

USING HUMIDIFICATION TO REDUCE THE TRANSMISSION OF VIRUSES

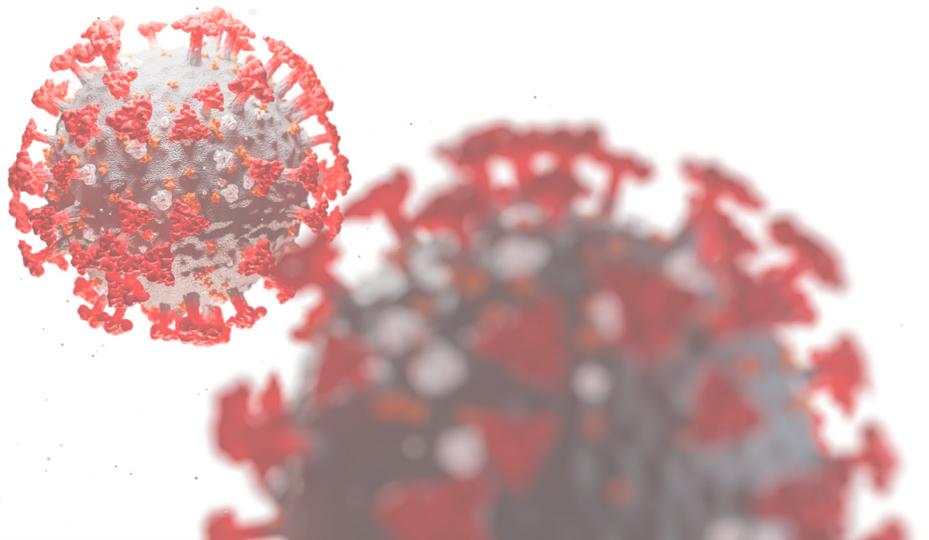
EXECUTIVE SUMMARY

Healthy levels of humidification can help to reduce the spread of viruses that includes those that infect our respiratory tract like COVID-19 (SARS- CoV-2) and Influenza A in the built environment.

While this applies to all buildings – hospitals, clinics, senior living communities, and schools are among those that may benefit the most from the implementation of optimal humidity levels. The World Health Organization has called for non-pharmaceutical approaches to mitigate the transmission of COVID-19, and the addition of humidity is a safe, efficient and easy way to protect staff, patients, residents, teachers, and students.

It is well known that too much water vapor within the building envelope can cause problems such as mold and fungus growth, but it is important to understand the benefits that precisely controlled humidification can add to all indoor environments.

The goal of this white paper is to improve the understanding of the role of humidification in reducing the transmission, infectivity and severity of COVID-19 and other viruses, review current industry standards, and present strategies for implementing this non-pharmaceutical approach to a healthy indoor environment.



ABOUT HUMIDIFICATION

Definition

Relative humidity, or RH, is a term used to describe the amount of water vapor in the air as a percentage of the maximum amount of water vapor which the air could hold at a given temperature.

While the absolute amount of water vapor stays constant, the RH will vary depending on the temperature.

Types of Humidification Systems

For commercial buildings and facilities, there are three main types of humidification systems:

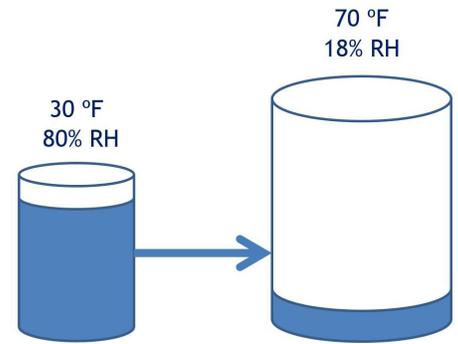
- Isothermal humidification systems use electricity or gas as an external heat source to change water to steam. This is the preferred technology for hospitals due to the inherent hygiene of steam.
- Steam exchange humidifiers generate clean steam from an existing on-site pressurized steam boiler.
- Adiabatic systems disperse water droplets or fog into air that has enough latent heat energy to cause dispersed water to change state to vapor.

