

Can I trust the Air?: Designing for Pandemic Resiliency

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Breathing in fresh air is a vital part of keeping a human body healthy and help function at its optimal level. In fact, there have been many studies that have shown how the level of oxygen we breath in is directly correlated with attentiveness, focus and cognitive performance. At the same time, the advancements in the built environment, the technologies associated with human comfort we now find ourselves doing majority of the work inside an enclosed space. What still has not changed is the fact that we need to breath in clean air to stay healthy and productive.

Given the COVID-19 pandemic, we find ourselves at a pivotal point in history. We have been debating many topics related to health and productivity in an occupied space, including the type of HVAC systems, space air delivery methods, filtration levels, Outdoor air ventilation levels, etc. The timing could not be any more critical to prioritize these items as we reopen our shared spaces and start rebuilding the future workspace.

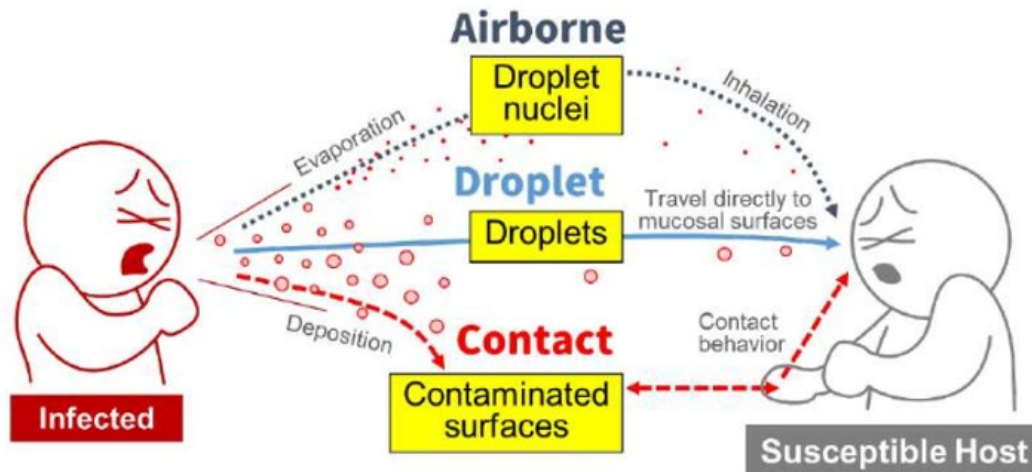
The focus of this article is to cover HVAC Systems, space air delivery methods and outdoor air ventilation. Filtration and air purification strategies will be covered in a separate article. However, before we consider what needs to be done, let's take a quick look at what we are dealing with.

Infection Control - Airborne Transmission through Respiratory Pathogens

As we can all imagine, this has been a hot topic of discussion. A lot of research has already gone into it and organizations like CDC, WHO and many industries leading HVAC System design consultancy firms are sharing their thoughts and findings. Below is an attempt to summarize them and draw some conclusion to outline considerations going forward.

There are three broad modes of transmission shown the following graphic. The one relevant to HVAC Systems will be Droplet nuclei (airborne transmission) as they tend to linger around in the air and can potentially travel with air currents.

The sketch below illustrates common modes of pathogen transmission



Modes of Transmission from Exhaled Pathogens (adapted from leaflet of the Office of the Prime Minister and the Ministry of Health, Labor and Welfare of Japan (2020))

(Taylor Engineering Covid-19 White Paper, 2020)

As per a leading HVAC System Consulting Firm in NYC

"As we talk, sing, shout, and laugh, we also spray a fine mist that remains aloft for hours, mixing promiscuously with the exhalations of others."

