

Health and Humidity

Fundamentals / Applications / Research

Presented by David Bennett

Agenda

1. Fundamentals of Humidity

- How indoor humidity changes throughout the year
- Where humidification matters most

2. Humidity and People

- Historical research
- Impacts of moisture to the human body
- Recent advances in humidity research

3. Recent Research

- Microbiome study details
- Example of hospital savings
- Mayo Clinic – school study

4. Humidifying Your Facility

- Technologies for Humidification

5. Standards and Guidelines

- ASHRAE

What is Humidity and How Do We Measure It?

Humidity

- The amount of water vapor in the air
- Measured in “Absolute” or “Relative” terms

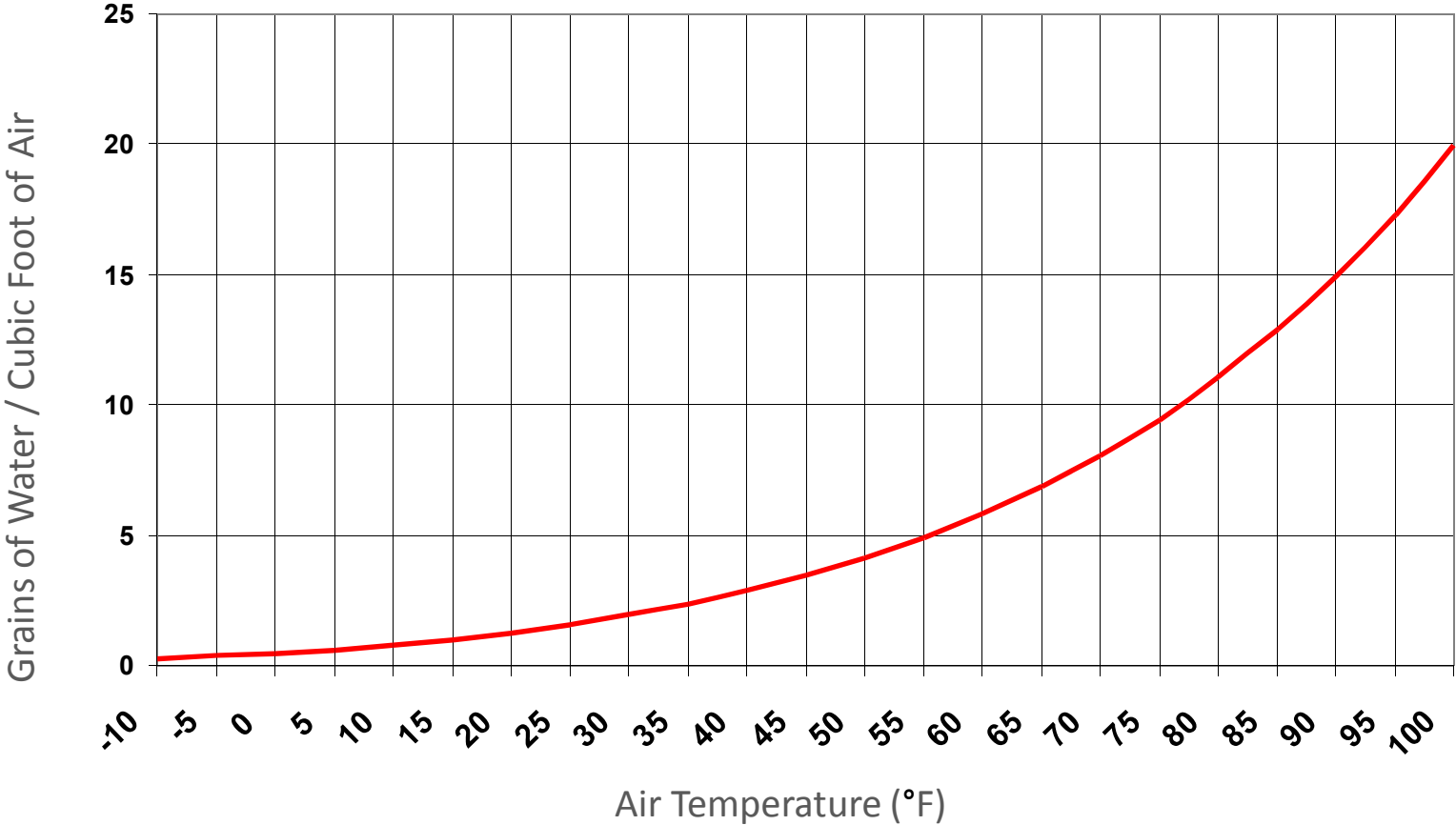
Absolute Humidity

- Mass of water in particular volume of air
- Expressed as mass (grains/lb_{da} or g_w/kg_{da})

Relative Humidity

- Amount of water vapor in the air relative to how much it can hold at a given temperature (%)

Maximum Moisture Content Of Air Depends On Air Temperature



Methods of Humidification

Steam vs. Atomizing



Isothermal

Adiabatic

	Isothermal	Adiabatic
ASEPTIC HUMIDIFICATION	Steam doesn't carry bacteria	Water droplets introduced in the air: no recirculation Treated water
CAPACITY	Small to Medium sized loads (100s lbs/hr)	Small to Large sized loads (1000s lbs/hr)
ENERGY CONSUMPTION	High	Very low
REQUIRED FREE SPACE	Steam is easily and quickly absorbed by the air	Minimum evaporation space (> 36" - 60" typ.)
TEMPERATURE CHANGE	Temperature doesn't change significantly	Yes COOLING EFFECT
WATER	Tap and treated (maintenance)	Tap and treated (maintenance)

*Typical for the industry

Questioning 20% RH ASHRAE 170 Lower Humidity Limit

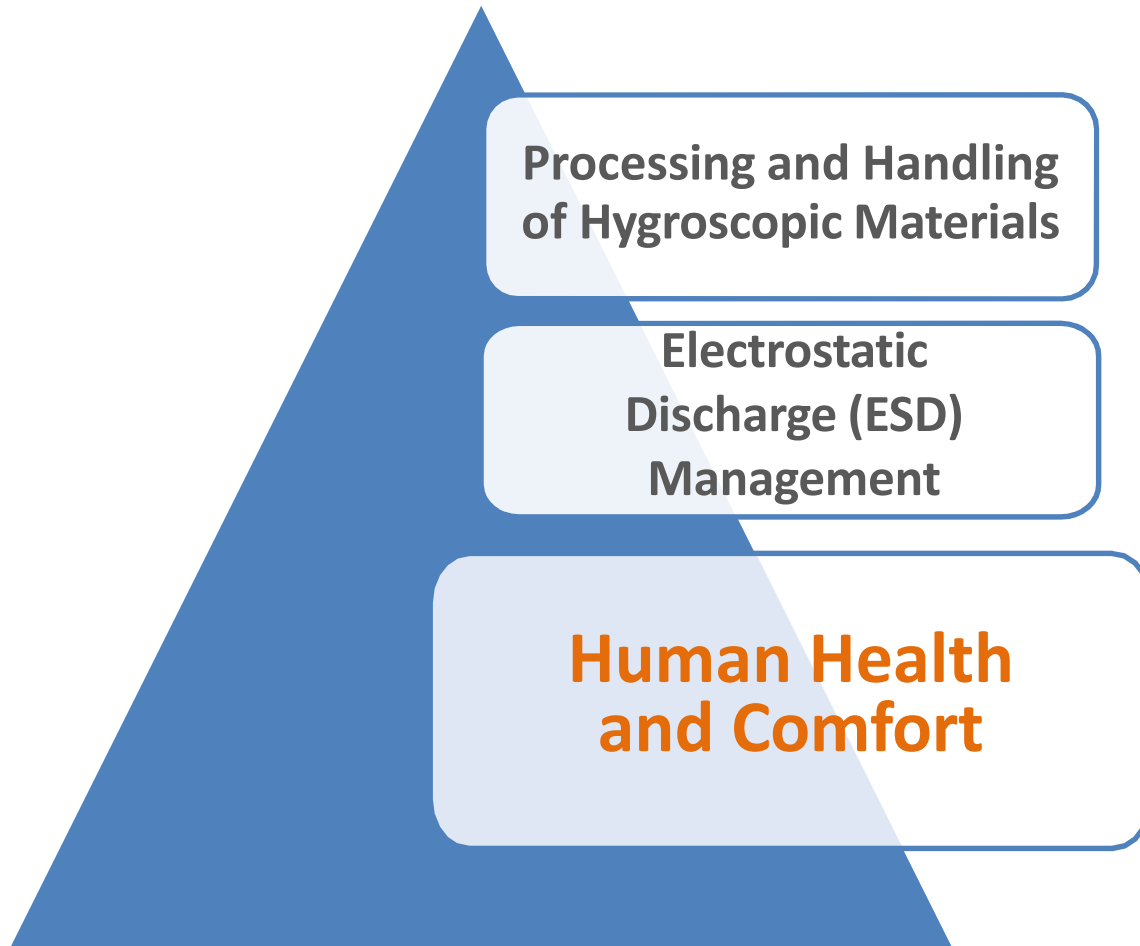
ASHE's Advocacy Alert – 2015

RH lower than 30% can “pose challenges” for some equipment and sterile supplies:

- Impact the shelf life and product integrity of sterile supplies
- May affect the operation of some electro-medical equipment in the OR, particularly older models
- Humidity regulation is difficult to control when weather changes occur



Typical Humidification Reasons



Humidity and People

Importance of Proper Humidification for Wellness

SKIN

Maintaining healthy skin as a barrier is critical to wellness.

