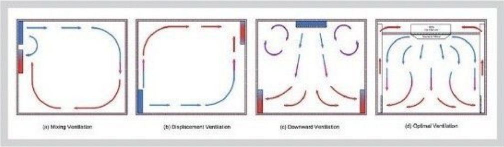


Figure 2: The localisation of indoor air supply and suction grilles in ventilation systems and schematisation of their airflow movements



> **Revision of air ducts and suction vents may not significantly change total costs**

Conclusion

In airborne microbial epidemics, the most effective spread occurs in closed environments with high human traffic. Creating a hygienic air environment in these environments is necessary to protect public health. Leaving aside the other parameters, the most basic criterion for providing a hygienic air environment is to remove sub-micron particles from the indoor environment in the fastest way.

Adapting and applying cleanroom technologies to traditional buildings can achieve the desired hygienic indoor air environment. The easiest and most efficient way to achieve this adaptation is possible with local ventilation systems using fan filter units.

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