SAVE LIVES: Become A Mechanical Engineer

OK, the author knows that's not what the college recruiting brochures said back when you attended your bastion of higher learning, but that may change very soon. There is enough solid science available to back up the claims that controlling IAQ can, in fact, save lives. We focus on the airborne germ *du jour* — influenza — in order to illustrate how your decisions on controlling the indoor air in your clients' buildings can be critical to health and life preservation.

BY STEVEN WELTY, LEED® AP, CIE, CAFS

Since the influenza virus lives happily in pigs and large birds like ducks and chickens, for as long as we've lived near them we've swapped mutated flu viruses that can also infect us humans. As a result, influenza epidemics have swept across the world for thousands of years. Recorded flu pandemics started in 412 B.C., when Hippocrates described its impact in his book *Of the Epidemics,* and the first accepted pandemic by experts was in 1580.[1] There have been seven "modern" documented flu pandemics in the last 350 years: 1729, 1781-2, 1830-3, 1889-90, 1918-19, 1957-58, and 1968, and now we are recording 2009-10.

HOW YOU SPEW FLU

If you're infected with the flu, each time you breathe, cough, sneeze, sing, or talk, you spew out airborne mucus/saliva droplets filled with viruses called virions.[2] A critical factor in efficient airborne human flu infection is the impact of low grain moisture indoor environments, which force the mucus/saliva shell surrounding the virions to evaporate faster, creating "droplet nuclei." The small droplets that become airborne droplet nuclei are created in less than a second and can stay airborne and survive for hours or days within indoor air spaces.[3,4]

HERE'S HOW VIRIONS ACT IN THE AIR

Because it is so small, once a virion is launched, dries out, becomes a droplet nuclei, and is airborne inside a building, the following forces work together to keep it afloat for hours until it plates out on a surface or is inhaled by one of us:

- People movement
- People breathing, sneezing, coughing, talking, and singing
- Heat plumes from people
- HVAC fan created air currents
- Air temperature thermal differentials
- "Stack effect" air movements

The science of in-room air mixing clearly demonstrates just how air movements allow airborne virions to catch a ride on these invisible currents just as fish do on ocean currents. If you had electron microscope glasses, you'd see a cavalcade of invisible virions, bacteria, fungal spores, and other debris floating effortlessly on these invisible currents around you right now. I use a laser particle counter instrument to document these microbial objects, and I regularly find one million airborne particles 0.3 microns in size indoors. Sometimes I find five million or more.

HOW DOES OUR BODY PREVENT AIRBORNE VIRIONS FROM HARMING US?

Whether or not you drink your eight glasses of water every day, you have to breathe 40,000 glasses of air each and every day. Your respira-

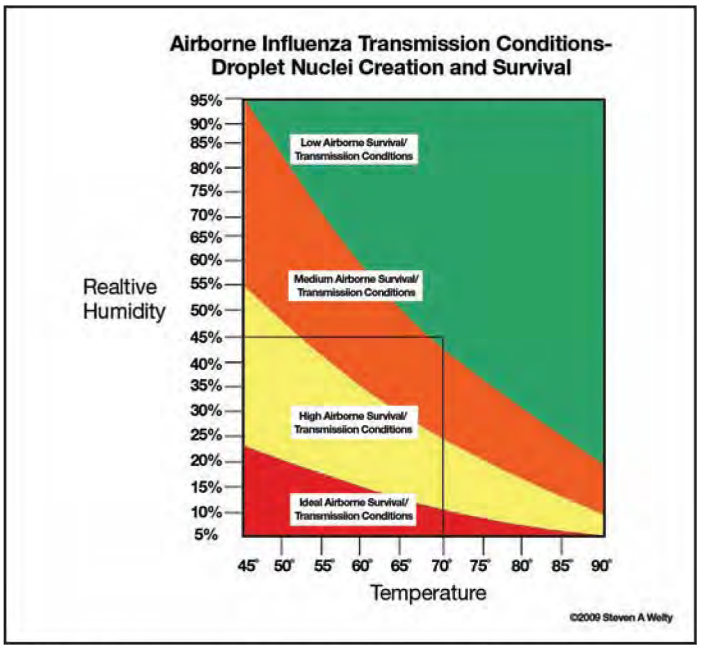

FIGURE 1. Airborne flu survival and transmission conditions.

tory system is equipped with a natural filtration mechanism, which works 24/7/365 to capture airborne virions in order to prevent them from making you sick.

Your entire respiratory system is covered in mucus. Every time you breathe in millions of particles of various sizes, your respiratory system captures many of those particles in order to prevent them from harming you. Think about skipping a rock across a smooth lake; eventually, the friction of the lake stops and swallows the rock. Your mucus lining traps incoming virions, bacteria, and mold in just the same way. Then your cilia hairs, though an undulation motion mimicking ocean waves, move the virions up to your nasopharynx where you can blow them out or swallow them down. The virions that bypass the cilia hair protection system, which ends half way into your lungs, are the ones which do us the most harm when they land deep within the lungs. Airborne influenza virions do this quite efficiently, which is why they can make you so sick.