"There is strong likelihood that airborne transmission is happening, and every new piece of evidence supports it, and so far nothing has refuted it" (Davidson, 2020)

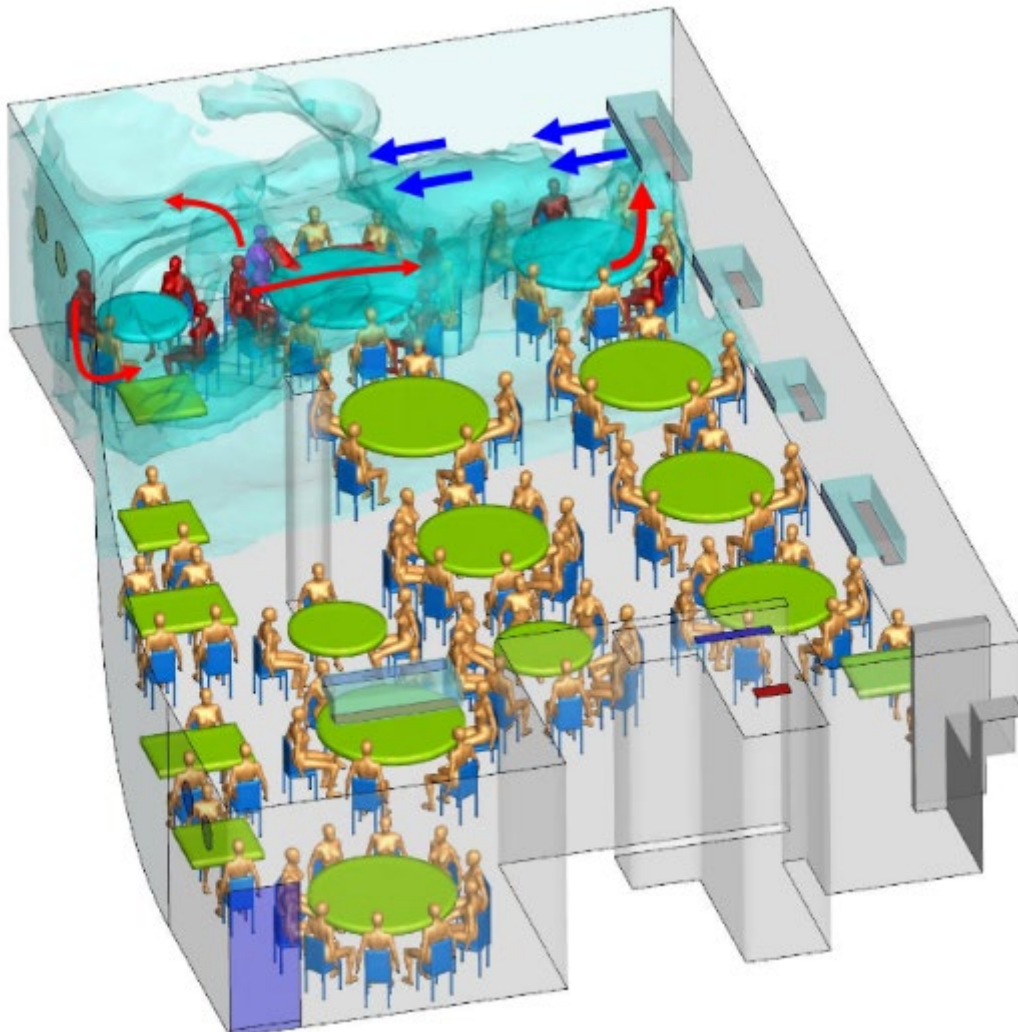
This would mean that an individual can only do so much to control their exposure. Handwashing, face-touching, mask-wearing, and social distancing will help but don't offer much when it comes to airborne transmission.

Restaurant Study:

Effects of a poorly designed HVAC system and possible airborne transmission were discussed in this [research letter](#) shared by CDC.

"The lighter droplets and aerosols were apparently distributed within the north side of the restaurant by a ductless fan-coil." (Taylor Engineering Covid-19 White Paper, 2020)

The sketch below illustrates airflow scenario at the northside of the restaurant



(Lu, 2020)

Notice the airflow direction out of the fan coil on the north side and potential exposure for all the occupants in the airflow range.

Call Center Study:

Another study ([Korean Call Center](#)) on CDC's website documents how, in the time period of a week, a single infected employee infected 94 of the 216 employees working on the same floor.