- Water content of innermost skin cells is ~70%
- Below ~30% RH conditions, the skin becomes dry¹
- Dry skin symptoms include itching and cracking.
- Skin conditions such as psoriasis may become aggravated at lower relative humidity (RH) levels

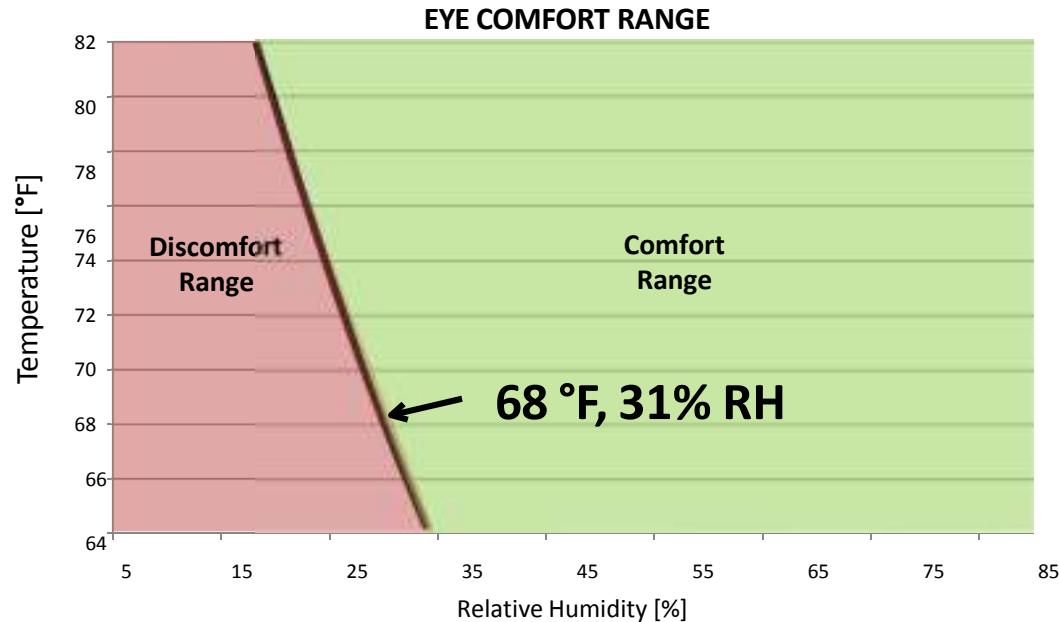


¹ Sunwoo Y, *Physiological and Subjective Responses to Low Relative Humidity in Young and Elderly Men*, (J Physio Anthropol, 2006 May), 25(3):229-38.

Importance of Proper Humidification for Wellness

EYES

- Low humidity causes a breakdown of the tear film
- Discomfort to the eye increases with time if the dew point is below 26 °F¹



¹J.E. Laviana, F.H. Rohles, Jr. and P.E. Bullock, *Humidity Comfort and Contact Lenses (ASHRAE, 1988) 94(1), 3-11.*

Importance of Proper Humidification for Wellness

THROAT

- Humidity below 30% RH can irritate vocal chords¹
- Dryness of throat
- Increased hoarseness or laryngitis
- National Institute for Health (NIH) recommends:
 - Drink water, six to eight glasses a day
 - ***Use a humidifier***
 - ***Keep relative humidity > 30% RH***



¹ National Institute on Deafness and Other Communication Disorders, *Taking Care of Your Voice*, www.nidcd.nih.gov/health/taking-care-your-voice (December 14, 2016)

Importance of Proper Humidification for Wellness

NASAL PASSAGES

- Membranes in the nose dry out quicker in low humidity¹
- Humidity above 30% RH is needed for the mucous membranes in the nose to properly filter the air we breathe

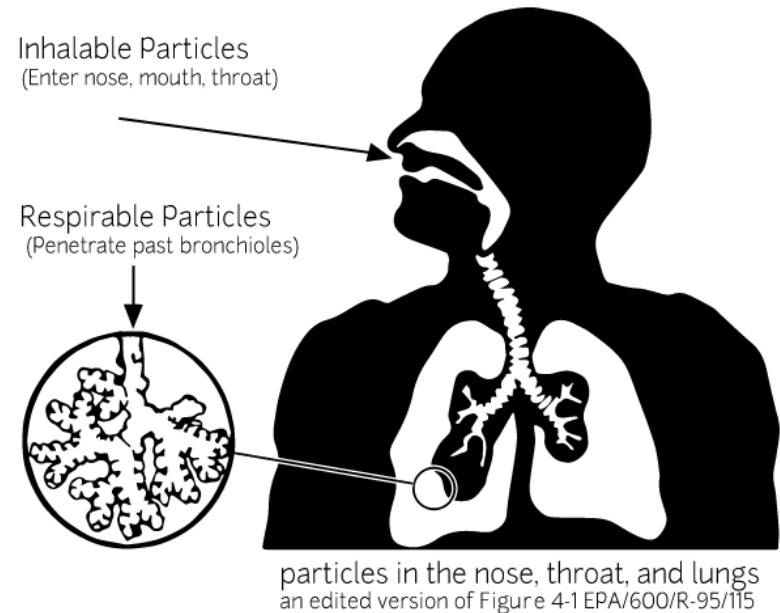


¹J.P. Guggenbichler, R. Huster and S. Geiger, *Luftfeuchtigkeit und Immunabwehr Die Rolle der Schleimhaut und Auswirkungen auf die Klimatechnik (2007)*
Tab Technik AM, Vol. 38, No. 9

Importance of Proper Humidification for Wellness

LUNGS

- Low humidity results in breathing smaller particles¹
- Low humidity can increase creation of smaller exhaled breath aerosols that can retransmit microbes
- Greater likelihood of particles being inhaled deeply



¹ASHRAE Guideline 10-2016, *Interactions Affecting the Achievement of Acceptable Indoor Environments*

