Safer, Healthier Buildings

Lessons from the Healthcare Industry

Companion Document

This is a companion document to complement Willdan's presentation on Safer, Healthier buildings. If you or your organization would like to discuss this information or see the presentation, don't hesitate to reach out to me:

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What we'll Cover & Why This Presentation + Handout

- How can HVAC, UV lighting, and other building systems help control the spread of infection inside your buildings?
- Should you be upgrading your filters?
- Increasing your outside air?
- Can these measures do more harm than good?

Drawing on healthcare standards, healthcare best practices, and peer-reviewed data on how infections spread, we will help you understand how pathogens such as COVID-19 move through your buildings and how engineered systems can contribute to safer, healthier buildings.

There is a lot we don't know about COVID-19, but the healthcare industry has been working to understand and prevent the spread of infection for decades. We can use these strategies in combination with what we do know about COVID-19 to reduce the transmission of infections in your buildings and help everyone in your buildings stay healthy and productive.

COVID-19 has changed the way we all think about indoor air quality and staying healthy while indoors and around others. There is no silver bullet to safer, healthier buildings, despite what any spam e-mail or product promotion might suggest. The advice from State and Federal authorities lacks clarity, and while it might inform facility managers on **what** to do, it does not share **how** to do it.

Everyone is making administrative interventions to make their buildings safer: policies on masks, handwashing and social distance; plexiglass barriers; and advanced cleaning regimens. How can engineered building systems contribute to safer, healthier buildings? How can we use the catalyst of the COVID-19 pandemic to make our communities safer not just now from COVID-19, but in the future from COVID-19, flu, tuberculosis, the common cold, and other communicable diseases?

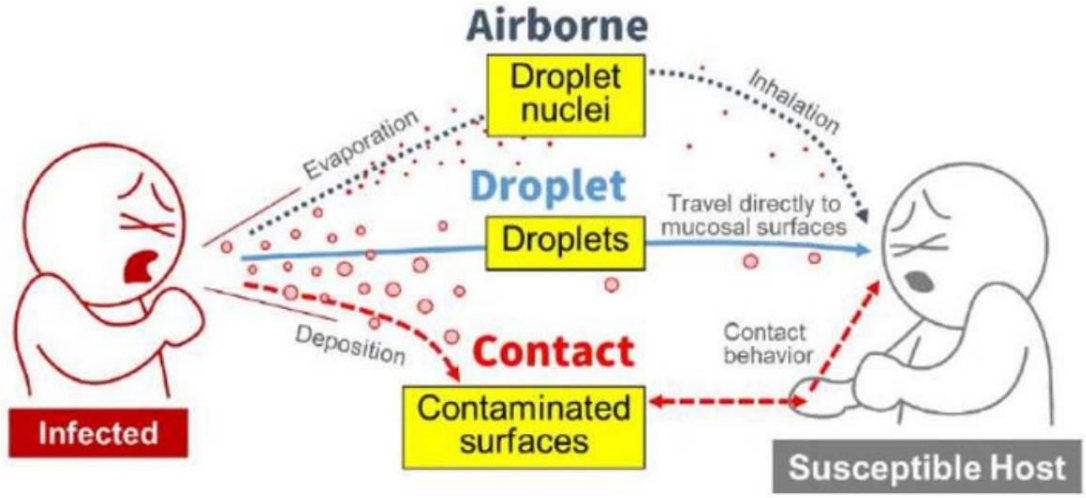
Luckily, we don't have to reinvent the wheel. The healthcare industry has been thinking about how to create safer, healthier buildings for over 100 years. Drawing on healthcare industry standards and peer-reviewed research, we will learn:

1. How Infection Spreads in Buildings
    a) Droplets, person to person (direct)
    b) Droplets, person to surface to person (indirect)

    c) Droplet nuclei (airborne)
2. How to Reduce the Spread of Infection
    a) Help droplets stay droplets and fall to surfaces
    b) Disinfect surfaces
    c) Prevent aerosolization and dilute, filter or disinfect indoor air
    d) Support the immune system
3. Building System Strategies that Create Safer, Healthier Buildings
    a) Ventilation
    b) Disinfection
    c) Filtration
    d) Humidity
4. Recap & Recommendations