"While exact number of people infected by respiratory droplets and fomite transmission is unknown, the pattern of the infected workers suggests short-range aerosol transmission also was a factor." (Taylor Engineering Covid-19 White Paper, 2020)

The sketch below illustrates all the people infected over the week



(Coronavirus Disease Outbreak in Call Center, South Korea, 2020)

Notice how one side of the office is primarily infected, see blue workstations in the sketch above.

"These two studies suggest that "social distancing" may not be sufficient to prevent transmission due to transmission from smaller virus-carrying particles." (Taylor Engineering Covid-19 White Paper, 2020)

o To summarize the findings above, there are multiple modes of transmission for the COVID-19 virus

- Large Droplets (particles larger than roughly 5 to 10 microns).
- Contaminated surfaces.
- Droplet Nuclei (airborne particles smaller than about 5 micron).

And the above information from various studies and articles suggest that, while we go about addressing the first two, airborne transmission has to be considered to minimize an individual's exposure to the infection in a built environment.

Immune System - Space Relative Humidity

Our immune system is the most critical part of our defense mechanism against virus's like COVID-19. In fact, it's primarily our only hope when it comes to viral infections that we have not yet developed a vaccine for. While there are many biological and genetical ways to enhance it, the focus of this article is to discuss how HVAC systems can help.




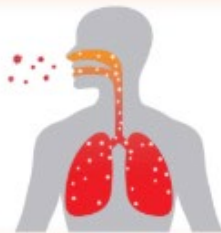




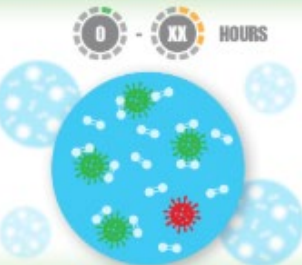
There has been a lot of research that has gone into space relative humidity levels and its impact on human immune system.

"There is overwhelming scientific evidence that mid-range air humidity has significant benefits for human health." (Taylor, n.d.)

Dr. Stephanie Taylor has been leading the charge with understanding the effects and what it really means for us. The matrix below from <https://40to60rh.com/> does a good job of showing the 3 keys reasons why we should always maintain 40 - 60 % RH in our spaces.

The mid-range humidity control enables effective functioning of our defense system allowing it to capture, remove and fight germs.

At the same time, it has shown to be helpful with reducing the "float" time for the airborne virus particles (by making them heavier) while allowing physiochemical reactions to deactivate the virus.

	 Respiratory immune system efficiency	 Virus "float" time	 Virus survival time
Dry indoor air 0-40%RH			
	Respiratory immune system's defenses are impaired, allowing viruses to infect us more easily	Airborne droplets containing viruses shrink by evaporation, are lighter and float for longer	Airborne droplets containing viruses dry, allowing the virus to survive for longer
Ideal indoor air 40-60%RH			
	Respiratory immune system's defenses function effectively, capturing, removing or fighting germs	Airborne droplets containing viruses retain moisture, are heavier and fall out of the air	Airborne droplets containing viruses retain moisture, allowing physicochemical reactions to deactivate the virus
Studies:	Kudo E. 2019 Salah B. 1988	Noti JD. 2013 Yang W. 2011	Noti JD. 2013 Yang W. 2012

(Taylor, n.d.)

This should be enough evidence for us to mandate 40 - 60 % RH as a part of a building OPR (Owners Performance Requirements). Whether we are dealing with a pandemic or not, maintaining the right RH in the space will go a long way in keeping the employees healthy and productive.

Having looked at what we are dealing with, it's time to discuss where we go from here.

