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Impact of Indoor Temperature and Humidity in IAQ of Health Care Buildings

Vijaykrishna G.[1,*], G. Balaji[2]

[1]School of Architecture and Interior Design, SRM Institute of Science and Technology, Kattankulathur, India
[2]Department of Mechanical Engineering, SRM Institute of Science and Technology, Kattankulathur, India

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Abstract Indoor air quality (IAQ) is important, especially in settings with a high number of users, such as healthcare facilities, where the vulnerable patients count is more. Both developed and developing nations are currently paying attention to the issue of indoor air quality (IAQ). IAQ values are influenced by several parameters, with temperature and humidity being the most significant contributors. Very few studies have examined the impact of hospital temperature and humidity on indoor air quality, because they are directly related to thermal comfort. As defined by indoor environmental quality (IEQ), these parameters were selected. This article provides an overview of the significance of temperature and humidity in hospital environments, the criteria provided by the authors based on guidelines and standards, and the relationship between the two along with a few other parameters. In addition, the article attempted to determine the nosocomial infections caused by indoor air temperature and humidity. The study assumes that even though the parameters have been specified in various standards, they can vary according to space usage, occupancy, HVAC design, climate zones, etc. This research may result in a paradigm shift regarding the significance of temperature and humidity in hospitals.

Keywords Temperature, Humidity, Hospital, Indoor Air Quality, Indoor Environmental Quality

1. Introduction

Air pollution is considered as a serious threat to human health [1]. It was responsible for 6.7 million deaths [1, 2]. People spend 90% of their time indoors [3] and maintaining the cleanliness is critical [4]. Health care providers spend their extended time in the environment that needs to be pollution free [5,6]. Indoor air quality parameters are Air temperature, Relative humidity, Air Velocity Airborne bacteria, Respirable suspended particles (Particle matter - PM10), Carbon dioxide, Carbon monoxide, Formaldehyde, Toluene, Xylene and Benzene, Total Volatile Organic Compounds (TVOC), Particle pollution, Ozone, Sulphur dioxide, Nitrogen Dioxide (NO2), Lead (Pb), Naphthalene, Trichloroethylene, Tetrachloroethylene, Radon (Guideline value) and total Microbial Count. Various organizations are involved in standardizing the permissible count for these parameters. The effective management in IAQ in health care is needed. Health care providers continuously complain about small ailments that are linked to poor IAQ [7-11]. The hospital operates continuously, and little to no effort is made to clean the air that has been contaminated by emissions of any kind. Chemical contamination may result from the use of anesthetic gases and other chemical agents during medical procedures [12,13]. There is a wide range of spaces in the hospital that care for patients and staff. A group's comfort requirements vary based on its preferences and health. Temperature variations can have serious consequences for those at risk of hypothermia. Compared to research on IAQ in residential buildings, schools, and commercial buildings, hospital and other healthcare studies are scarce [12]. Organizations in the healthcare industry prioritize the health and well-being of their patients and employees.

In any hospital, nosocomial infections endanger patient safety. In healthcare facilities, temperature and relative humidity are often monitored due to their direct relationship with microbial development [12-15]. Indoor biological pollution is caused by the aerosolized spread of microbiological pathogens in a clinical setting, with the potential to induce nosocomial infections and occupational respiratory disorders [14–15]. Intensive Care Units (ICUs) have a higher prevalence than other hospital areas. Nosocomial infections endanger patient safety in every hospital. Temperature and relative humidity are frequently monitored in healthcare facilities due to their direct relationship with microbial development [12-15]. The aerosolized spread of microbiological pathogens in a clinical setting causes indoor biological pollution, with the potential to cause nosocomial infections and occupational respiratory disorders [14-15]. ICUs have a higher prevalence rate compared to other spaces in the hospital areas. The incidence of nosocomial infections is on the rise, and low relative humidity can affect interior comfort and cause dryness of skin, nose, and throat. Simply having fungi inside the hospital atmosphere can result in hospital-acquired infections (HAIs) and occupational illnesses. Ventilation action affected a significant number of individuals. Considering the health and circumstances of the patients and staff when determining the room's temperature is needed. The thermal comfort of patients and staff was generally proportional to their gender and age. Additionally, it is believed that patients are more tolerant of temperature fluctuations than visitors and staff. The thermal comfort requirements of patients and staff were influenced by their roles and length of stay.

2. Impact of Temperature on Health Care Buildings

Hospital and healthcare facility temperature requirements vary per facility or room type: In medical clinics and long-term care facilities, a temperature range of 70°F to 75°F (21°C to 24°C) can prevent bacteria from spreading. and keep patients safe. Hence, for comfort and safety, hospital rooms should be kept at 75°F (24°C). Operating rooms and inpatient rooms should be kept at 68°F to 73°F (20°C to 23°C) [16]. Table 1 Suggested ideal temperatures for various areas in a hospital building.