Mechanics of Infections: Droplets in Air

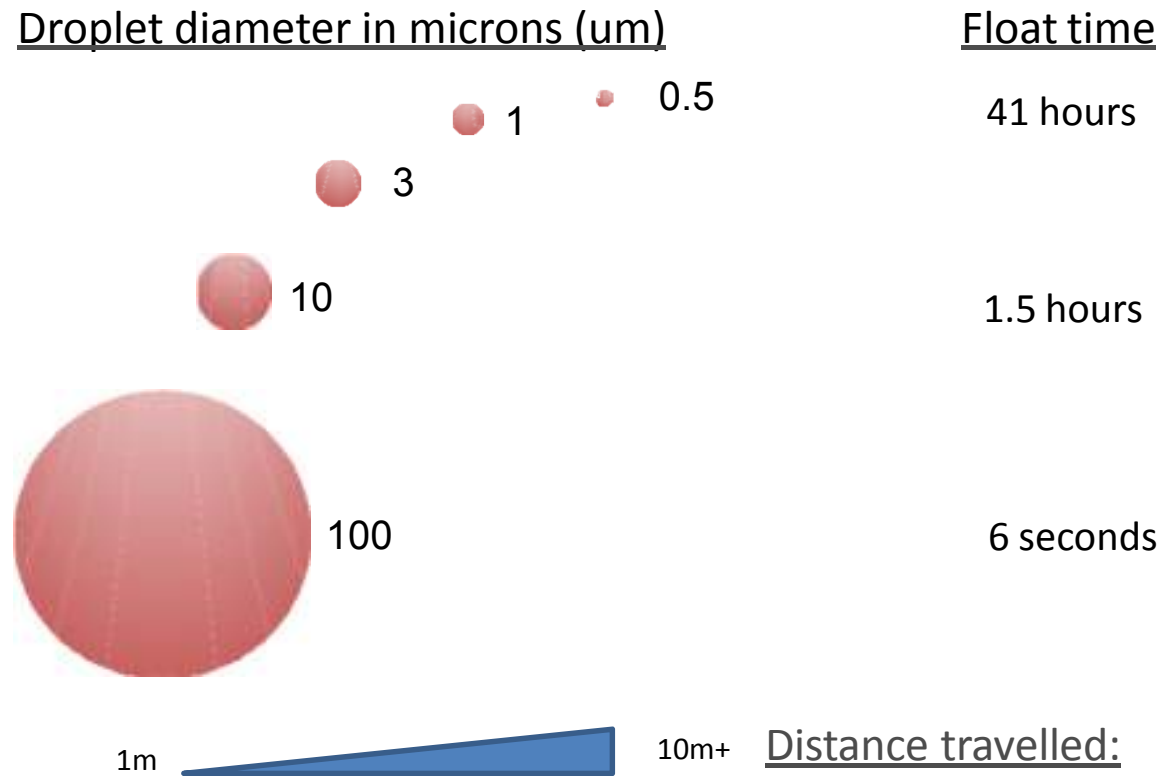


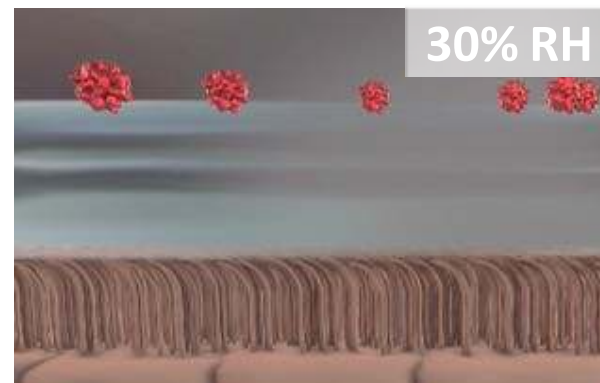
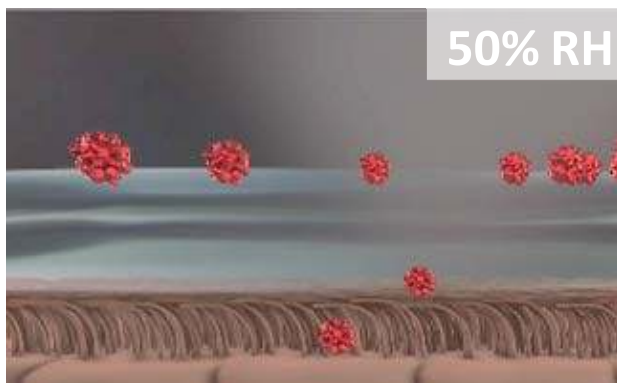
Image Courtesy: Dr. Stephanie Taylor

Mechanics of Infections

Infectious particles survive longer in dry air



Bodily defenses less effective in dry air



Images Courtesy: Condair AG

Recent Humidification Research

ASHRAE Research Project 1630 completed in 2016

"Update of the Scientific Evidence for Specifying Lower Limit Relative Humidity Levels for Comfort, Health and IEQ in Occupied Spaces"

- Authors: Melanie M. Derby, Maryam Hamehkasi, Steven Eckels, Grace M. Hwang, Byron Jones, Ronaldo Maghirang
- About 600 articles were identified and 70 articles were reviewed in detail concerning effects of humidity on comfort, health, and indoor environmental quality

Update of the Scientific Evidence for Specifying Lower Limit Relative Humidity Levels for Comfort, Health and IEQ in Occupied Spaces (RP-1630)

Melanie M. Derby, Maryam Hamehkasi, Steven Eckels, Grace M. Hwang,
Byron Jones, Ronaldo Maghirang & David Shulan

Abstract

Nearly 600 papers were located in citation and keyword searches regarding the effects of humidity on comfort, health, and indoor environmental quality (IEQ). Of these, around 70 papers reported the effects of low humidity (RH \leq 40%) and were analyzed in detail. Information in some categories was well chronicled, while other categories had significant knowledge gaps. Low humidity decreased house dust mite allergens. Due to different envelopes, generalizations could not be made for all bacteria and viruses. However, lower humidity increased virus survival for influenza. For comfort, low humidity had little effect on thermal comfort, but skin dryness, eye irritation, and static electricity increased as humidity decreased. For IEQ, low humidity had non-uniform effects on volatile organic compound (VOC) emissions and perceived indoor air quality. Across many low humidity studies, ventilation rates and exposure times were noted as confounding variables. A majority of studies that used human subjects utilized exposure times of three hours or less with adult subjects; few studies used children, adolescents, or elderly subjects.

1. Introduction

Humidity levels in indoor environments affect occupant health, comfort, and indoor environmental quality (IEQ). High humidity can reduce human comfort and impact disease transmission (Sterling et al., 1985; Berglund, 1998). In response to tightly sealed buildings to reduce building energy consumption, upper limits on relative humidity (RH) have been prescribed for human comfort and to mitigate growth of mold and fungi in buildings (ASHRAE, 2012). However, low humidity can also cause discomfort for building occupants (e.g., dry skin, dry eyes, dry nose). Low humidity also has implications for disease transfer, allergies, and respiratory functions, although firm, scientifically-grounded conclusions regarding the effects of low humidity are challenging to find. The literature review by Sterling et al. (1985) considered aspects of low humidity on building occupants, but there is a clear need to compile and analyze

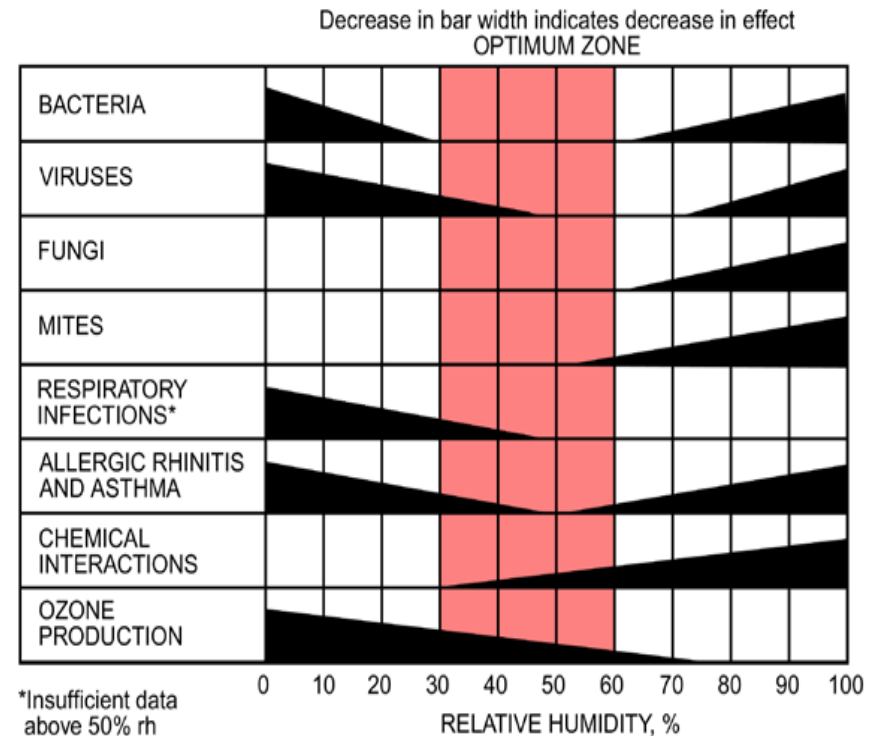
1

Recent Humidification Research

Findings include:

- Lower humidity decreased house dust mite allergens
- Lower humidity increased virus survival for influenza
- Health & comfort issues, skin dryness, eye irritation, and static electricity increased as humidity decreased

RP 1630 results are consistent with the updated Sterling Chart in the ASHRAE Handbook.



E.M. Sterling, Criteria for Human Exposure to Humidity in Occupied Buildings, 1985 ASHRAE

Low and high humidity control is important for wellness, health and comfort

RP 1630 Study in ASHRAE Journal

Humidity plays an important role in health and comfort.

- Our bodies are ~60% water
- Our skin, eyes, and respiratory system all need proper humidity

Research shows a link between low humidity and the likelihood of flu.