CONTROL IAQ TO PREVENT ILLNESS

Since mechanical engineers design and specify the machines and connected delivery devices which cool, heat, and ventilate buildings, they usually dial in the AHUs targeted grains of moisture. By controlling the building's temperature and grains of moisture, you may be tangentially responsible for saving a life that may have otherwise succumbed to influenza and the deadly bacterial infections that accompany it. The biggest opportunities are in hospitals, schools, and offices where lots of infected people are mixing with uninfected and healthy (naïve) persons.

THE CURRENT H1N1 PANDEMIC, 'FLU SEASON,' AND IAQ

Until November 2009, the US H1N1 pandemic flu deaths and illnesses were mostly from close contact with infected persons. I'll explain why warm, humid conditions reduce the efficient creation of droplet nuclei while lowering the long airborne survival times necessary for the annual wintertime flu season outbreaks. Now that the 2009-10 Northern Hemisphere's wintertime outdoor weather has become dry enough to influence a building's indoor humidity levels, let's see how that affects flu season.

LOW GRAIN AIR AND FLU SEASON

Scientists and laypeople have speculated for years why flu season comes every winter. Whether it is in the Northern or Southern hemisphere, there is a surge of flu cases each winter. The most popular hypotheses have been:

- Increased indoor crowding
- Less ventilation air
- Weakened human immune systems
- Colder weather
- Lower indoor relative humidity levels

The last two reasons are the closest. Colder outdoor air holds fewer grains of moisture, which means lower humidity levels indoors as the cold air infiltrates the building, which is a primary flu season factor for airborne transmission. As we all know from our handy psychrometric charts, relative humidity is not the same as grains of moisture. Understanding the impact of grains of moisture within indoor air is critical in understanding how airborne flu transmission affects flu season.

LOW GRAIN AIR AND AIRBORNE VIRION TRANSMISSION

Low grains of moisture air is the key to airborne flu virion infection transmission. Low grain air provides an environment which not only creates more airborne flu droplet nuclei when you spew them out, but also keeps those flu virions airborne and alive longer, thereby increasing flu transmission and infection rates.

SCIENCE CRAWLS OUT OF THE DARK AGE

Scientists have known since the 1950s that flu virions survive better in low relative humidity with low temperatures (which they didn't know was low grain air). By the '60s, they were postulating that winter flu season was due to low relative humidity indoor air and not to crowding or less outdoor ventilation air.[5,6]

The latest breakthroughs came in 2007-08 when influenza expert Professor Peter Palese[7] and his colleagues at Mt. Sinai Medical School created a set of brilliantly simple experiments: infect flu-susceptible Guinea pigs within different temperatures and relative humidity environments.[8] Since infected Guinea pigs can't sneeze, cough, or shake their paws with naïve (healthy) ones, it's only through normal breathing (think airborne transmission) that one flu-infected Guinea pig could infect a naïve one. With lungs similar to ours, naïve Guinea pigs are the perfect mammal to demonstrate airborne flu transmission in relation to environmental conditions.

Palese put infected and healthy pigs in two separate cages in order to simulate the distance required for airborne transmission.[9] While Palese's experiments varied the relative humidity and temperature, I've converted the results to grains of moisture. At higher grain conditions (40 to 96 grains), none of the naïve pigs got infected. When they dropped the conditions to below 38 grains, fully 50% of the naïve pigs caught the flu. At 41° and 20% rh (7 grains), 100% of the naïve pigs were sickened by the flu! Palese had demonstrated the connection between grains of moisture and airborne flu transmission.

HUMIDITY IS TOXIC TO AIRBORNE FLU

The connection between low grains and airborne flu survival and transmission becomes even stronger when you convert earlier airborne survival rate experiments done in the 1950s, '60s, and '70s. I converted those results into grains of moisture, and low grain air infection rates synch up with earlier airborne influenza survival experiments, which saw high flu survival in low grain air conditions.

The Mt. Sinai scientists were part of a long line of scientists who never connected relative humidity at different temperatures with variable levels of grains of moisture. It's no wonder they were baffled by low airborne survival at 70° and 50% rh, because you have a whopping 55 grains of moisture. Whereas at low temperatures (40° to 45°) and 50% rh, airborne flu virions were surviving due to a low 20 grains of moisture environment.