Relative Humidity and Health

A key study done in 1986 by Sterling and Arundel¹ showed that the optimal conditions to minimize risks to human health occur between 40-60% RH at normal room temperatures.

This study is still referenced by HVAC professionals today and forms the basis of standards for healthy built environments set by the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE).

Maintaining RH within this 40-60% range decreases the impact of viruses, bacteria, and allergens found in the environment while also preventing skin dryness and eye irritation.

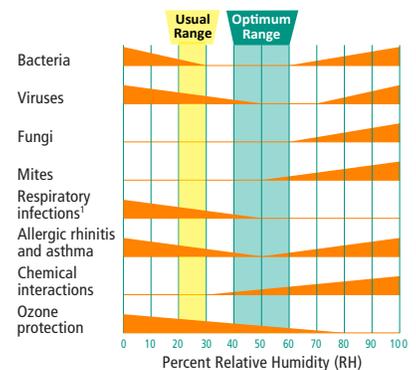


19 grains/lb of water vapor and RH at 30 °F vs 70 °F



Isothermal humidifier

Optimum relative humidity range for a healthy environment



Graph from the Sterling and Arundel study, 1986

¹ Arundel, A V, et al. "Indirect Health Effects of Relative Humidity in Indoor Environments." *Environmental Health Perspectives*, U.S. National Library of Medicine, Mar. 1986, www.ncbi.nlm.nih.gov/pmc/articles/PMC1474709/.

WHY ARE HUMIDITY LEVELS SO CRITICAL IN HEALTHCARE FACILITIES?

Protection

Healthy levels of humidification in hospitals, clinics, and other healthcare facilities can help to reduce the spread of viruses like COVID-19, protecting staff and patients.

It is critical to keep the relative humidity level in healthcare facilities between 40 and 60% RH in order to:

- Reduce viral activity (infectivity)
- Protect our body's built-in barriers to illness
- Assist the self-clearing mechanism of the airways in our respiratory system, which is our innate antiviral defense
- Ensure proper tissue repair function, especially in our lungs

Costs

In addition to viral respiratory infections, healthy humidity levels can also play a role in other hospital and clinical care settings where we see hospital acquired infections (HAIs) from bacterial pneumonia, C. Difficile, medicine resistant staphylococcus aureus (MRSA), and others.

The presence of these HAIs in the hospital puts a huge burden on the hospital in terms of the cost of care because the hospital is effectively responsible for the cost of treatment if a patient acquired an HAI during their stay. When thinking about the cost of implementing and operating humidification equipment, remember that it has a tremendous payback in the sense that a lot of unnecessary costs associated with hospital acquired infections will be avoided.

Loss of Accreditation

These infections are the cause of significant economic costs to the hospital system where these facilities must conform to the Joint Commission (JCAHO) Healthcare Relative Humidity standards in order to avoid issues such as delays of operating room procedures, withheld Medicare or Medicaid payments, and potential loss of facility accreditation.



WHY ARE HUMIDITY LEVELS SO CRITICAL IN SENIOR LIVING COMMUNITIES?

Protection

Nursing homes, assisted living facilities, and senior living communities can also benefit from healthy levels of humidification to reduce the spread of viruses like COVID-19, protecting staff and residents – many of whom are among our most vulnerable population.

In addition to combating viral infections, senior living community residents can benefit in other ways from healthy levels of indoor humidity.

- People with diabetes are more susceptible to developing infections, as high blood sugar levels can weaken their immune system defenses.
- Bacteria and viruses can spread through urinary catheters used by immobile patients and attack patients through soft tissues exposed as bedsores or wounds.
- A serious infection caused by a bacteria known as MRSA can also spread from casual contact among residents and visitors. The infection threats have grown more serious with the spread of bacteria like this that are resistant to antibiotics.¹

Costs

The presence of viral and bacterial infections puts a huge burden on nursing homes and assisted living facilities in terms of the cost of care because the facility is effectively responsible for the cost of treatment if a patient acquired an infection during their stay.