How infection spreads, and how to reduce the spread of infection

Transmission Factor	Design Objective
Direct (droplet)	Masks & plexiglass barriers; social distance policies; reduce float time by maintaining droplet mass (size of particles).
Indirect (surfaces)	Inactivate particles on surfaces (wash your hands, clean your rooms)
Airborne (aerosol)	Prevent aerosolization, dilute the air, and disinfect air/surfaces.



Building system strategies: Ventilation

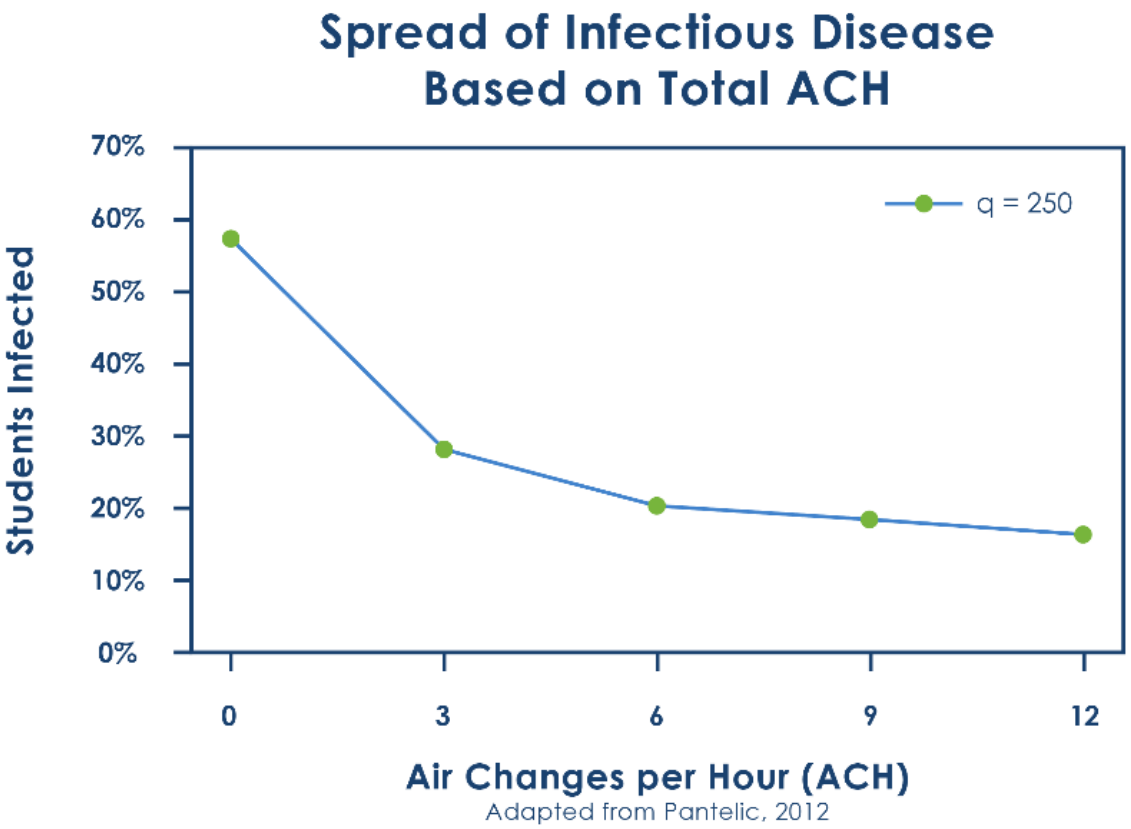
The most common question Willdan is getting about safer, healthier buildings is whether building managers should adjust their HVAC to provide as much outdoor air as possible, up to 100% outdoor air. If your building meets current International Mechanical Code, was designed using typical engineering standards, **and is functioning as designed**, your classrooms should be receiving at least 3 outdoor air changes per hour, and 6-8 total air changes per hour.