- Our body defenses are stronger above 30% RH
- There is less infectious flu virus in the air at higher RH levels
- The likelihood of flu infectivity decreases at higher humidity levels



September 2017 ASHRAE Journal

Humidification for People

Human body response

- Human body is ~60% water
- Body doesn't sense moisture well

Humidity and respiratory infections

- Evidence of link between moisture and cold/flu transmission
- Clinical trials between 1963 and 1985 showed significant reduction of respiratory infects when mid-range humidity was maintained [1-5]
- NIOSH/CDC Research in 2013 showed reduced infectivity of flu virus aerosols with mid-range air humidity levels [6]



1. Ritzel G, Sozialmedizinische Erhebung zur Pathogenese und Prophylaxe von Erkältungskrankheiten, sog. «Kindergartenstudie» Zeitschrift für Präventivmedizin 1966, 11. 9-16
2. Sale C, Humidification to Reduce Respiratory Illnesses in Nursery School Children, Southern Medical Journal, July 1972, Vol 65
3. Green GH, Winter humidity and related absenteeism in Canadian hospitals, Digest of the 3rd. CMBES
4. Green GH, The effect of indoor relative humidity on absenteeism and colds in schools, ASHRAE Trans., Vol. 80, Part II
5. Gelperin A, Humidification and upper respiratory infection incidence, Heating, Piping and Air Conditioning, 45:3, 1973
6. Noti JD et. al, High Humidity Leads to Loss of Infections Influenza Virus from Simulated Coughs, PLoS ONE 8(2): e57485, 2013

Updates in Humidity Research

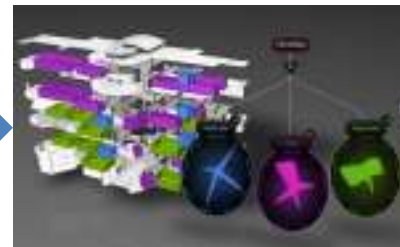
*With Contributions from Dr. Stephanie Taylor
and Dr. Med. Walter Hugentobler*

What is the Microbiome?

- Microbiomes are communities of microbes
 - Bacteria, viruses and fungi-that live in, on and around every living thing
- Microbiome of the gut, the skin, the built environment, the air, etc.



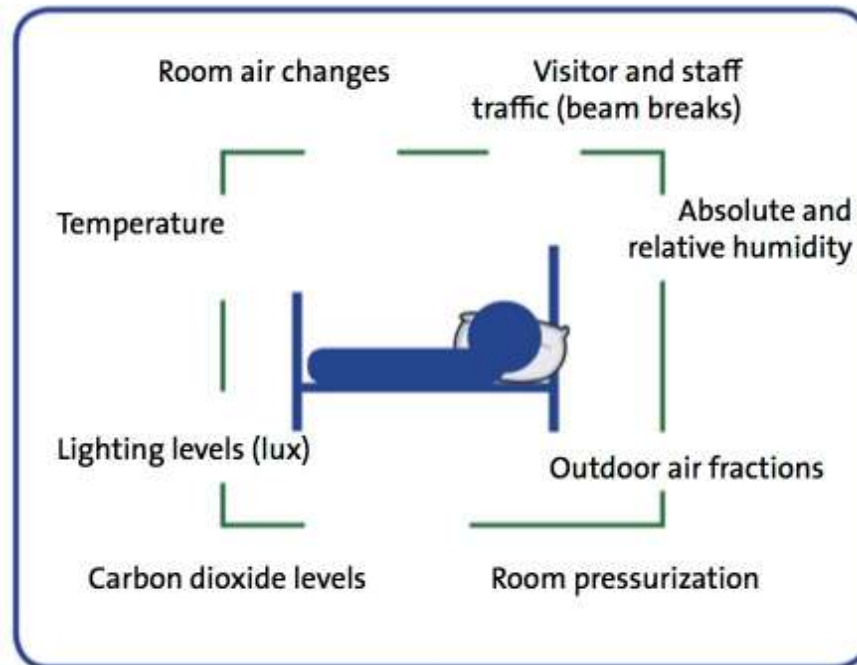
*We send our microbes
into buildings*



*Buildings send their
microbes into us*

Research Goals: Patient Room vs. Patient Outcome

- Monitor the physical environment (10 rooms, 2 RN stations)
- Measure microbial footprint
- Determine Healthcare Associated Infections (HAIs)



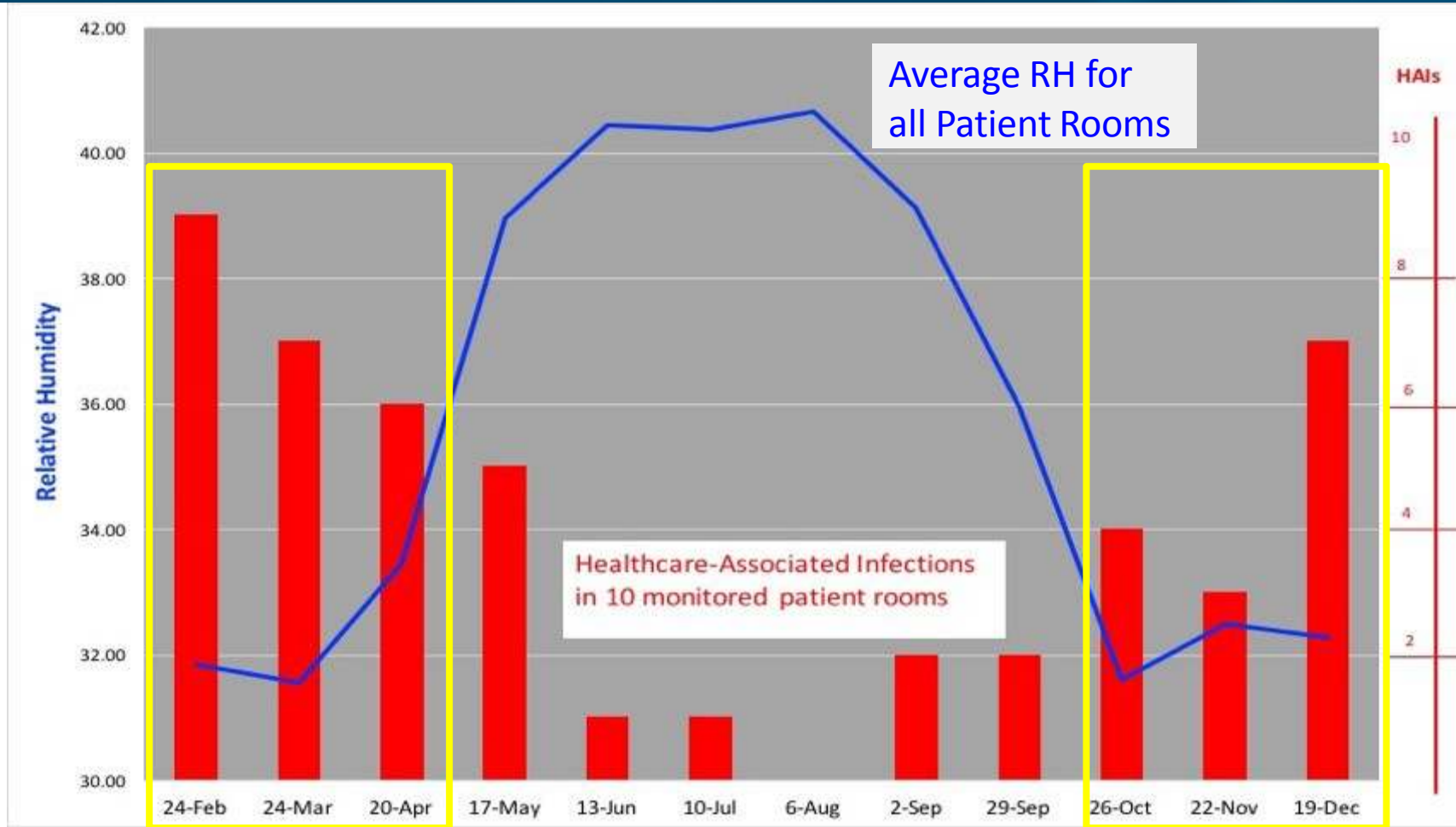
5 minute samples for 1 year = 8 million data points