The staff of senior living communities must also be protected from infection. They are unable to care for elderly residents if they are ill, and it is important to control the cost of staff absenteeism.



¹ Rau, Jordan, and Elizabeth Lucas. "How Well Does Your Nursing Home Fight Infections? Look It Up Here." Kaiser Health News, 13 Mar. 2020, khn.org/news/how-well-does-your-nursing-home-fight-infections-look-it-up-here/.

WHY ARE HUMIDITY LEVELS SO CRITICAL IN SCHOOLS?

Protection

Teachers and students are in close contact for much of the day, and schools can become a place where respiratory diseases like COVID-19 can quickly spread. Frequent hand washing, and covering coughs and sneezes, provide a good start in reducing the spread of viruses that cause respiratory illnesses like influenza in schools, but more can be done.

Researchers at the Mayo Clinic in Rochester, Minnesota, investigated how indoor humidity levels affect transmission of respiratory viruses in a classroom setting.¹ This study showed that rooms with commercial-sized humidifiers had:

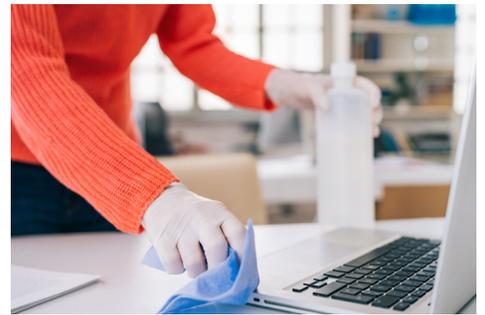
- A significant decrease in the percent of total air samples containing influenza A
- A trend toward a decreased percent of surface samples containing influenza A
- Samples with influenza A contained fewer “live” viruses and were therefore less infectious
- Fewer flu-like illnesses reported

Absenteeism

Besides posing a danger to health and wellness, viral outbreaks are detrimental in other ways. Student absences increase during the dry winter months, often due to respiratory illnesses. Chronic absenteeism or missing $\geq 10\%$ of school days within a year, for any reason, predicts low student achievement.²

Cost

When viruses spread among students, parents and teachers also tend to get ill and must take sick days. Having to rely on substitute teachers too often can negatively affect lesson plans and is expensive. School budgets suffer when students don't attend. In many states, school budgets are based on the average daily attendance at a school. If many students are absent, the school has less money to pay for essential classroom needs.



¹ Reiman, J. M., Das, B., Sindberg, G. M., Urban, M. D., Hammerlund, M. E., Lee, H. B., ... Pierret, C. (2018). Humidity as a non-pharmaceutical intervention for influenza A. doi: 10.1101/273870

² The Connection Between Missing School and Health. schoolhealthteams.aap.org/uploads/ckeditor/files/Chronic-Absence-and-Health-Review-10_8_14-FINAL-REVISED.pdf.

UNDERSTANDING AIRBORNE VIRUSES

Airborne viruses are expelled as aerosols through breathing, speaking, coughing and sneezing. Researchers have captured pathogen-bearing aerosols traveling up to 25 feet from a simple sneeze. Airborne viruses may also be expelled during surgical procedures such as intubation.¹

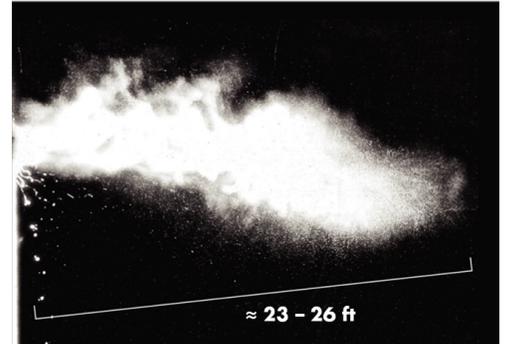
COVID-19 (SARS-CoV-2) behaves as an aerosol in similar ways to SARS (SARS-CoV-1), MERS, and influenza A.