Let's compare this to ASHRAE hospital requirements. In the most sensitive hospital spaces, the American Society for Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) requires 2-4 outdoor air changes per hour (ACH), 6-20 total ACH, and only a few spaces are required to exhaust all room air directly to the outdoors (implying no recirculation of air in those spaces, or 100% outdoor air). So, current classroom ventilation design standards meet hospital standards for many of the most sensitive spaces.

Function of Space	Pressure Relationship to Adjacent Areas (n)	Minimum Outdoor ach	Minimum Total ach	All Room Air Exhausted Directly to Outdoors (j)
SURGERY AND CRITICAL CARE				
Critical and intensive care	NR	2	6	NR
Delivery room (Caesarean) (m), (o)	Positive	4	20	NR
Emergency department decontamination	Negative	2	12	Yes
Emergency department exam/treatment room (p)	NR	2	6	NR
Emergency department public waiting area	Negative	2	12	Yes (q)
Intermediate care (s)	NR	2	6	NR
Laser eye room	Positive	3	15	NR
Medical/anesthesia gas storage (r)	Negative	NR	8	Yes
Newborn intensive care	Positive	2	6	NR
Operating room (m), (o)	Positive	4	20	NR
Operating/surgical cystoscopic rooms (m), (o)	Positive	4	20	NR
Procedure room (o), (d)	Positive	3	15	NR
Radiology waiting rooms	Negative	2	12	Yes (q), (w)
Recovery room	NR	2	6	NR
Substerile service area	NR	2	6	NR
Trauma room (crisis or shock) (c)	Positive	3	15	NR
Treatment room (p)	NR	2	6	NR
Triage	Negative	2	12	Yes (q)
Wound intensive care (burn unit)	NR	2	6	NR

From ASHRAE Standard 170-2017, Ventilation of Health Care Facilities

The reason ASHRAE does not require higher levels of ventilation is because there are diminishing health returns to increased ventilation, and because there are additional capital, operation, and maintenance costs as ventilation is increased. The diminishing health returns to increased ventilation are demonstrated by Pantelic (2012) and Stephens (2012):



Does that mean you should not worry about increasing ventilation in your buildings? **No**. It is highly likely that your building is not delivering 3 outdoor ACH or 6-8 total ACH to your occupied spaces. This would be the case if your building was either designed to older, less strict standards, or is not operating within its design specifications – and most buildings will fall into one of these two categories.

If your building was built before 2005, you should start planning on what your HVAC systems will look like when it's time to replace them (which will likely be between 0 and 10 years). This includes adding mechanical ventilation if you don't have it!

If your building was built after 2005, an effective recommissioning of your building would identify building deficiencies that result in insufficient outdoor air being delivered to your occupied spaces and identify ways to remedy the situation. A re-commission process will usually pay for itself quickly through reduced energy consumption, and you will get fewer comfort complaints from your building users.