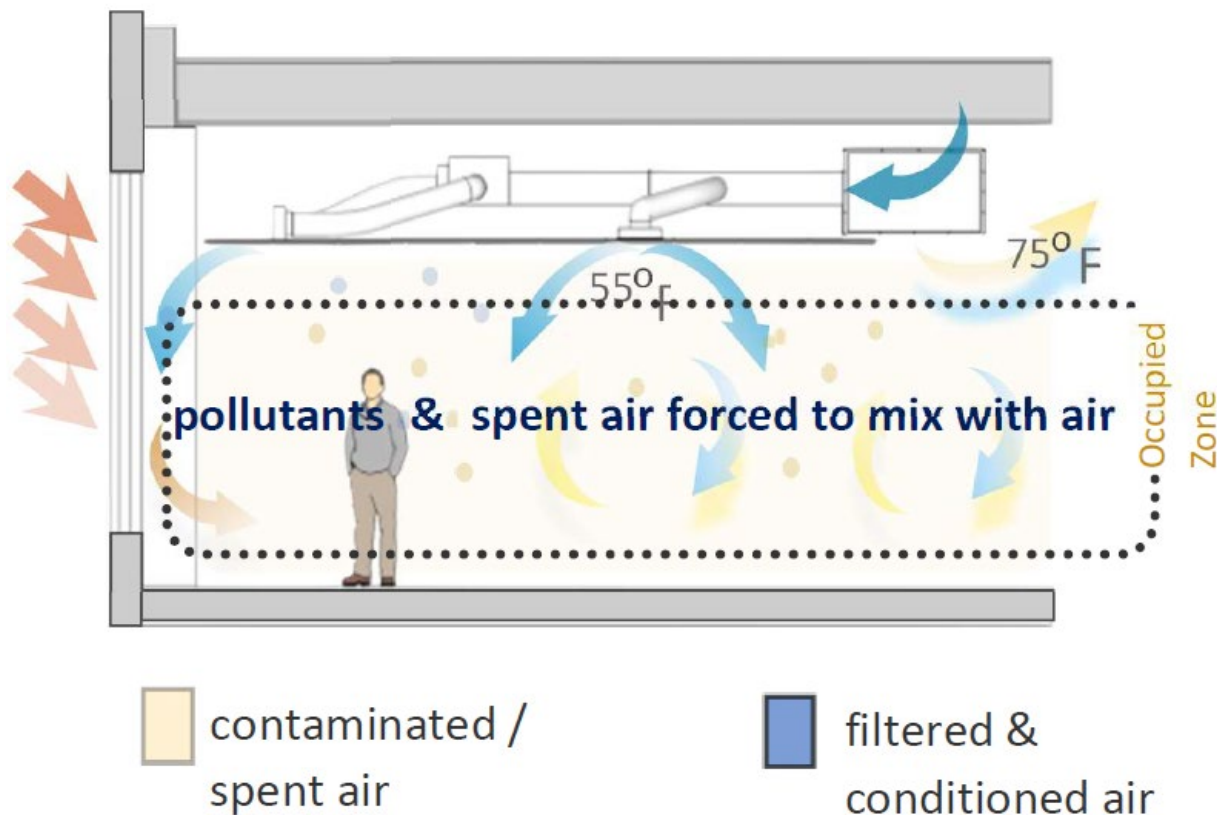
How can HVAC Systems help?

Given the discussion above, the need for HVAC Systems to minimize the airborne transmission and optimize space RH control has never been more important.

Our ability to create unique and large enclosed spaces has immensely evolved over the last few decades. We can create bigger, better and more functional spaces than we did 40 - 50 years ago. This includes systems like building envelopes, communication systems, interior finishes, ergonomics and many more. One aspect that has not evolved as much (or did not get as much attention) is the HVAC System type or the way we introduce air into our occupied spaces. By far, a large majority of our buildings still use the types of systems we did decades ago. Our go to solution still is to introduce the conditioned air at high velocities and mix it with room air as quickly as possible.

The sketch below gives us an illustration of what typical systems are designed to do.