How long an aerosol remains airborne and how far it travels affects not only the spread of infection but the severity of infection because respiratory viruses are most harmful when inhaled deep into the lungs.

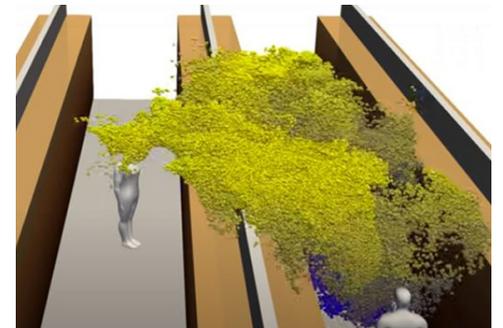
Aerosols that desiccate into virus nuclei due to low ambient humidity may be traveling distances and infect patients beyond the current 6 foot/2 meter rule, so social distancing may be less effective in low humidity environments.

Researchers modeled the airborne movement of aerosol particles smaller than 20 micrometers.²

- For a dry cough, which is a typical symptom of the current coronavirus, the particle size is typically less than 15 micrometers.
- Extremely small particles of this size do not sink on the floor, instead they move along in the air currents or remain floating in the same place.
- Studies of influenza A have confirmed that the influenza A virus can be found in the smallest particles, which measure less than 5 micrometers.



Pathogen-bearing aerosols travel up to 25 feet from a simple sneeze



Simulated carrier on bottom right generates a particle cloud that drifts across the top of supermarket shelving

¹ Bourouiba, Lydia. "Turbulent Gas Clouds and Respiratory Pathogen Emissions." JAMA, American Medical Association, 12 May 2020, jamanetwork.com/journals/jama/article-abstract/2763852.

² "Researchers Modelling the Spread of the Coronavirus Emphasise the Importance of Avoiding Busy Indoor Spaces." Aalto University, 7 Apr. 2020, www.aalto.fi/en/news/researchers-modelling-the-spread-of-the-coronavirus-emphasise-the-importance-of-avoiding-busy.

HUMIDITY LEVELS AND HUMAN IMMUNE-RESPONSE

Not only does controlling humidity in buildings to a range of 40-60% RH reduce the impact of viruses and bacteria in the air and on surfaces, it also acts to protect our body's built-in barriers to illness, assists the self-clearing mechanism of the airways in our respiratory system (our innate antiviral defense), and ensures proper tissue repair function in our lungs.¹

How do humidity levels work to reduce the spread of viruses like COVID-19? There are three key elements:

Persistence and Dispersion

Low ambient humidity reduces droplet size which allows for a prolonged airborne period which in turn allows for further distance traveled. The low weight due to loss of water (desiccation) prevents the virus from being knocked down and then cleaned up with usual surface cleaning/hygiene control methods.

Extended airborne time may be as much as 36 to 72 hours and allows for significant travel. In addition, low humidity and low droplet weight may allow viruses to become airborne after settling (resuspension).

Infectivity

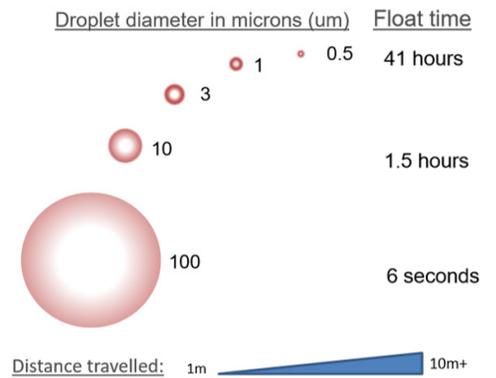
Low ambient humidity with associated reduced droplet size allows for deeper penetration into the lungs where there is a less effective biological response.