Study Results

15% of patients contract HAIs

Rate	Symptom	HAI Organism
1	Unspecified infection	Citrobacter infection
6	Colitis and Diarrhea	Clostridium difficile
6	Post-surgical Wound Infection	Organism Unspecified
2	Pneumonia	Cytomegalovirus, Pseudomonas, Epstein-Barr
5	Urosepsis	Organism unspecified, E-Coli
3	Infection with Joint Prosthesis	MRSA
6	Central Line with Blood Stream Infection	Bacteria Unspecified
4	Pneumonia	Organism Unspecified
1	Gastritis, Enteritis	Cytomegalovirus , Salmonella
4	Bacteremia	Organism Unspecified
2	Pneumonia	MRSA

Study Results: Indoor Relative Humidity vs. Patient HAIs

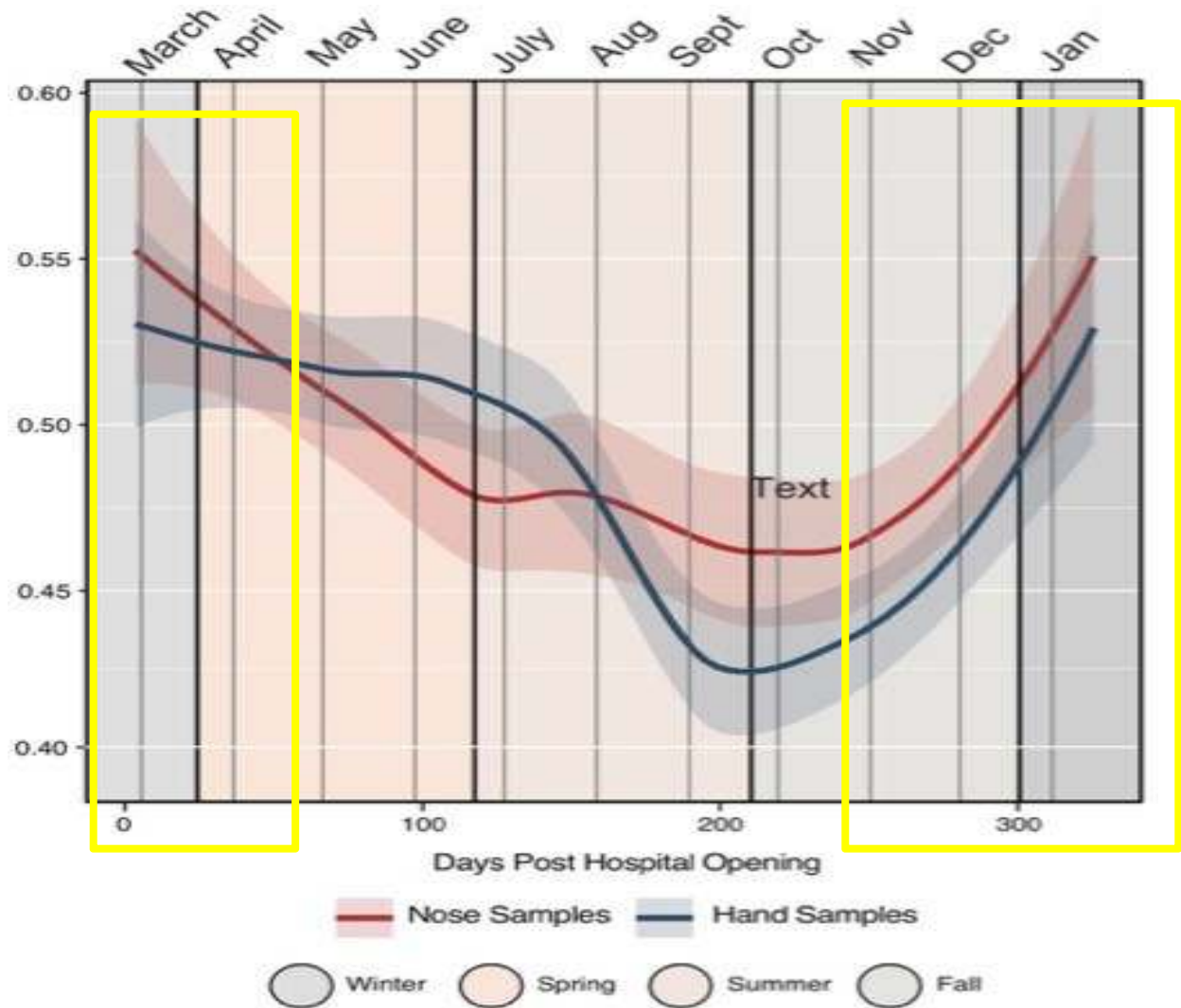


Source: *Colonization and Succession of Hospital-Associated Microbiota, in Press 2016*

Simon Lax, Daniel Smith, Naseer Sangwan, Kim Handley, Peter Larsen, Miles Richardson, Stephanie Taylor, Emily Landon, John Alverdy, Jeffrey Siegel, Brent Stephens, Rob Knight, Jack A Gilbert

Study Results: Indoor RH vs. Bacteria Spread

Spread of skin bacteria from clinical staff



Source: *Colonization and Succession of Hospital-Associated Microbiota, in Press 2016*

Simon Lax, Daniel Smith, Naseer Sangwan, Kim Handley, Peter Larsen, Miles Richardson, Stephanie Taylor, Emily Landon, John Alverdy, Jeffrey Siegel, Brent Stephens, Rob Knight, Jack A Gilbert

Study Conclusions

As Relative Humidity goes



Infections and bacterial spread goes



How Costly Is This?

Summary of Total Excess Costs and Hospital Days Due to Hospital Acquired Infections

	Total Infections	Total Excess Costs	Total Excess Hospital Days
Urinary Tract Infections	1,296	\$1,435,968	2592.0
Surgical Wound Infections	365	\$7,042,464	4378.0
CRBSI	148	\$4,990,636	2509.0
VAP	15	\$401,369	170.0
MRSA	120	\$927,162	646.0
CDIFF	122	\$500,200	733.0
TOTAL	2,066	\$15,297,799	11,028.0

Not Just Hospitals! Offices, Schools, Homes

- **Results of study apply more broadly**
 - Infectious organisms found everywhere
 - Controlling humidity is essential
- **Healthy employees pay dividends**
 - Fewer sick days
 - Reduced healthcare costs
 - Increased productivity
- **Costs and incentives**
 - Hospitals penalized monetarily by HAI rates
 - Schools incentives for performance
 - What does illness cost your organization?