Building system strategies: Filtration

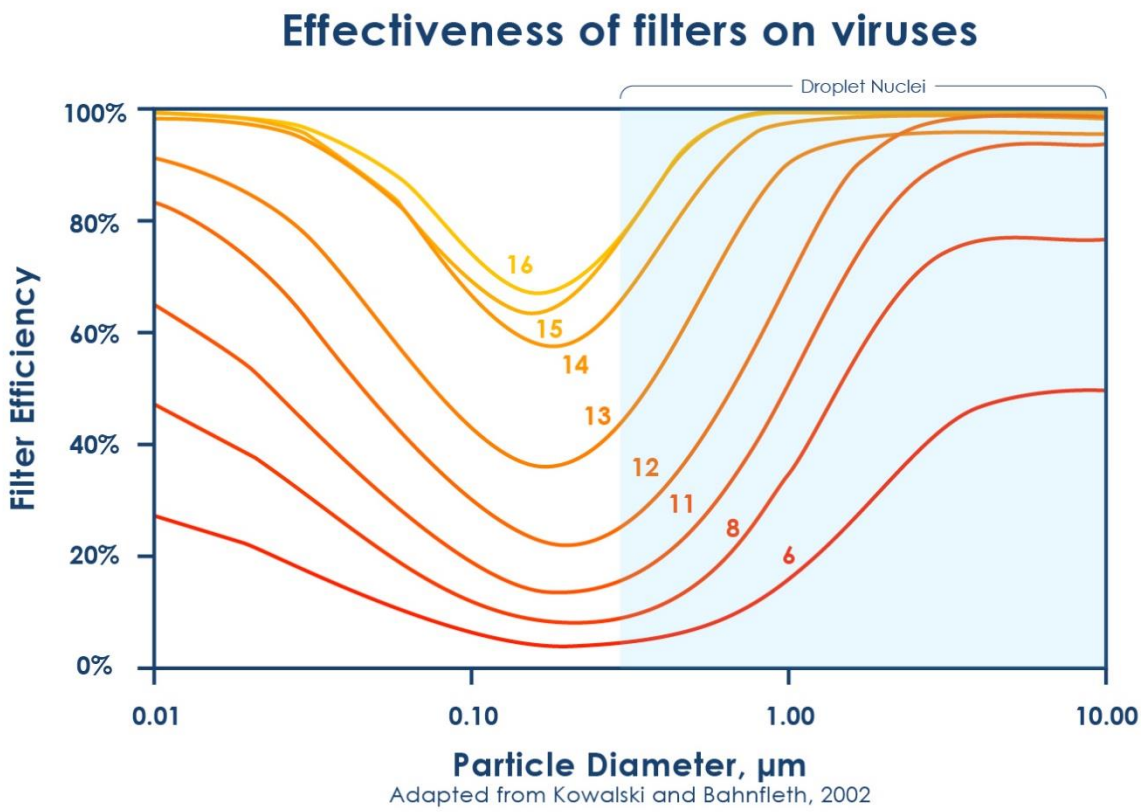
Most commercial facilities, including schools and universities, specify Minimum Efficiency Reporting Value filters of level 8 (MERV 8). This is usually specified as sufficient to protect HVAC equipment, but it does not take infection control or human health into account.

With the rise of COVID-19, many building owners are asking if they should upgrade to High Efficiency Particulate Air (HEPA) filters. ASHRAE standards for sensitive hospital areas do not require HEPA filtration except in one case (see graph below).

