HUMIDITY
CONTROL GROUP
of the HEVAC Association

Humidity and its Impact on Human Comfort and Wellbeing in Occupied Buildings

HEVAC
HEATING | VENTILATION | AIR CONDITIONING

Contents:

INTRODUCTION

A controlled and regulated indoor environment is necessary for humans to be comfortable inside buildings. Humans need to have a thermal balance between themselves and the environment they occupy, known as 'Thermal Comfort'. Thermal Comfort directly influences the actual and perceived quality of the indoor environment; it is determined by the effect of the interrelationship between air temperature, relative humidity (RH) and air movement on occupants; together with human metabolic rate and thermal insulation value of clothing that occupants wear.

> Air Conditioning – A process of altering the properties of air; primarily temperature and humidity; to more favourable conditions.
>
> - The definition of air conditioning as held by the Humidity Control Group

The amount of humidity in the air has a direct impact on perceived thermal comfort, which in turn impacts the health and wellbeing of building occupants. Maintaining the level of indoor humidity between 30-70%RH is essential in spaces that human beings occupy as it allows them to function optimally.

HUMAN THERMAL COMFORT

Thermal Comfort is defined in British Standard BS EN ISO 7730 (1) as: 'that condition of mind which expresses satisfaction with the thermal environment.'

So the term 'thermal comfort' is used to describe an individual person's relationship with their environment and is often simply referred to in terms of whether someone is feeling too hot or too cold. In reality however, thermal comfort is very difficult to define in a numerical sense because of the need to take into account a range of environmental and personal factors when deciding what will make people feel comfortable.

The environmental factors are determined by the effect of the interrelationship between air temperature, mean radiant temperature, RH, and air movement on the occupants.

Personal factors include age, gender, metabolic rate, activity level, disabilities, cultural differences and the thermal insulation values of worn clothing.

Office Aircon is Sexist to Women, Study Finds

A study on office temperature complaints has suggested that women are less likely to be comfortable with their workplace temperature than men are.

It found that a phenomenon dubbed “overcooling” during the summer, in which air conditioning systems cool down rooms more than is necessary, may lead to women in particular feeling uncomfortable.

The study concluded there is “a need to rethink the approach to air-conditioning office buildings” as a result of its findings.

The U.S. study involved data from two main sources: 38,851 responses to the CBE Occupant Survey between March 2000 and December 2019, in which people were asked questions about the indoor environment of their workplace, including temperature; and Twitter, from which 16,791 tweets between January 2010 and December 2019 were studied. The tweets were limited to the U.S. and had to include a location plus keywords like “cold” and “office”.

From the CBE survey alone, the study found that out of 38 percent of people who said they were dissatisfied with office temperature, 64 percent were women.

The study was published in the journal Scientific Reports on Dec 8th 2021. three of it’s four authours were affiliare with the Centre for the Built Environment at the University of California, Berkeley, while the other was based at the Indoor Environment Quality Lab at the University of Surrey.

https://www.newsweek.com/office-aircon-temperature-sexist-unfair-women-overcooling-study-1663949

The Government of Canada (2) has published a table that compares a range of air temperatures against a range of relative humidity values and determines at each value an apparent temperature the occupant would feel. This is part of their ‘warm season weather hazards’ resources. This clearly highlights the relationship between air temperature and RH (%rh).