This is aggravated by the low humidity conditions reducing the body's own immune response and causing inactivated or reduced functioning of cilia and thickened or reduced mucous.

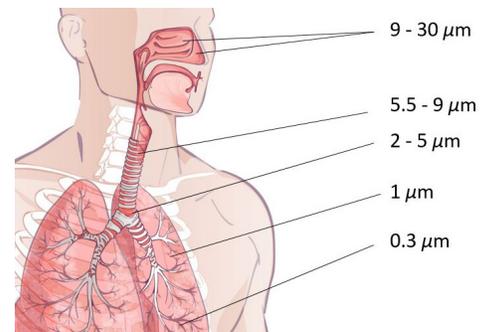
Viral Activity

Low ambient humidity levels act on the aerosol's salt content which allows for prolonged viral activity. Higher RH renders viruses inactive. In addition, higher humidity levels influence our own cellular recovery.

Humidity also plays a role in maintaining our immune response and the ability for us to fight off diseases like COVID-19.



Mechanics of Infection: Droplets in the Air



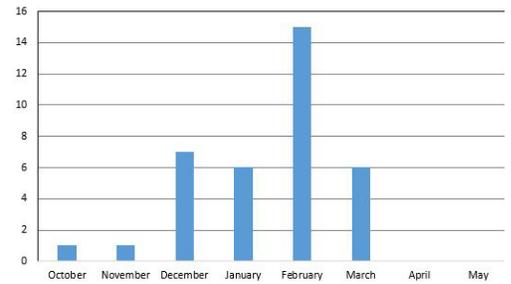
Smaller particles enter deeper into our lungs. A μm is a micron or 1/1,000,000 of a meter. The smallest particle we can see is 30 μm .

¹ Yang, Wan, and Linsey C. Marr. "Mechanisms by Which Ambient Humidity May Affect Viruses in Aerosols." *Applied and Environmental Microbiology*, American Society for Microbiology, 1 Oct. 2012, aem.asm.org/content/78/19/6781.

SEASONALITY OF RESPIRATORY VIRUSES

Flu Season

The Centers for Disease Control and Prevention (CDC) monitors the progress of the flu season every year. While seasonal influenza (flu) viruses are detected year-round, flu viruses are most common during the fall and winter. The exact timing and duration of flu seasons can vary, but influenza activity often begins to increase in October. Most of the time flu activity peaks between December and February, although activity can last as late as May.¹

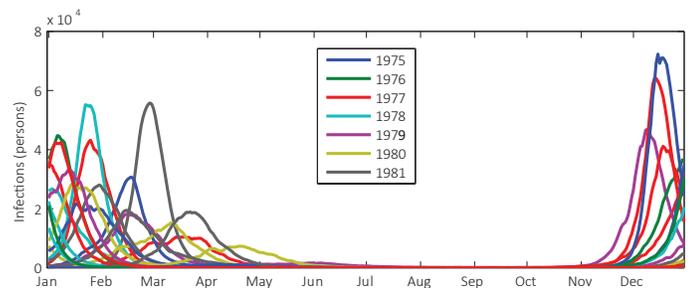


Peak Month of Flu Activity
1982-1983 through 2017-2018

Seasonality of Influenza and Coronaviruses

In a recent study,² the seasonality of influenza viruses and endemic coronaviruses was tracked over an 8-year period to assess key epidemiological reduction points in disease incidence for an urban area in the northeast United States.

The 8-year average peak activity of human coronaviruses occurred in the first week of January, when droplet and contact transmission was enabled by the low indoor RH of 20-30%. Previous studies have shown that an increase in RH to 50% has been associated with markedly reduced viability and transmission of influenza virus and coronaviruses.



New York Simulated Infections
1972-1981

As disease incidence was reduced by 50% in early March, to 75% in early April, to greater than 99% at the end of April, a relationship was observed from colder temperatures in January with a low indoor RH to a gradual increase in outdoor temperatures in April with an indoor RH of 45-50%.