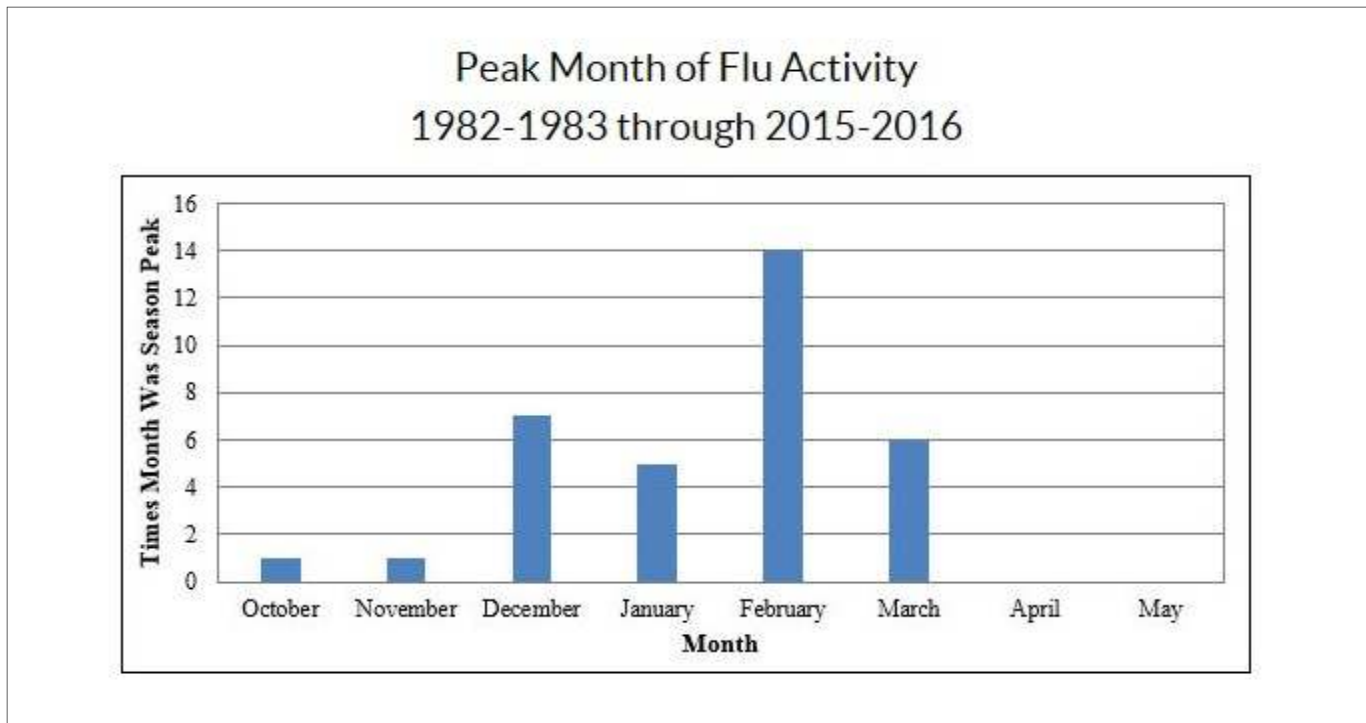


Image Courtesy: N. Lea

Recent Humidification Research

Health: Viruses and Seasonal Influenza

- Influenza is more common in the fall and winter months¹

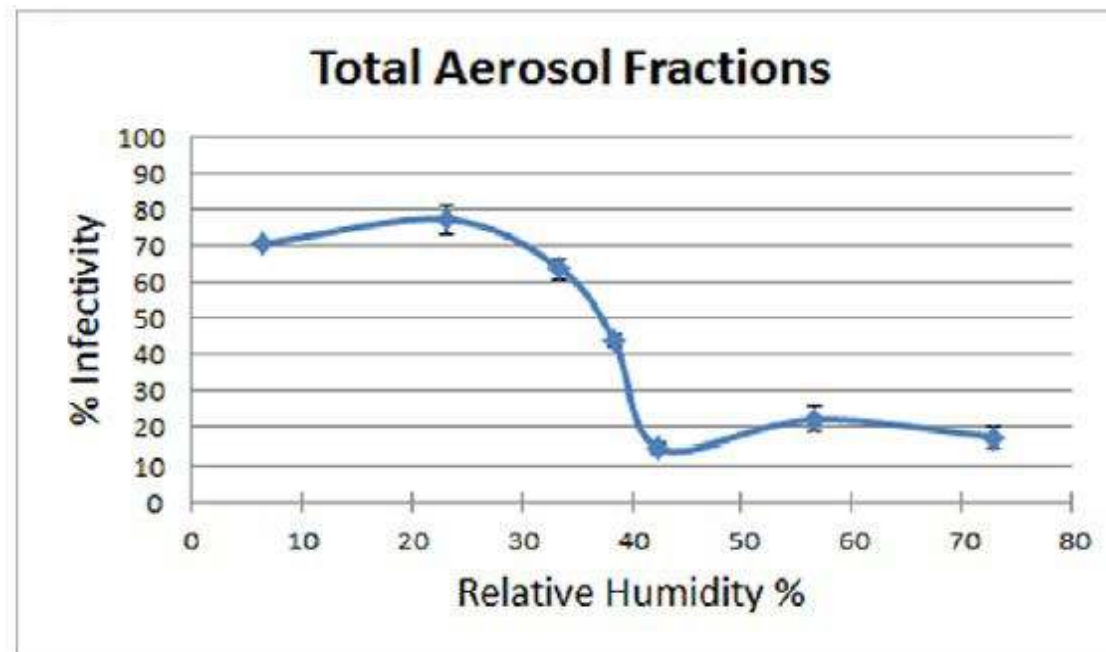


¹ www.cdc.gov/flu/about/season/flu-season.htm

Recent Humidification Research

Influenza Virus

- Studies show that higher humidity reduces infectivity of influenza
- Research indicates that 1 hour after coughing, the influenza virus is ~5 times more infectious at 7-23% than at > 43% RH



¹ John Noti, et al, *Humidity Leads to Loss of Infectious Influenza Virus from Simulated Coughs* (February 27, 2013)

Recent Humidification Research

Health: Viruses and Seasonal Influenza

- Possible reasons for increased winter influenza include¹:
 - People spend more time indoors in proximity of others
 - Exhaled aerosols can dry out and become smaller in lower humidity and have longer settling times
 - Drying of nasal mucous membrane weakens respiratory system
 - Virus is most stable at lower RH
- Data suggests that humidifiers may be adequate to raise humidity to levels associated with a significant reduction in influenza virus survival²

¹ Anice Lowen, et al, *Influenza Virus Transmission Is Dependent on Relative Humidity and Temperature* (October 19, 2007)

² J. Metz, et al, *Influenza and Humidity – Why a bit more damp may be good for you!* (June 2015)

Cost of Influenza

Huge economic cost with an annual influenza epidemic

(based on 2003 US population)¹:

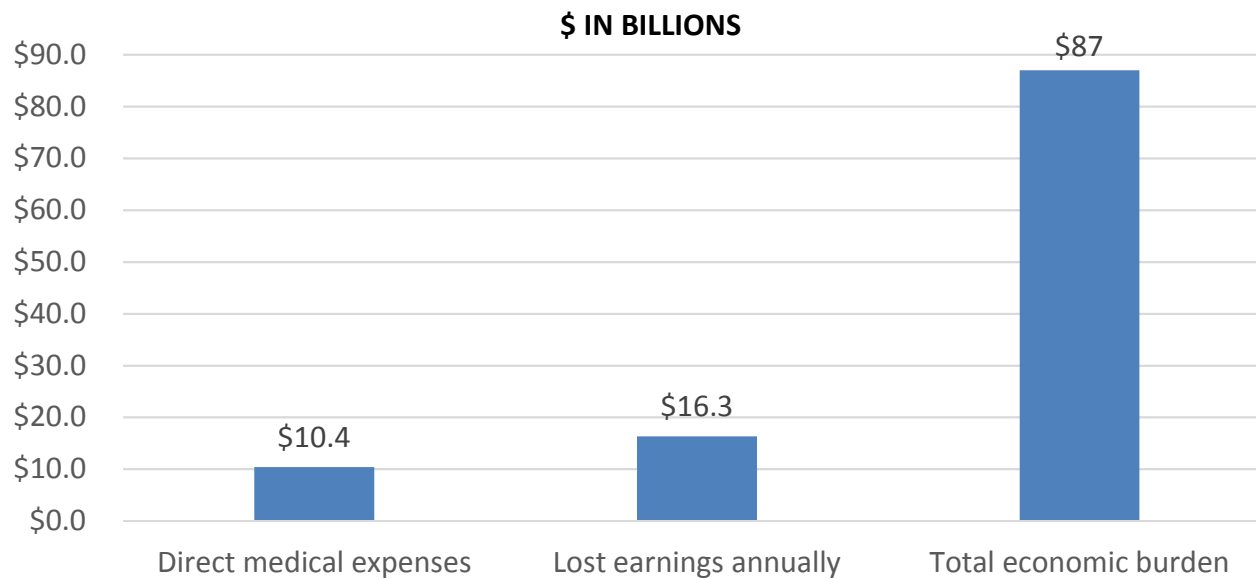
- \$10.4 billion a year in direct medical expenses
- \$16.3 billion in lost earnings annually
- \$87 billion a year total economic burden

Influenza A incidence peaks during winter in temperate regions

1. Molinari NA et al. 2007. *Vaccine* 25:5086-5096.

Cost of Influenza in United States

Huge economic cost with an annual influenza epidemic (based on 2003 US population)¹