Relative humidity (%) Temperature (°C)	100%	95%	90%	85%	80%	75%	70%	65%	60%	55%	50%	45%	40%	35%	30%	25%	20%
21 °C	29	29	28	27	27	26	26	24	24	23	23	22					
22 °C	31	29	29	28	28	27	26	26	24	24	23	23					
23 °C	33	32	32	31	30	29	28	27	27	26	25	24	23				
24 °C	35	34	33	33	32	31	30	29	28	28	27	26	26	25			
25 °C	37	36	35	34	33	33	32	31	30	29	28	27	27	26			
26 °C	39	38	37	36	35	34	33	32	31	31	29	28	28	27			
27 °C	41	40	39	38	37	36	35	34	33	32	31	30	29	28	28		
28 °C	43	42	41	41	39	38	37	36	35	34	33	32	31	29	28		
29 °C	46	45	44	43	42	41	39	38	37	36	34	33	32	31	30		
30 °C	48	47	46	44	43	42	41	40	38	37	36	35	34	33	31	31	
31 °C	50	49	48	46	45	44	43	41	40	39	38	36	35	34	33	31	
32 °C	52	51	50	49	47	46	45	43	42	41	39	38	37	36	34	33	
33 °C	55	54	52	51	50	48	47	46	44	43	42	40	38	37	36	34	
34 °C	58	57	55	53	52	51	49	48	47	45	43	42	41	39	37	36	
35 °C		58	57	56	54	52	51	49	48	47	45	43	42	41	38	37	
36 °C			58	57	56	54	53	51	50	48	47	45	43	42	40	38	
37 °C					58	57	55	53	51	50	49	47	45	43	42	40	
38 °C							57	56	54	52	51	49	47	46	43	42	40
39 °C									56	54	53	51	49	47	45	43	41
40 °C										57	54	52	51	49	47	44	43
41 °C											56	54	52	50	48	46	44
42 °C												56	54	52	50	48	46
43 °C													56	54	51	49	47

Humidex and degree of comfort: Legend

Humidex	Degree of comfort
20 - 29	Little discomfort
30 - 39	Some discomfort
40 - 45	Great discomfort; avoid exertion
46 and over	Dangerous; possible heat stroke

CURRENT LEGISLATION

All workplaces in the UK are covered by the Health and Safety at Work Act 1974 (HSW Act) (3) plus the amended Workplace (Health, Safety and Welfare) Regulations 1992 (MHSWR) (4). These set out the general duties that building owners have towards employees and members of the public in providing a working environment that is both safe and without risk to health.

The act states that “effective and suitable provision shall be made to ensure that every enclosed workplace is ventilated by a sufficient quantity of fresh or purified air.” (regulation 6); it goes on to state that to effectively ventilate a workplace, fresh clean air should be drawn from a source outside and circulated through the building. The ventilation system should remove and dilute warm, humid air and provide air movement, to create a sense of freshness without causing a draught. Humidity and ventilation should be maintained at levels which prevent discomfort or problems of sore eyes.

The HSE Website discusses thermal comfort and identifies practical ways to achieve workplace health safety and welfare. Thermal comfort is identified in two particular ways: firstly the environment inside the workplace, and secondly the way the individual interacts with that indoor environment. Indoor humidity is one of six specified influencing environmental variables. The other variables are;

- air temperature,
- mean radiant temperature,
- ventilation and air velocity,
- clothing and PPE insulation
- work rate and metabolic heat. (5)

PUBLISHED RESEARCH

THERMAL COMFORT

The influence of relative humidity on adaptive thermal comfort (6), concluded that Relative Humidity (RH) is an important variable for Thermal Comfort and the well-being of humans. If the air is too dry, respiratory problems coupled with skin and eye irritation can occur. Very high levels of RH can lead to respiratory ailments, thermal discomfort and condensation problems. The study further suggests an advancement in the adapative thermal comfort model to include the effect of relative humidity.

Özdamar and Umaroğullari (7) considered the interaction between human comfort and indoor air quality particularly in light of the increasing hours humans spend in indoor environments. *Toftum and Fanger* (8) in 1999 proposed an updated model to evaluate the impact of high relative humidity levels on human comfort. More recent studies into the impact of low humidity levels on health and comfort in an office building were reported by *Al horr et al.* (9); the combined effects of air temperature, relative humidity and work rate on human stress in hot and humid environments has also been extensively studied (10). The purpose-built climate chamber studies concluded that the combined effect of temperature and humidity had a significant, noticeable impact on the productivity of those experiencing the test environment.

TEWL and the relationship to thermal comfort

TEWL – Transepidermal Water Loss is defined as the quantity of water that passes from inside a body through the epidermal layer to the surrounding atmosphere via diffusion and evaporation processes. This is not the water loss that is associated with sweating but the natural loss of water vapour from the skin.