Workplace Considerations

Another study³ recommended that while the benefits of maintaining higher indoor temperatures as well as RH between 40% and 60% is being studied in greater detail, hospitals may want to consider routinely measuring indoor climate. Optimizing these parameters is a relatively simple, low-cost approach to potentially decrease the risk of aerial transmission of viruses among healthcare providers and patients.



Keep relative humidity between 40-60%
to protect staff and patients

¹ "The Flu Season." Centers for Disease Control and Prevention, Centers for Disease Control and Prevention, 12 July 2018, www.cdc.gov/flu/about/season/flu-season.htm.

² Evangelista, Alan T. "The Seasonal End of Human Coronavirus Hospital Admissions with Implications for SARS-CoV-2." MedRxiv, Cold Spring Harbor Laboratory Press, 1 Jan. 2020, www.medrxiv.org/content/10.1101/2020.05.15.20103416v1.

³ <https://oem.bmj.com/content/oemed/early/2020/05/28/oemed-2020-106653.full.pdf>

INDUSTRY STANDARDS FOR HUMIDITY LEVELS

ASHRAE Guidelines

ASHRAE is a global society advancing human well-being through sustainable technology for the built environment. The Society and its members focus on building systems, energy efficiency, indoor air quality, refrigeration, and sustainability within the industry.



Current ASHRAE guidelines for hospitals range from 20-60% RH, depending on the usage of the space. ASHRAE guidelines have higher RH levels in certain clinical settings such as:

- Intensive Care Units (ICU): 30-60% RH
- Burn Units: 40-60% RH

However, a large part of the overall building can be as low as 20% RH and some areas have no minimum.

Global View

Other countries maintain higher standards for relative humidity levels in their healthcare facilities. Japan has for some time recognized the importance of higher RH levels and is willing to hold patient safety and well-being ahead of energy savings.



USA

20 - 60 % RH



CHINA

30 - 60 % RH



UK

35 - 60 % RH



JAPAN

40 - 65 % RH

ASHRAE EPIDEMIC TASK FORCE

In response to the COVID-19 pandemic, ASHRAE recently created an Epidemic Task Force and has made resources available on-line at www.ashrae.org/technical-resources/resources.

ASHRAE leadership has approved the following two statements regarding transmission of SARS-CoV-2 and the operation of HVAC systems during the COVID-19 pandemic:¹

- Transmission of SARS-CoV-2 through the air is sufficiently likely that airborne exposure to the virus should be controlled.
- Changes to building operations, including the operation of heating, ventilating, and air-conditioning systems, can reduce airborne exposures.

In addition, the recently published ASHRAE Position Document on Infectious Aerosols² recognizes the role of the built environment in reducing the transmission and impact of the virus and, more importantly, has extended this to commercial buildings that currently lack minimum RH guidelines. Included in this document are the following statements:

- Infectious aerosols can pose an exposure risk, regardless of whether a disease is classically define as an “airborne infectious disease.” This position document covers strategies through which HVAC systems modulate aerosol distribution and can therefore increase or decrease exposure to infectious droplets, droplet nuclei, surfaces, and intermediate fomites in a variety of environments.
- Infectious diseases can be controlled by interrupting the transmission routes used by a pathogen. HVAC professionals play an important role in protecting building occupants by interrupting the indoor dissemination of infectious aerosols with HVAC and local exhaust ventilation (LEV) systems.



¹ "COVID-19 (Coronavirus) Preparedness Resources." COVID-19: Resources Available to Address Concerns, www.ashrae.org/technical-resources/resources.

² www.ashrae.org/file%20library/about/position%20documents/pd_infectiousaerosols_2020.pdf

CISBE GUIDANCE

CISBE, the Chartered Institution of Building Services Engineers, is the standard-setter and authority on building services engineering. It publishes guidance and codes that are internationally recognized as authoritative, and sets the criteria for best practice in the profession.