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AIRBORNE TRANSMISSION 'ZONES'

When I compiled the airborne guinea pig data along with the earlier airborne virion survival experiments, I found that indoor conditions above 45% rh and 70° (50 grains) lower airborne flu virions survival times in order to infect less people. I constructed a graph with four different transmission condition zones to reflect these results. The green zone has 50 plus grains of moisture, and thus lower airborne virion survival/transmission. The orange zone has "medium" airborne virion survival/transmission rates (26 to 49 grains), with infection increasing within the "high" yellow zone (11 to 25 grains). The red zone has the most ideal conditions for airborne flu survival/transmission, with conditions below 10 grains of moisture (Figure 1).

AIRBORNE VIRUS SCIENCE HAS LANDED IN THE REAL WORLD

If you're wondering where the evidence is of airborne flu virions in the real world, here's your proof: the CDC's NIOSH (National Institute for Occupational Safety & Health) documented (for the first time) that airborne flu virions were not only present in human occupied indoor air spaces, but in astonishing quantities.[10] They trapped and identified 15,000-16,000 airborne flu virions in three rooms within a West Virginia Hospital in February 2008. The breakthrough was threefold:

- They used a novel three-stage air sampling device created by NIOSH that could filter out all the other interfering airborne microbials like fungi, bacteria, etc., in order to isolate microscopic influenza virions.
- Advanced PCR (DNA) lab testing methods determined that they had trapped these levels of airborne influenza virions in the following locations:
  - 16,278 influenza virions in the emergency waiting room at 6 ft.
  - 15,065 influenza virions in the children's waiting room at 3 ft.
  - 15,532 influenza virions in the emergency waiting room at 3 ft.
  - 460; 1,114; 1,367; 4,623; and 5,762 virions in waiting rooms at 3 ft and 6 ft.
  - In addition 309; 3,160; and 4,623 virions were captured by personal airborne flu virion samplers worn by physicians with tubes positioned near their mouths and nose levels (i.e., their breathing zones).

HOW DID ALL THOSE VIRIONS STAY AIRBORNE?

The most important factors allowing NIOSH to trap all those flu airborne virions were:

- It was done in February, so it was the height of flu season, with lots of flu-spewing infected people coming into the hospital.
- The average temperature of the rooms was 74.3° with 30% rh or 38 grains of moisture. This is right in the medium airborne survival/transmission zone, supporting longer airborne virus times (Figure 1).

Even the NIOSH scientists were taken with the high airborne virion counts when they commented, "More than one half of the viral particles detected by PCR (DNA testing) were within the respirable aerosol fractions (diameter less than 4 microns), and these results support the hypothesis that influenza virus can be transmitted through the airborne route."

AIRBORNE VIRIONS AND GETTING THE FLU

Here's why the NIOSH results really blew me away: earlier studies found that it took only 1 to 3 flu virions[11] to make healthy volunteers sick! That's why flu epidemics can propagate so quickly within ideal conditions. With 15,000 flu virions floating around, do the math and you'll appreciate impact of airborne flu transmission.

THE DEW IS IN YOUR CORNER

Now, for the first time you can advise your clients about the impact that indoor relative humidity and temperature can have not merely as a comfort issue, but as an occupant health issue. I recommend that you humidify indoor spaces to 45 grains or more with 50 grains and above putting your clients in the green low-survival/transmission zone. This can also reduce the drying out of occupant's mucus membranes, which will keep these important virus trapping mechanisms in their fully functional state. I've taken readings in schools and buildings with 20% rh levels in the winter, which at 68° is a low 20 grains of moisture. These levels put those school occupants at great airborne virion transmission risk as they are in the high-survival/transmission zone.

CONSERVING HUMIDITY FOR HEALTH

A new way to look at latent energy recovery is that it can conserve indoor humidity levels in order to raise grains of moisture that would otherwise be thrown out of the building. Now with your newly empowered knowledge base of how grains of moisture impact airborne virion transmission, you'll be able to inform your clients about the health impacts that latent energy recovery can have by reducing airborne virus survival and transmission conditions.

AVOID BAD DEW

Whereas controlling summertime indoor humidity is focused on wringing out latent heat, increasing low wintertime humidity is more complex. The strategy of adding humidity can in many cases bring more problems. Keeping insulation dry is critical as I've seen too many cases of adding humidity which ends up over-saturating downstream duct areas leading to mold and bacteria growth. Determining the best equipment to efficiently aerosolize humidity droplets into the smallest size possible in order to avoid droplets plating out on plenum and duct surfaces is critical to denying mold and bacteria a food source to promote their growth.

THE FINAL AIRBORNE WORD

I've focused on airborne virus transmission and how the available airborne grains of moisture influence virion creation and survival. I hope you've got a better understanding of why there is an annual flu season and how the ambient grains of moisture conditions during the flu season can have a profound effect on building occupant's health. Consider going back to your clients and educating them on the benefits of wintertime humidity control. Better yet, look at your own working space and dial that up to a 50 grains standard; the life you save may be your own. **ES**

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