Source: Photo of a Person Wearing a Black Dress by Taryn Elliott

An examination of 25 different studies worldwide in TEWL and it's influences (11) concluded that temperature and humidity are only two of many variable influencing the seasonal and climate variations on TEWL, and recoomend further studies take care to control known biological variables such as age of subjects, and experimental factors such as taking readings from different anatomical locations.

Humidity has a direct impact upon the structure and fabric of buildings, and has a noted effect on mould growth, fabrics and furniture. The control of RH in buildings is essential for occupant well-being. Trying to maintain a relative humidity level below 70 %RH is also one of the drivers for the 2010 Building Regulation Approved Document F: Ventilation (12). CIBSE Guides (13) and ASHRAE Fundamentals Guide (14).

Source: Slime Mold Amoeba Wood by adege

HUMAN HEALTH

The primary influences of humidity on health are through biological pollutants and their survival in the air. At a temperature of 21°C, influenza survival in the air is lowest at a mid-range 40 %RH to 60 %RH. A detailed study by *Božič* in 2021 into the mechanics airbourne transmission recommended a target RH of approximately 50% to balance between human comfort and to reduce transmission rates of airborne diseases. (15)

Source: Person Holding White Tissue by cottonbro studio

Most infectious diseases spread when pathogens are transmitted through human-to- human contact when droplet nuclei form as a result of sneezing or coughing and are subsequently inhaled by a human receptor.
Biological pollutants include pathogens such as bacteria (e.g., Streptococcus, Legionella), viruses (e.g., common cold, flu), and fungi (e.g., Aspergillusfumigatus). Allergic reactions (e.g., asthma, rhinitis) and dust mites are all affected by the amount of humidity in the air. In review, *Dhaliwal* of the DAV College Bathinda concluded "reducing the relative humiditiy below 45% at a particular place is an effective method to prevent the population of dust mites." (16).

An environment with relative humidity lower than 50 %RH will increase the spreading rate of influenza virus. Hemmers (17). More recently, the US National Institute for Occupational Safety and Health has also demonstrated that relative humidity of >40% can be a factor in controlling the spread of flu (18).

Studies have shown that an increase in humidity can reduce nose tissue inflammations. It was found that an increase in humidity can reduce the nose irritations of 1 in 6 people by Hashiguchi, N's study in 2007 (19). A study of the effect of relative humidity on droplet and airbourne transmission found "virus viability decreases as RH falls below 100%, ... [and] recovers as RH is decreased below 50%, giving rise to a quite common U-shaped viability curve in response to RH." (20)