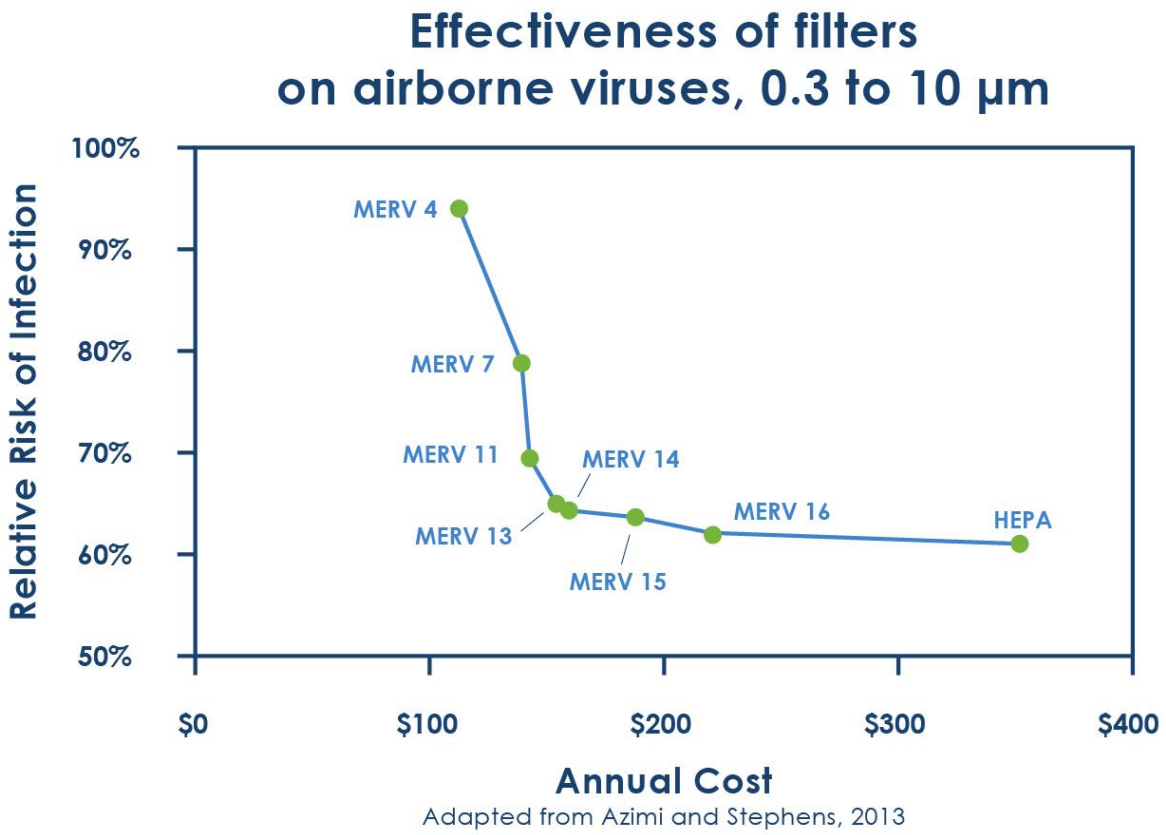
Space Designation (According to Function)	Filter Bank No. 1 (MERV)[a]	Filter Bank No. 2 (MERV)[a]
Operating rooms (ORs); inpatient and ambulatory diagnostic and therapeutic radiology; inpatient delivery and recovery spaces	7	14
Inpatient care, treatment, and diagnosis, and those spaces providing direct service or clean supplies and clean processing (except as noted below); AII (rooms)	7	14
Protective environment (PE) rooms	7	HEPA[c,d]
Laboratory work areas, procedure rooms, and associated semirestricted spaces	13[b]	NR
Administrative; bulk storage; soiled holding spaces; food preparation spaces; and laundries	7	NR
All other outpatient spaces	7	NR
Nursing facilities	13	NR
Psychiatric hospitals	7	NR
Resident care, treatment, and support areas in inpatient hospice facilities	13	NR
Resident care, treatment, and support areas in assisted living facilities	7	NR

From ASHRAE Standard 170-2017, Ventilation of Health Care Facilities

This is because increased filter values have diminishing returns of effectiveness:



Looked at another way in a different study, you can see the clear balance between filter effectiveness and cost:



Should building owners upgrade their filters? **Probably**. Your building likely has MERV 8 filters and increasing to MERV 13 or MERV 14 would create a safer, healthier building at minimal added costs. There are usually retrofit options available to increase your filter level without purchasing all new HVAC equipment. Work with your existing HVAC service provider or a company like Willdan to understand your options. However, do not just put in higher level filters to replace your existing filters! This will increase static pressure in the HVAC system and can damage equipment, which will likely result in some of your occupied spaces not receiving enough conditioned air.

Building system strategies: Disinfect Air & Surfaces

Many building owners are familiar with Ultraviolet Germicidal Irradiation (UVGI) technology as an option to disinfect air and surfaces inside their buildings. Instead of this, Willdan recommends bipolar ionization (BPI) as the best option for most building owners. BPI is:

- Safe:
    - Early ionizers produced ozone, which is harmful to human health. Most newer ionizers are third party certified to not produce ozone. Look for models that are UL-867 certified.
    - BPI ions are safe for people. Prolonged exposure to UV light is not safe for people. In-room UV light applications require either an empty room or careful design to not harm occupants.
    - BPI ions are safe for all building materials. UV light is not safe for all building materials and will degrade many materials common inside HVAC systems and buildings, especially polymers, natural rubber, and paint. This can damage or destroy important components such as filters, gaskets, or insulation on exposed wiring.
- Effective:
    - "Kills" viruses: the ions created by BPI strip virus molecules of their hydrogen, disabling their ability to infect a new host.
    - Increases filter efficacy: BPI ions make particles in the air stream larger, making them more likely to be caught in a filter.
    - Disinfects air and surfaces: BPI will first disinfect the air stream, and once no particles are present in the air stream, ions will move into occupied spaces to disinfect air and surfaces. UV light installations are usually designed to disinfect either air or surfaces but would require separate installations to do both.
    - Ions more easily move through a coil when compared to UV light, so they provide better disinfection of coils in an HVAC system. In contrast, UV light tends to lose intensity without reaching deep within the coil, and so UV systems often struggle to keep coils free of pathogens such as mold.
- Efficient:
    - BPI requires much less energy to operate than UV lights.
    - BPI can reduce the energy needed to condition air, because it allows you to use less outdoor air and recycle more conditioned air.
    - BPI equipment requires much less maintenance than UV light equipment. Willdan recommends self-cleaning BPI equipment. Global Plasma Solutions is a good brand that we have worked with.

Independent Laboratory Testing Results Summary

GPS

PATHOGEN	TIME IN CHAMBER	RATE OF REDUCTION	TESTING LAB
SARS-CoV-2	30 MINUTES	99.4%	INNOVATIVE BIOANALYSIS
Norovirus*	30 MINUTES	93.5%	ATS LABS
Human Coronavirus**	60 MINUTES	90.0%	ALG
Legionella	30 MINUTES	99.7%	EMSL
Clostridium Difficile	30 MINUTES	86.8%	EMSL
Tuberculosis	60 MINUTES	69.0%	EMSL
MRSA	30 MINUTES	96.2%	EMSL
Staphylococcus	30 MINUTES	96.2%	EMSL
E. Coli	15 MINUTES	99.6%	EMSL

* Surrogate for Norovirus, actual strain tested was Feline Calicivirus, ATCC VR-782, Strain F-9
** Surrogate for Human Coronavirus SARS-CoV-2, actual strain tested was Human Coronavirus 229E

This table, provided by Global Plasma Solutions, shows the effectiveness of BPI at eliminating pathogens over time.