The Institution speaks for the profession and is consulted by government on matters relating to construction, engineering and sustainability. It is represented on major bodies and organizations that govern construction and engineering occupations in the UK, Europe and worldwide



COVID-19: Infection Prevention Control

As businesses start to consider bringing staff back into work premises, a number of issues need to be considered for the safety of everyone entering the building. This guidance document¹ covers considerations concerning both safe working practices and the assessment of building services. Key points include:

- The transmission of COVID-19 is thought to occur mainly through respiratory droplets generated by coughing and sneezing, and through contact with contaminated surfaces. The predominant modes of transmission are assumed to be droplet and contact.
- Droplets will generally fall out of the air stream within a short distance (depending on airflow speed and direction), hence the guidance to remain 6ft/2m apart. However, these droplets may evaporate, reducing in size and mass, and travel further in air streams, contaminating surfaces and increasing the risk of airborne transmission.
- There is an emerging and growing body of evidence that COVID-19 can be spread through the air, particularly in poorly ventilated indoor spaces, and that ventilation provision in buildings should be reviewed in light of this.
- Transmission-based precautions are recommended against contact, droplet, and airborne infection transmission, including local consideration to any enhancements that could be made to improve ventilation in healthcare premises.

¹ Public Health. "COVID-19: Infection Prevention and Control (IPC)." GOV.UK, GOV.UK, 21 May 2020, www.gov.uk/government/publications/wuhan-novel-coronavirus-infection-prevention-and-control.

NEXT STEPS

Site Survey

Taking RH readings with a hygrometer in areas that may experience COVID-19 cases (or areas where asymptomatic cases may present) will quickly determine if a facility is optimizing its defense against virus transmission.

A target of 45% RH is generally recognized as providing positive benefits. If you are seeing lower RH levels, then:

- Check equipment to see if it is operating
- Adjust/raise setpoint if required
- Work with a local sales agent to explore options for additional capacity/output

Most health care facilities were commissioned with humidification. This equipment may not be operating due to maintenance issues, turned off, or the humidification levels reduced.

Getting There Quickly

Commercial grade humidification equipment provides the control needed to maintain proper levels – not too low and not too high. Simple access to power, water, and drain is all you need to get a system operational – think of anyplace there is a sink nearby.

Whether recirculation or 100% outside air is being implemented, consider replacing adiabatic technologies with high efficiency gas units to reduce energy usage.

You can count on a system from DriSteem to provide superior performance, protecting everyone in your building and your investment.

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RESOURCES

Studies Over the Years

The notion that humidification levels reduce the transmission of viruses, bacteria, and allergens is not new. Studies have proven this over and over again:

- 1986 – Arundel et al., [Indirect health effects of relative humidity in indoor environments](#)
- 2007 – Lowen et al., [Influenza Virus Transmission Is Dependent on Relative Humidity and Temperature](#)
- 2012 – Noti et al., [Detection of Infectious Influenza Virus in Cough Aerosols Generated in a Simulated Patient Examination Room](#)
- 2012 – Yang, Marr, [Mechanisms by Which Ambient Humidity May Affect Viruses in Aerosols](#)
- 2013 – Welty, [Airborne Influenza in Dry Wintertime Indoor Air: Is 50% RH Indoor Humidity One Cure for “Flu Season”?](#)
- 2018 – Reiman et al., [Humidity as a non-pharmaceutical intervention for influenza A](#)
- 2019 – Iwasaki et al., [Low ambient humidity impairs barrier function and innate resistance against influenza infection](#)
- 2020 – Van Dormelen, [How Long Will Coronavirus Live on Surfaces or in the Air Around You?](#)
- 2020 – Gough, [Humidity helps in the fight against COVID-19, virologists report](#)
- 2020 – Wei Luo, [The role of absolute humidity on transmission rates of the COVID-19 outbreak](#)

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