SICK BUILDING SYNDROME

Source: A Sick Man Covering His Mouth by Edward Jenner

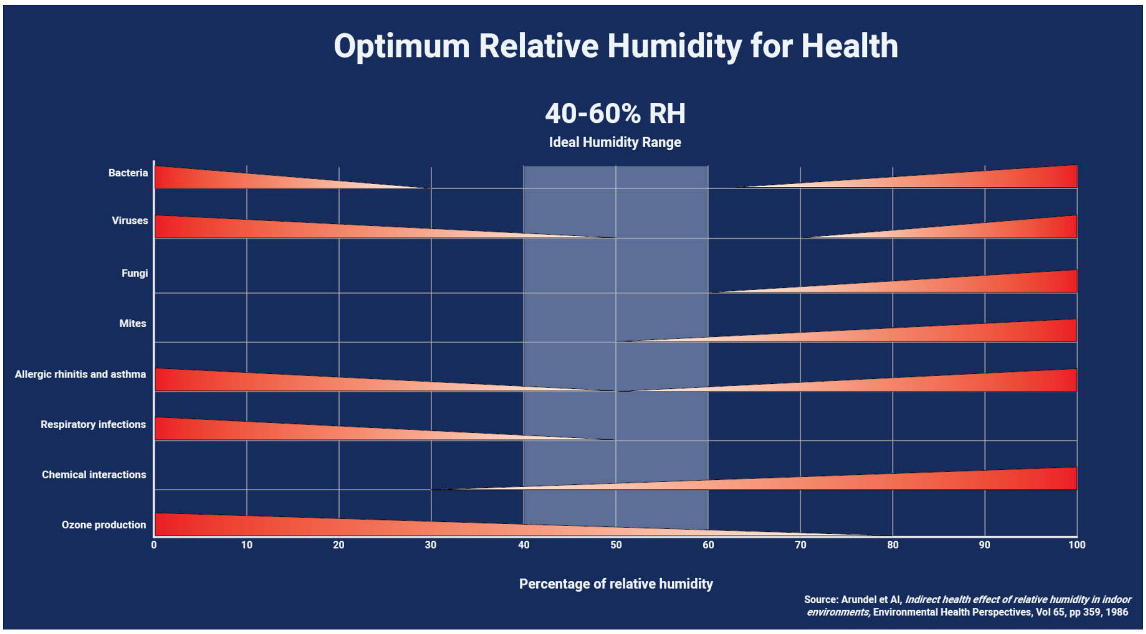
The control of an appropriate thermal environment is important for the good health of the building's occupants. This is vital in healthcare facilities, such as hospitals and remains a significant challenge. R. L. Hwanga et al. (21) found that the reason a high percentage of indoor climates, in wards, fell outside of the comfort zone is proved not to be improper temperature control but improper humidity control". The thermal comfort standards used in this studt were those deffined by ASHRAE.

The researchers note that cultural biases may be significant on the study's findings, however there were still a lot of people inside such a temperature controlled environment suffering from nose irritations, stuffy and runny nose, eye irritations, coughs, tightness in the chest, fatigue, headaches and skin irritations.

Such symptoms are called sick building syndrome (SBS) which is affected by relative humidity inside the room (22). This is because humidity affects the rate of water evaporation in the air and the balance of energy inside the body and therefore the Thermal Comfort of human beings, as supported by L. Harriman et.al 2001(23).

Research by Sookchaiya into the study and development of a temperature and relative humidity control system in hospital buildings in Thailand found "too high and too low relative humidity had direct and indirect effects on sick building syndrome, illness, respiratory diseases, growth and distribution of bacte-ria, virus and house mites" (24)

It has also been shown that the RH affects the intensity of chemical pollution in the air by changing the distribution rate of gas from the materials used inside the buildings and the reaction between water and chemicals in the air. (25)



ENERGY USAGE AND HUMIDITY CONTROL

Humidity control is typically handled through the use of humidifiers and dehumidifers, depending on the specific need. The specific application and requirements of a target environment can be met using a vairety of technologies, from low-emission evaporatve humidifers for warm rooms requiring humidity to dessicant dehumidifers designed for cold temperature dehumidification.

Humidity control and heat control are closely linked due to the strong influence these factors have on each other. Air conditioning and heating account for a significant amount portion of building running costs. Heat Pumps are a form of technology which are increasing being adopted across the UK. These carbon-concious solutions harness similiar technology to air conditioners, relying of refridgerant gas with inbuilt heat recovery and both air-source and ground-source available.

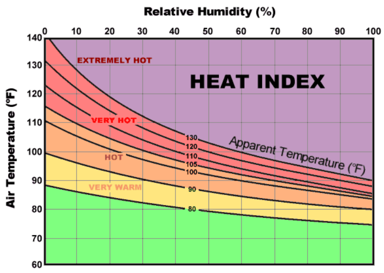
Optimised climate control (controlling both heat and humidity levels) can result in significant cost savings rather than trying to rely on a singular lever. The creation of an improved work environment through air quality, humidity control and temperature regulation not only promotes a healthier work-force, but avoids the impact SBS can have on productivity and morale. Razjouyan et al found "a 25% lower stress response between individuals spending more than 50% of their time in 30%-60% RH compared with those spending most of their time in drier air at the office" (26), a significant reduction when work-related stress are burnout predicted to cost the UK ecomony £28 million a year. (27)