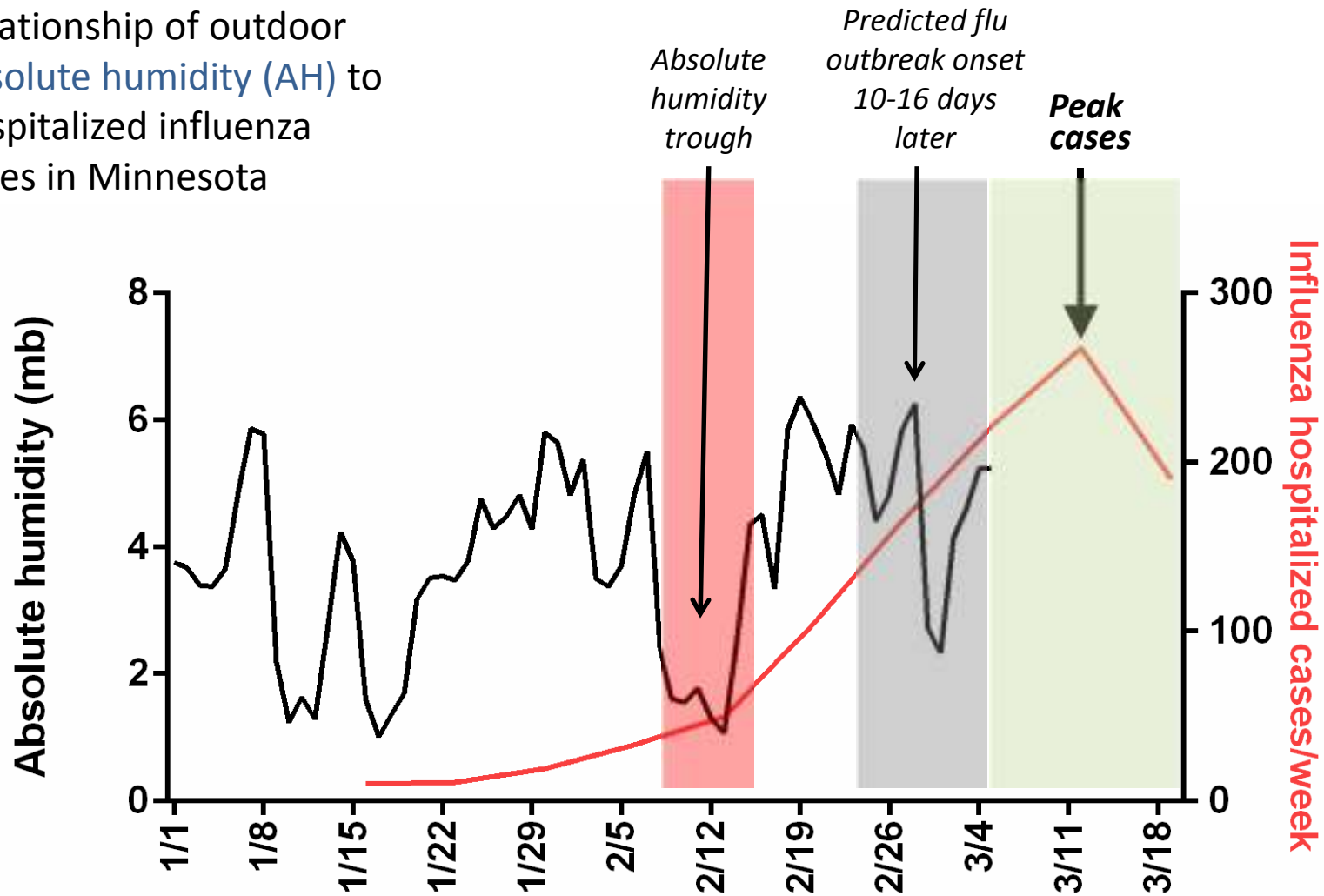


1. Molinari NA et al. 2007. Vaccine 25:5086-5096.

Influenza A incidence peaks during winter in temperate regions

Flu Season Correlation to Outdoor Humidity

Relationship of outdoor absolute humidity (AH) to hospitalized influenza cases in Minnesota



Mayo Clinic Study in Preschool Classrooms

Can altering indoor humidity reduce transmission of respiratory viruses?

Pilot study done January-February 2016



*Aldrich Nursery School
Rochester, MN*



*Jennifer Reiman, PhD
Postdoctoral Research Fellow,
Mayo Clinic*



Questions Mayo Researchers sought to answer:

Impact of humidity on:

1. Viral transmission (presence and quantity)

- Air particles
- Fomites (paper wrapped objects)

2. Survivability of influenza

- Ability of samples to infect cells in culture

3. Droplet size

- Changes in particle size distribution

4. ILI (influenza like illnesses) and absences of students and staff

FIGURE 1. METHODOLOGY FLOW CHART



Sample Collection (Aldrich preschool)



Wrap additional classroom objects
(if needed)

Calibrate air sampler pumps

Run 150 minutes (during class)

Morning preschool classes
(students ages 3-5) in rooms



Unwrap school objects
Collect wrapped objects



Measure air particle sizes

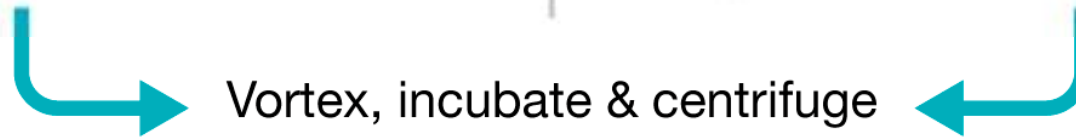


Sample Processing (Mayo Clinic)

Dust paper with
fingerprinting powder
Remove fingerprint
(+) pieces
Place paper into media



Disassemble air
samplers
Add media to tubes
Place filter into media



Vortex, incubate & centrifuge
Isolate viral RNA

RT-PCR

Identify Flu A+

Infectivity assay (electrical impedance)

Humidification Added to School Classrooms

Hypothesis:

Increasing the relative humidity of classrooms to 40-60% will reduce the capacity of influenza to survive on classroom surfaces, or spread between classmates as aerosols.

- Stand-alone electrode humidifiers were installed in some classrooms
- Actual RH levels controlled to $\pm 35\%$ in rooms with humidifiers
 - vs $\pm 20\%$ for non-humidified rooms

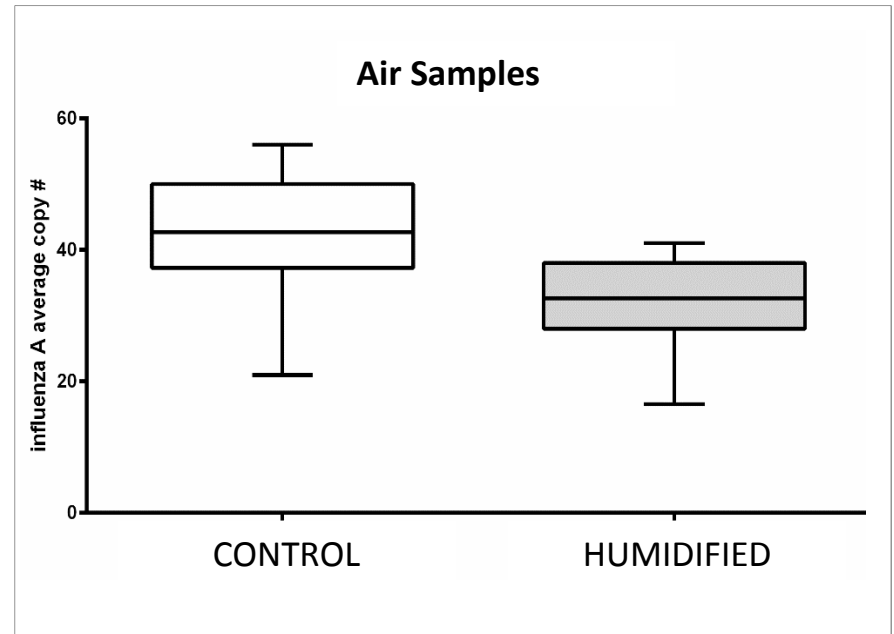
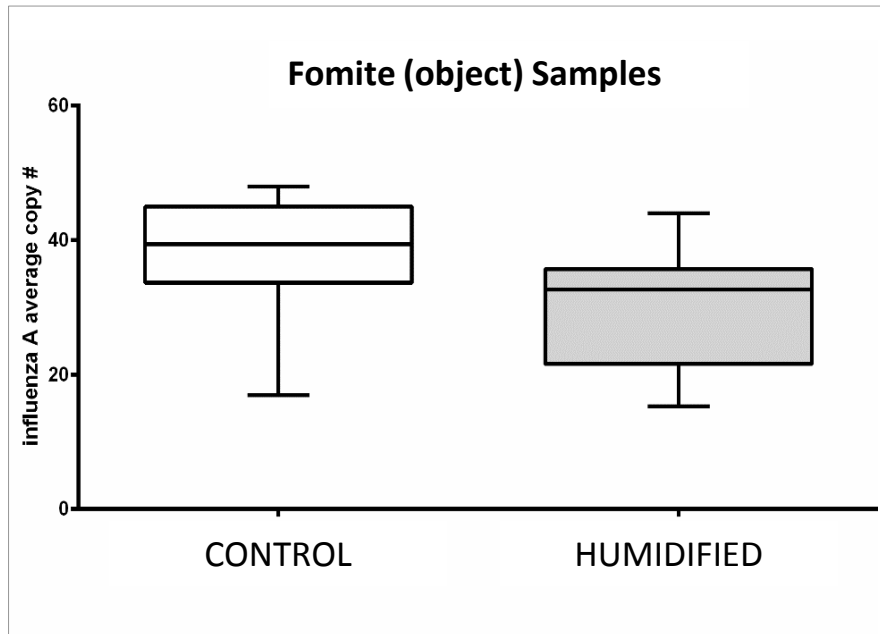