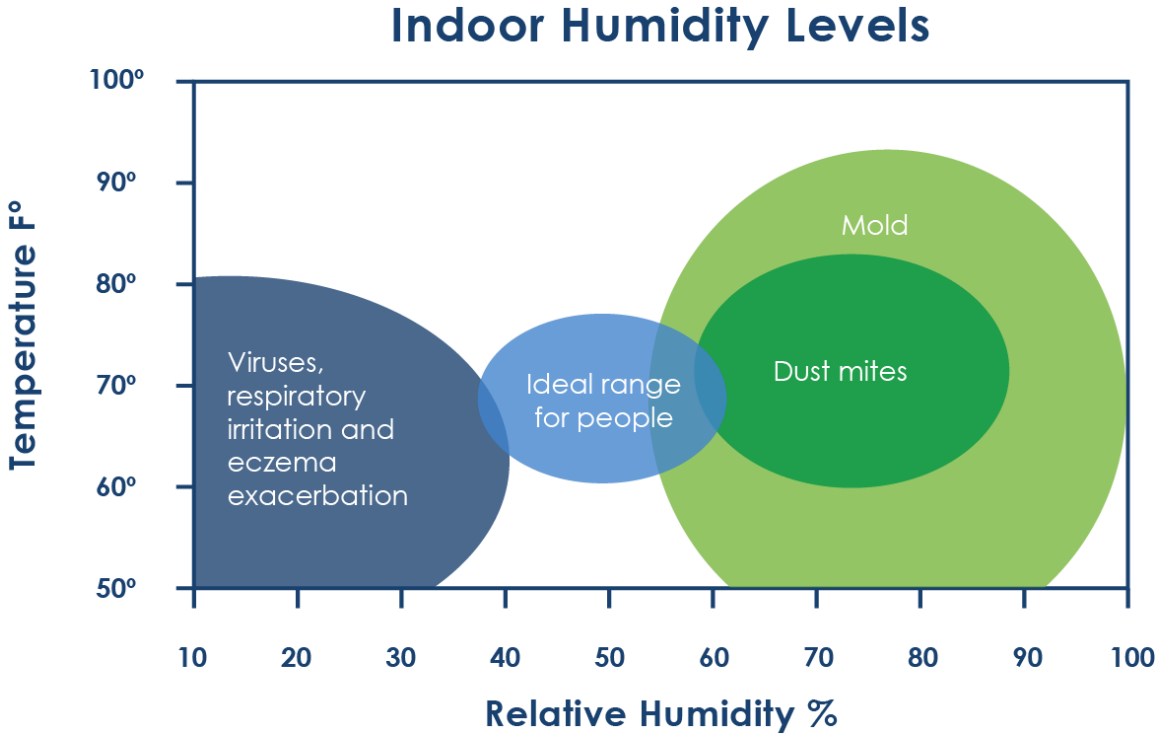
Building system strategies: Humidity

Proper Relative Humidity (RH) levels play an important role in safer, healthier buildings (Wolkoff, 2018), including increasing safety from COVID-19 (Dietz, 2020). ASHRAE standards for hospitals require a minimum of 40% RH in sensitive areas such as operating rooms. Lower RH negatively affects human health in a variety of ways:

- Virus droplets desiccate more easily to become droplet nuclei and thus airborne
- Human mucous membranes dry out and are less able to filter virus droplet nuclei from the breath
- Human health conditions such as eczema become exacerbated

One study compared the spread of flu virus in K-12 classrooms with 20% RH versus classrooms with 80% RH. The study found that airborne viral flu load was reduced by 80% in the high-humidity classrooms (Noti, 2013). Another study examined the use of portable humidifiers in K-12 classrooms and found that flu spread was reduced 75% in the classrooms that had humidifiers (Dietz, 2020).

Relative Humidity higher than 40% provides an ideal range for health hazards such as mold and dust mites. Taken together, the ideal RH range for human health is 40%-60%.



Should building owners consider humidity control systems in their buildings? **Not necessarily.** These systems are expensive to install and operate, and they require careful maintenance. Poorly maintained systems can actually work to distribute mold through a building and get people sick ("humidity fever"). Willdan recommends building owners understand their humidity levels and how they change throughout the year. Owners then should consider whether humidity control systems are worth the investment, or if other interventions could be made (for example, increasing social distance or not using buildings when humidity is very low and infectious outbreaks are present in the community).

Demonstrate Effectiveness & Effective Communication

As building owners work to create safer, healthier buildings, many are wondering how they can demonstrate the effectiveness of their interventions. Willdan encourages building owners to not engage in "hygiene theater," or making interventions that are obvious but not necessarily effective. Willdan works with its clients on IAQ projects to "make the invisible visible" through custom building signage, email press release communications, website updates, and workshops for staff and community. Building owners also have options to certify their spaces by working with a company such as EWF Environmental to certify that spaces are free of COVID-19.

Paying for it All

Because facilities and building infrastructure tend to be chronically underfunded, Willdan is often asked, "but how will I pay for any of this?" We encourage you to not let a perceived lack of funds delay your plan to have a safer, healthier building! Work with a company like Willdan that will help you "find the money." Below are just some of the ways we help our clients fund projects. Pay particular attention to the "Federal Funding" option – it is highly likely that infrastructure dollars, stimulus dollars, or both will become available for public building owners to make IAQ improvements. If you work with a company like Willdan to make a plan now, you are more likely to receive that funding if it becomes available. Make yourself "shovel ready!"