Mixing with Overhead VAV

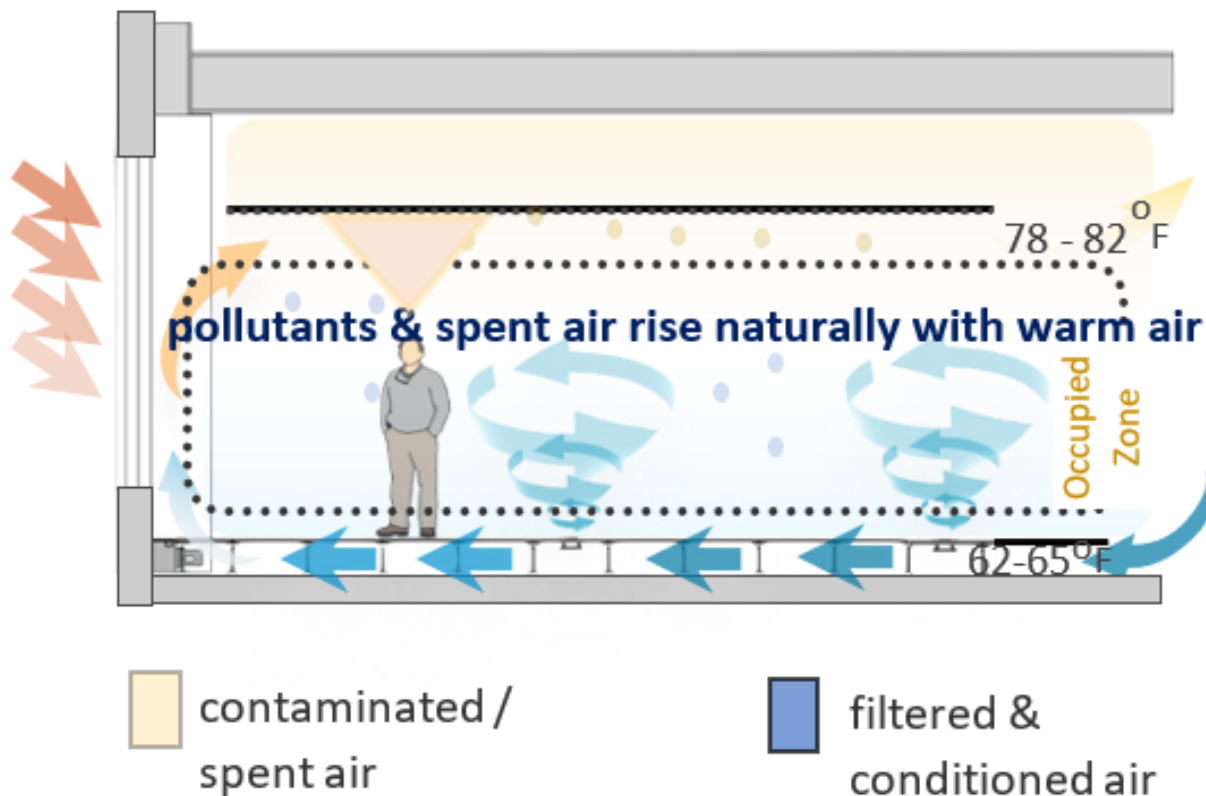


As you may notice, the high velocity air introduced at the ceiling level tends to create air currents that help mix the air quickly in the space. The drawback is that these movements can possibly enhance the particle air movement along with it. A well-designed mixed air system will have same particle count in the breathing zone as it will at the ceiling / return air grille level. This is not ideal when one of the goals is to minimize airborne transmission.

On the contrary, another way of conditioning the space could be to stratify the air in the space in lieu of creating mixing (per the traditional air delivery method). These types of systems introduce the air at the low / floor level through lower velocity air outlets. The air then rises to the ceiling level as it picks up heat from the occupants and other equipment. This is also known as "The Buoyancy Effect". Essentially, hotter air is lighter and naturally rises to the highest level in the occupied space. This creates both temperature and particulate stratification in the space, higher concentration of airborne contaminant at the ceiling / return grille level compared to the breathing zone. The hotter and older air will rise to outside the occupied zone replaced by fresher / cleaner / conditioned air introduced at the low / floor level. This brings some unique system benefits like minimizing airborne transmission exposure, improving ventilations effectiveness and reducing energy consumption.

The sketch below illustrates how stratification / UFAD can help minimize the risk of airborne transmission.

Stratification with UFAD



As stated in the article link below the President at one of the largest HVAC System consulting firms in the world says,

"Displacement or underfloor air distribution (UFAD) systems can minimize air currents and the horizontal movement of air. UFAD systems basically create an air zone per occupant workstation."