At lower temperatures, patients appear to complain more, and their levels of arousal rise, whereas at higher temperatures, thermal acceptability increases even when ambient conditions are outside the expected comfort range [31]. Patients with weakened immune systems preferred warmer temperatures [31]. To ensure a patient's maximum comfort, medical personnel will take all reasonable measures. This may involve providing additional robes or cosy blankets, as well as adjusting the room's temperature or air conditioning. Few studies have examined the insulating properties of patient bedding [32].

Table 1. Suitable temperature for hospital spaces

Spaces in hospital building	Optimum temperature set point	References
Operating room	>26°C (78.8°f)	De witte and Sessler [17]
	24 - 26 °C (74.2 -78.8°f)	Balaras et al [18], sadrizadeh and loomans [19]
	≥21°C (69.8°f)	Melhado et al [20], khodakarami and Nasrollahi [21]
Postoperative care area / room	≥24°C (75°f)	Hooper et al [22]
Intraoperative care area / room	20-25°c (68-77°f)	Hooper et al [22], Association of perioperative registered nurses [23], Morris [24] Morris and Wilkey [25], Wang et al [26]
Delivery room	≥26°C (78.8°f)	Knobel et al [27], Knobel and Holditch [28]
Nursery (For infacnts)	Around 28°c (82.4°f)	Lyon and Freer [29]

Source: (Shajahan et al., 2019) [30]

When setting patient room comfort temperatures, the HVAC designer must consider the cooling needs of other representative occupants and adding clothing or bedding to it is an option. Temperature is one of the most important environmental factors affecting virus survival because it can affect the condition of viral proteins and virus DNA. Between 20.5°C and 30°C, survival of the virus steadily declines. For patient treatment, operating rooms and nursery units need a several-degree temperature range around a year.

3. Impact of Humidity in Health Care Buildings

RH (expressed as a percentage) is the ratio of the amount of water vapour in the air at a specific temperature to the maximum amount of water vapour that air at that temperature can hold. The capacity of air to hold water vapour increases exponentially with temperature [33].

Humidity is also a crucial component in healthcare facilities. External air humidity has the potential to affect healthcare germs and viruses. Humidity must be monitored and maintained to protect patients and workers from disease. The thermal comfort and hygiene of hospital patients are affected by relative humidity [RH] levels. Dryness caused by low humidity encourage blood clotting which is harmful to surgical patients. Monitoring humidity is critical for healthcare safety. Controlling humidity and condensation in the facility reduces cross contamination

and disease spread.

The humidity level in a hospital should be between 40% and 60%, depending on the facility and procedures. Humidity accelerates breathing and sweating while damaging the antibacterial mucous layer of the respiratory system. Relative humidity has a greater impact on evaporation than absolute humidity. Although the body can tolerate a wide range of RH (typically 35%-75%), extremes of dryness and wetness can cause serious problems (high RH).

Although no single factor can consistently be applied to a wide range of infectious viruses to reduce airborne or contact transmission, there is substantial evidence in the literature that RH levels play a role in virus and other infectious agent survival [34]. Low humidity in the room can cause mucosa evaporation and upper respiratory tract micro fissures, both of which can result in illness. This is an issue for those who wear contact lenses. At 25% relative humidity (RH), carbon monoxide (CO) kills bacteria but protects them at 90% RH.

4. Relationship between Temperature and Relative Humidity

According to this assessment of the research, temperature, humidity, and the indoor air ventilation system in hospital buildings affect many infectious organisms, which consequently affect patient outcomes [30].

There is a lot of controversy around the link between cyclical change and the spread of virus outbreaks. It is believed that cold temperatures can extend the half-lives of viruses, whilst low relative humidity (RH) can interfere with natural mechanisms that would normally result in the inactivation of viruses [35]. In general, temperatures that are above 24°C tend to have a detrimental effect on the survival of airborne microorganisms [36].

Airborne influenza virus may not be able to survive in conditions of high temperature (above 30°C) and relative humidity (over 50%) [36]. Different airborne infectious organisms (such as viruses, bacteria, and fungi) will necessitate different suppression levels; it must be determined which airborne pathogen poses the greatest risk to hospital patients and personnel. During the pandemic, several regulatory authorities in the United States recommend that throughout the winter months, indoor temperatures be kept between 20°C and 24°C, and RH be kept between 20% and 60% [37].

Few epidemiological studies have examined the optimal ranges of multiple indoor environmental parameters (e.g., temperature, Relative Humidity, Air changes per hour), Hence hospitals lack patient-oriented guidelines. Despite the extensive simulation-based research, patient-oriented evidence is scarce [30].

5. Nosocomial Infections due to Indoor Air Temperature

Potential airborne infections including viruses, fungi, and bacteria can seriously harm human health. Patients' vulnerability to nosocomial germs relies on how long they can survive on different surfaces. One of the key elements affecting the transmission and viability of these microbes is temperature. Lower temperatures enhance flu virus propagation by making infectious organisms hardier. ASHRAEa Standard 55 recommends 30°C (86°F) at 50%RH to limit airborne influenza virus survival [38].