Financing Vehicle	Benefits	Experience Examples
 **WA State LOCAL Loans**	▪ Client applies directly to fund projects ▪ Very low lending costs (~1%)	▪ Willdan helped Wahkiakum County fund infection control and capital improvements with a $1MM LOCAL loan at 0.96%
 **WA State Grants**	▪ Varied requirements and application processes ▪ Require careful planning ▪ Reduce the cost of project or increase scope	▪ Willdan helped TESC secure a $1.1 MM State grant for Science Lab I renovations. TESC was one of a few recipients and received the largest grant value.
 **Lease-Purchase**	▪ Funds are used for energy savings investments such as lighting, HVAC, and renewable energy systems ▪ Energy savings produce cash flow and reduce interest rate	▪ Willdan has helped connect our EE project customers with financial advisors, securing $100M+ in lease-purchase financing. This delivery model has been used extensively for projects at CWU.
 **Green Bonds**	▪ Bonds earmarked for climate or environmental projects ▪ Lower interest rates	▪ Willdan helped a Midwest municipal fund a $10MM energy efficiency project with Green Bonds for 40+ city facilities.
 **Rebates & Incentives**	▪ Utilities offer financial incentives for energy upgrades at a customer facility ▪ Lowers installation cost and improves measure payback	▪ Willdan has helped our customers save over $1.2 billion in rebates and incentives nationwide.
 **Federal Funding**	▪ Available for energy resiliency projects, economic and disaster relief, and more ▪ Does not need to be repaid	▪ Willdan has clients using CARES act funding for IAQ improvements. ▪ Willdan implemented infrastructure projects with twelve clients using funds provided under the American Recovery and Reinvestment Act between 2011 – 2013.

Summary

There are many interventions building owners can make to create safer, healthier buildings. Some changes are administrative and some are engineering interventions, but all are backed by existing standards and over a hundred years of health care experience in creating safer, healthier buildings. Any building owner can get to the same standards as sensitive hospital areas, which will help you meet your core mission. There are no silver bullets, but there are silver BBs, and when applied together, they can make real and measurable improvements on making buildings safer and healthier. Without knowing anything about your buildings, Willdan's IAQ recommendations can be boiled down to the following:

1. **Always work with an expert.** HVAC systems are complex, and a change in one place will affect every part of the system. Don't make changes to your outside air settings, your filters, or anything else without consulting with your existing service provider or an engineering company like Willdan.
2. **Make a plan** to improve your building to meet current ventilation standards (especially adding mechanical ventilation if you have none) OR recommission your building to ensure it's operating as designed.
    a. Willdan has a self-perform checklist to help you understand how well your building is functioning.[1]
3. **Check your controls** to optimize for safer, healthier spaces:
    a. Disable or alter demand-controlled ventilation.
    b. Flush your buildings for two hours prior to occupancy and two hours after occupancy.
    c. If your bathrooms have exhaust fans, keep your windows closed and your toilet seats down (when present). Otherwise, open bathroom windows.
4. **Upgrade your filters** to MERV 13 or MERV 14
5. **Install bi-polar ionization.** Check that your equipment meets UL-867 and is self-cleaning. There are many good companies; one good option is Global Plasma Solutions.
6. **Tell your community!** Make the invisible visible. Work with companies like EWF Environmental to certify your spaces as safe.
7. **No matter your situation, start now.** There has never been more attention paid to this subject. And don't let a perceived lack of funds stop you! Work with a company like Willdan that will help you "find the money."

Good luck on your path to safer, healthier buildings. You can get yourself to hospital standards! Willdan is happy to help you start this journey. You can reach us at:

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Disclaimer:
Willdan is an engineering firm. We have expertise in HVAC systems, especially in the measures we will discuss here and experience working in healthcare environments; however, we are not medical professionals. The information in this presentation represents our reading of the current literature and our interpretations on how to best act on the available information.

[1] See link to my Medium article in the references.

References and More Information

ASHRAE 170-2017 available at:
https://www.ashrae.org/technical-resources/standards-and-guidelines/standards-addenda/ansi-ashrae-ashe-standard-170-2017-ventilation-of-health-care-facilities

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