Function List and assignment to energy performance classes (section from table 1 of the EN 15232:2007 [D])

	Heating/Cooling Control	**Ventilation/Air Conditioning control**	**Lighting**	**Sun Protection**
A	- Individual room control with communication between controllers - Indoor temperature control for distribution network water temperature - Total interlock between heating and colling control	- Demand or presence dependant air flow control at room level - Variable set point with load dependant compensation of supply temperature control - Room or exhaust or supply air humidity control	- Automatic daylight control - Automatic occupancy detection manual on/auto off - Automatic occupancy detection manual on/ dimmed - Automatic occupancy detection auto on/auto off - Automatic occupancy detection auto on/ dimmed	- Combined light blind/HVAC control.
B	- Individual rom control with communication between controllers - Indoor temperature control of distribution network water temperature. - Partial interlock between heating and cooking control (dependant on HVAC system.	- Time dependant air flow control at room level - Variable set point with outdoor temperature compensation of supply temperature control. - Room or exhaust or supply air humidity control	- Manual daylight control - Automatic occupancy detection manual on/auto off - Automatic occupancy detection manual on/dimmed - Automatic occupancy detection auto on/auto off - Automatic occupancy detection auto on/auto dimmed	- Motorized operation with automatic blind control
C	- Individual room automatic control by thermostatic values of electronic controller - Outside temperature compensated control of distribution network water temperature - Partial interlock between heating and colling control (dependant on HVAC system	- Tome dependant air flow control at room level - Constant set point of supply temperature control - Supply air humidity limitation	- Manual daylight control - Manual on/off switch _ additional sweeping extension signal - Manual on/off switch	- Motorized operation with manual blind control
D	- No automatic control - No control of distribution network water temperature - - No interlock between healing and cooling control	- No air flow control at room level - No supply temperature control - No air humidity control	- Manual daylight control - Manual on/off switch + additional sweeping extension signal - Manual on/off switch	- Manual operation for blinds

Energy usage vs. apparent temperature

Apparent temperature is the general term for the perceived temperature, caused by the combined effects of air temperature, relative humidity and wind speed.



Source: *What is the Heat Index?*, US Dept of Commerce, accessed: Sept 2024

"This study proposed 4 systems in which mechanical dehumidification is combined with energy recovery measures like a heat pump, membrane enthalpy recovery, sensible heat exchanger and desiccant wheel. An hour-by-hour simulation reveals that the independent air dehumidification with heat recovery could save 29–42% of primary energy, depending on the system involved."

-Zhang, L., Z., (29)

The benefits carry on beyond just employee health, also improving the building itself. Buildings with optimised indoor environmental quality are valued ~10% higher for sale and and 5% higher for rent. (Sivunen M. et al, 2014) (28).

Around the world, new legislation is promoting the use of energy efficient technologies. The UK government are aiming to achieve net-zero carbon emissions by 2050, with real estate and the built environment playing a significant part in that drive through the implementation of the Minimum Energy Efficency Standard (MEES) in 2018, supported by the Minimum Energy Performance in Buildings Bill (currently in it's 2nd reading at the time of writing)

These standard describe the minimum requirements to improve energy efficency and reduce energy consumption acorss domestic and non-domestic buildings. The potential savings for thermal and electrical energy can enchanced through balanced humidity levels, placeing heating, cooling and HVAC systems under less strain. This reduces their energy consumption, and lenthens the serviceable lifespan on the equipment.

CONCLUSIONS

Humidity control has a strong bearing on Thermal Comfort, Indoor Air Quality (IAQ) and eventually on the health and performance of occupants in habitable and public spaces.

Buildings rely on a properly designed ventilation system to provide an adequate supply of cleaner air from outdoors or filtered, recirculated air. Rooms are often designed with specific conditions in mind including temperature, relative humidity, brightness, noise, and air flow. Careful engineering and implementation of building automation and control is the only way to ensure energy efficiency and building operation conditions are met during occupancy, at the lowest possible costs with the least possible impact on the environment.

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