As referenced in the article below, the Head of building services for WSP adds,

"Using displacement (another term for stratified) systems is not particularly new, but interest has been increasing as we've realized how energy efficient it can be. It's the thing we default to now." (Can Better Indoor Air Fight Covid-19?, 2020)

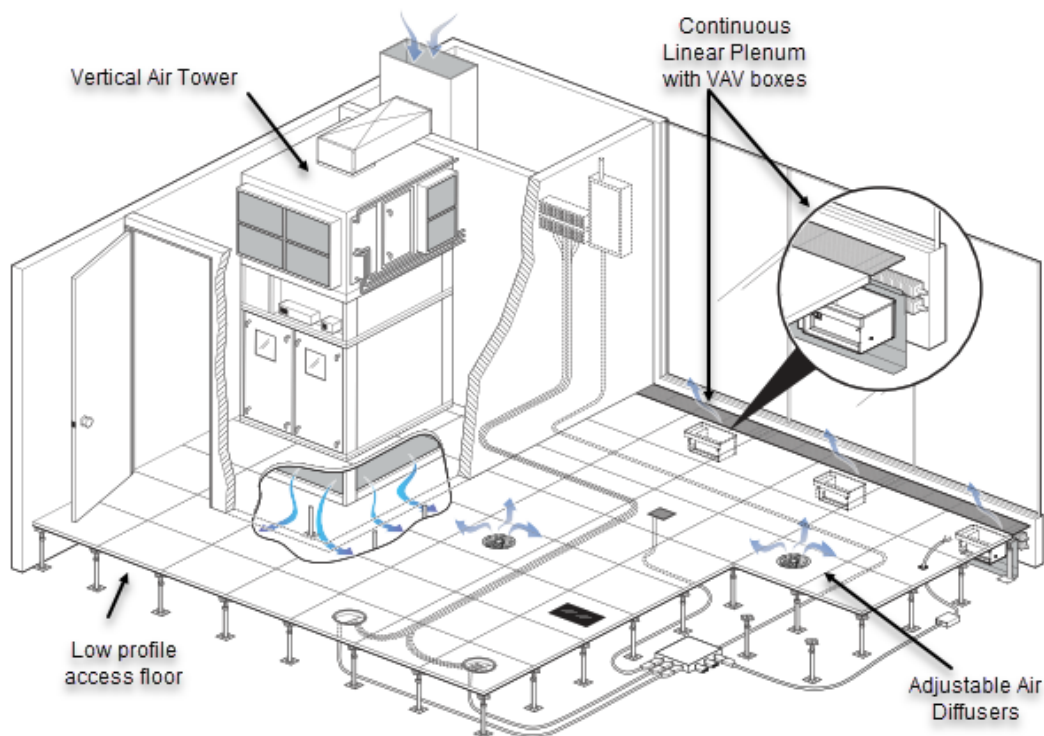
There are technologies like natural ventilations and other that are being discussed as well. While they seem like a good idea on the surface, they bring unique challenges like who gets to sit next to the window with positive wind flow and what happens when the wind brings airborne contaminants to the occupants downstream of the wind direction.

From the Relative Humidity perspective, the UFAD systems can be designed to decouple the humidification / dehumidification cycle. For example, Vertical Air Towers can be employed to provide space sensible cooling while the DOAS units does all of the latent cooling. This provides higher degree of control especially when trying to keep the RH from getting too high in the space. Also, humidifier can be incorporated into these units for the winter season to prevent the RH from going too low.

The more you think about it, the more you come back to the stratified / UFAD system. It's ability to provide control and localized environment is what makes it a good fit.

As an industry we need to look beyond the usual and consider systems like underfloor air distribution (UFAD) to create the safest environment for our workforce. These technologies have come a long way and don't necessarily cost any more than the traditional system. In fact, as a developer or building owner you can rightfully market the benefits of these systems to make employees feel safer and attract better talent. At the same time, they offer many other benefits like higher productivity levels and energy saving potentials.

The sketch below illustrates a Vertical Air Tower interacting with the UFAD system and a Vertical Outside Air Shaft



Works Cited

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