Humidification Resulted in Less Flu-like Illness

- Flu-like illnesses reported:
 - 70% were in control (non-humidified) rooms
 - 30% were in humidified rooms
- Humidified rooms had:
 - A significant **decrease** in % total air samples containing Influenza A
 - Trend toward **decreased** % of paper samples containing Influenza A
 - A significant **reduction** in Influenza A presence for total air and paper samples



Aldrich Memorial Nursery School Study



Within flu positive samples, a reduced amount within humidified rooms

Humidifying your Facility

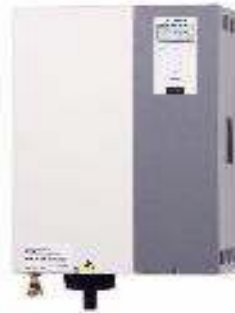
Technologies for Humidification

Steam Technologies

Gas Fired



Electric



Electrode



Resistive

Building Steam



*Centralized
Steam*



*Steam to
Steam*

Technologies for Humidification

Adiabatic Technologies

Wetted Media



Centrifugal



Ultrasonic



Medium Pressure



High Pressure



Compressed Air



Unintended Consequences of Optimal Humidity

Improved productivity through well being¹

- Reduced eye strain
- Reduced vocal strain
- Reduced allergy and asthma impact
- Increased performance
- Mental acuity
- Improved perceived comfort (“humidex”)



¹ Rief S and Juric M, *Air Humidity in the Office Workplace*, Fraunhofer IAO, 2014

Summary

- When outdoor air is cooler than indoor air you are generally going to see a drying effect in buildings.
- Air that is too dry has negative health effects for occupants. Target 30 – 60% RH for optimal occupant wellness.
- Research shows higher relative humidity with reduced spread of illness and in particular Hospital Acquired Infections (HAI's).
 - There is a clear payback in hospitals based on reductions in related patient costs.
- Today's humidifiers are available in many types and technologies to match applications and humidification needs.

Standards & Guidelines

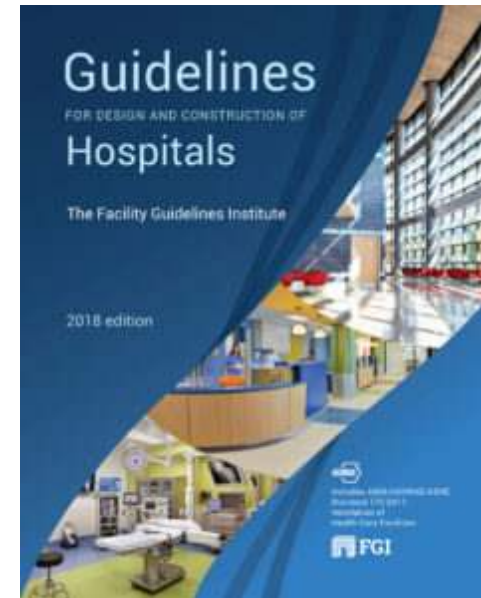
Standards & Guidelines

GUIDELINES

- Facility Guidelines Institute (FGI) guidelines (2018) for ventilation
 - Refers to ASHRAE Standard 170 - 2017

STANDARDS

- ANSI/ASHRAE/ASHE Standard 170 – Ventilation of health care facilities (2017)
 - Maintain relative humidity (RH) minimums between 20-40% in healthcare facilities
 - *60% maximum*
 - With a minimum of 30% RH, a safety factor may be prudent
 - *35% minimum setpoint*



ANSI/ASHRAE/ASHE Standard 170-2017 Ventilation of Health Care Facilities

Function of Space	Pressure Relationship to Adjacent Areas (n)	Minimum Outdoor ach	Minimum Total ach	All Room Air Exhausted Directly to Outdoors (j)	Air Recirculated by Means of Room Units (a)	Design Relative Humidity (k), %	Design Temperature (l), °F/°C
SURGERY AND CRITICAL CARE							
Critical and intensive care	NR	2	6	NR	No	30–60	70–75/21–24
Delivery room (Caesarean) (m), (o)	Positive	4	20	NR	No	20–60	68–75/20–24
Emergency department decontamination	Negative	2	12	Yes	No	NR	NR
Emergency department exam/treatment room (p)	NR	2	6	NR	NR	Max 60	70–75/21–24
Emergency department public waiting area	Negative	2	12	Yes (q)	NR	Max 65	70–75/21–24
Intermediate care (s)	NR	2	6	NR	NR	Max 60	70–75/21–24
Laser eye room	Positive	3	15	NR	No	20–60	70–75/21–24
Medical/anesthesia gas storage (r)	Negative	NR	8	Yes	NR	NR	NR
Newborn intensive care	Positive	2	6	NR	No	30–60	72–78/22–26
Operating room (m), (o)	Positive	4	20	NR	No	20–60	68–75/20–24
Operating/surgical cystoscopic rooms (m), (o)	Positive	4	20	NR	No	20–60	68–75/20–24
Procedure room (o), (d)	Positive	3	15	NR	No	20–60	70–75/21–24
Radiology waiting rooms	Negative	2	12	Yes (q), (w)	NR	Max 60	70–75/21–24
Recovery room	NR	2	6	NR	No	20–60	70–75/21–24
Substerile service area	NR	2	6	NR	No	NR	NR
Trauma room (crisis or shock) (c)	Positive	3	15	NR	No	20–60	70–75/21–24
Treatment room (p)	NR	2	6	NR	NR	20–60	70–75/21–24
Triage	Negative	2	12	Yes (q)	NR	Max 60	70–75/21–24
Wound intensive care (burn unit)	NR	2	6	NR	No	40–60	70–75/21–24

ASHRAE: 20 or 30% minimum RH typical for health care spaces

Questioning 20% RH ASHRAE 170 Lower Humidity Limit

ASHE's Advocacy Alert – 2015

RH lower than 30% can “pose challenges” for some equipment and sterile supplies:

- Impact the shelf life and product integrity of sterile supplies
- May affect the operation of some electro-medical equipment in the OR, particularly older models
- Humidity regulation is difficult to control when weather changes occur



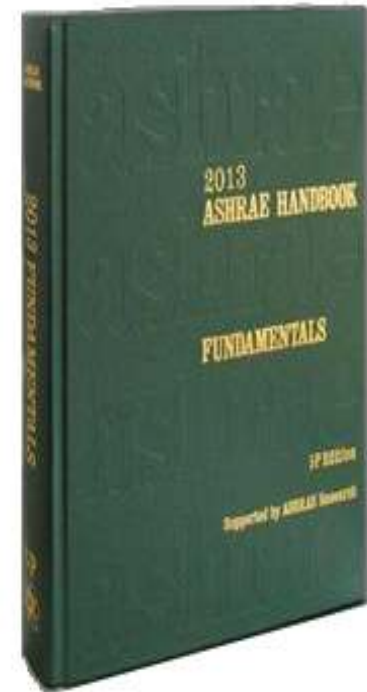
ASHRAE Standards 55-2017

Conditions for Thermal Comfort

- Does not specify minimum humidity levels but does acknowledge that low humidity can affect comfort factors
- Establishes a range of humidity and temperatures that are considered comfortable by 80% or more of the test objects
- “...ASHRAE Standard 55 recommends that the dew-point temperature of occupied spaces not be less than 36 °F.”
 - 27% RH @ 72 °F

Project Design Recommendation

If humidification is not accepted at the design level or is Value Engineered out, leave adequate space in the AHU for future steam dispersion with the appropriate absorption distance



Humidity Design Resources: More Information



©ASHRAE, www.ashrae.org

ASHRAE Handbooks

- 2016 Systems and Equipment Chapter 22
- 2015 HVAC Applications



©AHRI, www.ahrinet.org

AHRI Humidifiers Section

- www.ahrinet.org
- Click Contractors and Specifiers



Photo Credit: N. Lea

Local Standards and Norms

- Codes, Federal Standards, etc.
- Euro Standard EN 15251:2007

PDH Questions

PDH Questions

Q1: What is the optimal humidification range for human comfort?

Q2: Can humidification reduce HAI's?

Q3: What is the current ASHRAE Standard for humidification in healthcare?

Q4: Can proper humidification reduce the spread of the ILI's?

Thank You