Lowen et al. found that influenza virus transmission is impeded at 20°C (68°F) but eradicated at 30°C (86°F), regardless of relative humidity [39,40]. Most viruses live longer at low temperatures, including astrovirus, adenovirus, poliovirus, herpes simplex virus, and hepatitis A. Most of the bacteria, fungi, and viruses can survive longer at 4°C or 6°C. Tang analyzed disease-related research on the relationship between airborne pathogens and indoor temperature. Gram-negative, gram-positive, and intracellular bacteria are less likely to survive above 24°C [33].

6. ASHRAE Standards on Temperature and Humidity

Inpatient and surgical outpatient facilities that prioritize patient well-being employ the ASHRAE 0.4% dry-bulb (DB) and mean coincident wet-bulb (MWB) temperatures for cooling and 99.6% for heating. Outpatient clinics use ASHRAE 1% and 99% cooling and heating design temperatures [41]. The standard value of Temperature is given by ASHRAE and ISHRAE with maximum and minimum values in winter and summer [40]. The values are generally not pertaining to any of the zones. The same as the Humidity value too. Table 2 and table 3 give the details of various guidelines for hospital spaces for temperature and humidity.

Table 2. Sample of ASHRAE Standard 170 design parameters [42]

Functional space	Design relative Humidity, %	Design Temperature °F
Operating room	20 to 60	68 to 75
Emergency department public waiting area	max. 65	70 to 75
All room	max. 60	70 to 75
Patient Room	Max. 60	70 to 75

Table 3. Selection of temperature requirements as per hospital [43]

Spaces	Standards	Sources
Hospital ward	Depending on the ward facilities, the air temperature should be 20–26 °C. A serious burn ward should be able to change room temperature up to 32 °C and relative humidity up to 95%.	• CR 1752 (1998) [44] • ISO 7730 (2005) [45] • CSIP (2014) [46] • ANSI/ASHRAE/ASHE Standard 170-2008 (2012) [47] • ASHRAE Handbook (2007) [48] • EN 15251 (2007) [49]
For specialist procedures, operating rooms	Operating room temperature requirements for specific procedures include 17 °C for cardiac surgery, 18–24 °C for corneal surgery, and 30 °C for paediatric procedures.	

ASHRAE thermal comfort standard (ASHRAE 2017a) [50] demands a set of environmental and personal parameters that depend on the occupants' activity levels and garment insulation. Maintaining constant temperature and humidity and eliminating stagnant water under cooling coils reduced the infection rate to under 1%.

Flexibility can guarantee thermal safety and comfort. Specialized operating rooms may require colder temperatures, according to the Centers for Disease Control and Prevention (CDC), "temperatures outside of these ranges may be needed periodically in limited locations depending on unique situations during patient care." [51].

7. Temperature and Humidity Effects on Other IAQ Parameters

The above-mentioned factors have an impact on indoor air quality (IAQ) in every environment, except temperature and humidity. The growth of volatile organic compounds and microorganisms is strongly correlated with the combined temperature and humidity in an indoor environment with controlled air pressure [52]. The concentration of VOCs [53] (formaldehyde, toluene, xylene, and benzene, total volatile organic compounds (TVOC), naphthalene, trichloroethylene, and tetrachloroethylene) in indoor environments is directly proportional to the indoor temperature and humidity.

The association between combined temperature, humidity, and particle matter is modestly positive under controlled indoor air pressure [54]. Similarly, carbon dioxide and carbon monoxide have a marginally positive association. Lead, radon, sulphur dioxide, nitrogen dioxide, and ozone all have a slightly negative correlation [55].

In naturally ventilated rooms, this phenomenon has a different impact that must be understood by experimentation, observation, and research.

The growth of microorganisms would be accelerated by an increase in humidity at a constant temperature of between 20°C and 23°C. As a result, humidity needs to be maintained. It has been discovered that VOC emissions increase with rising temperature and holding humidity constant. Therefore, it is necessary to control the temperature to stop a rise in VOC emissions.

8. Conclusions

Regarding hospital temperature and humidity, insufficient research has been conducted. A literature review revealed that there is a relationship between these two IAQ parameters, as well as between these two parameters and the other IAQ parameters. It could be both advantageous and harmful. The link's strength requires additional investigation.

Even though ASHRAE and ISHARE have established standards for the temperature and humidity values to be maintained in hospital settings, these standards do not consider varying climatic zones or other factors influencing temperature and humidity, such as building materials. In hospital zones where temperature and/or humidity are not maintained, there is an increase in nosocomial infections and microbial growth because these areas are utilized by more vulnerable individuals. According to Section 5 of ASHRAE 55 versions 2004 and later, temperature changes under occupant control have no detrimental effect on thermal comfort and are therefore exempt from several criteria applicable to mechanically ventilated spaces. In addition, the standards are not specific to any type of building. The growth based on naturally ventilated and mechanically ventilated spaces must be investigated further. As materials play an important role, it is essential to comprehend their impact, which is also lacking at this phase.

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