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White Paper

Air humidification in hospitals

Balancing Health and Sustainability

Air humidity control is of fundamental importance in hospital environments. It affects patients' health status, the proper functioning of medical equipment, the thermal comfort of hospital staff and visitors, as well as healthcare costs.

This document explains why hospital environments must be humidified and outlines the regulatory requirements to consider when selecting the appropriate application-specific humidification solution.

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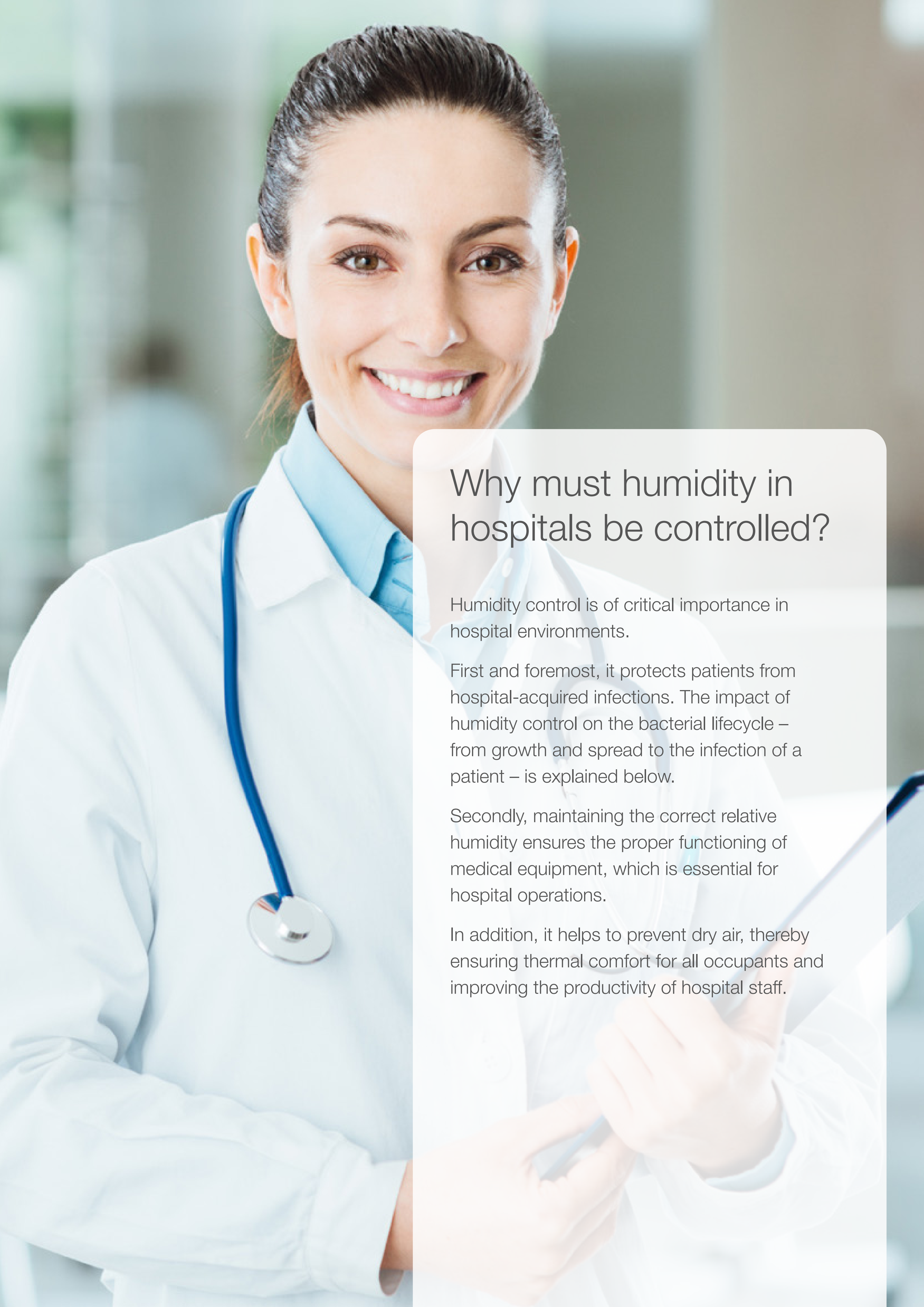


Why must humidity in hospitals be controlled?

Humidity control is of critical importance in hospital environments.

First and foremost, it protects patients from hospital-acquired infections. The impact of humidity control on the bacterial lifecycle – from growth and spread to the infection of a patient – is explained below.

Secondly, maintaining the correct relative humidity ensures the proper functioning of medical equipment, which is essential for hospital operations.

In addition, it helps to prevent dry air, thereby ensuring thermal comfort for all occupants and improving the productivity of hospital staff.

1. Humidification to protect patient health

The primary impact of humidification in healthcare facilities is undoubtedly the protection of patients from a wide range of bacteria and microorganisms.

Hospitals are environments where pathogens are present, some of which are resistant to antibacterial treatments as well as standard cleaning and disinfection procedures. Moreover, these microorganisms reproduce extremely rapidly and find suitable hosts in patients.

Patients themselves are particularly susceptible to infections due to their weakened immune systems and the direct exposure of internal tissues to the environment as a result of surgery or injury.

Humidity has a direct influence on bacterial growth. Properly controlled humidity is therefore an effective means of limiting hospital-acquired infections, protecting health and reducing costs.

Humidity and bacterial growth

Correct humidity control primarily prevents bacterial growth within buildings. Bacteria require water and nutrients to multiply. It is therefore essential to avoid situations in which moisture in the air condenses and leads to water stagnation, for example in air ducts.

If the relative humidity exceeds 80% over an extended period, not only surface condensation but also mould growth may occur. Mould spores are harmful when inhaled.

As a result, humidity levels in hospital environments must be limited at the upper end. However, this alone is not sufficient to ensure a healthy environment and minimise the risk of infection.

Hospitals are inherently environments with a high presence of bacteria due to the presence of patients and can never be completely sterilised. The challenge of humidity control therefore lies in minimising the proliferation of pathogens, preventing transmission, and supporting the body's natural defence mechanisms.

Humidity and the spread of disease

Most modern hospitals implement very strict cleaning procedures for surfaces and medical equipment. However, according to indoor air analyses, these procedures alone are not sufficient to reduce the number of bacteria. On the contrary, related infections are even increasing [1].

Large quantities of microbes are also released simply through speaking, breathing or coughing, carried within thousands of tiny airborne water droplets. Estimates suggest that 10 to 33% of all pathogens responsible for hospital-acquired infections are transmitted via the air.

When these droplets enter an environment with less than 40% relative humidity, they rapidly lose up to 90% of their volume. They shrink in size and are able to remain suspended in the air for long periods, travelling considerable distances. This naturally increases the likelihood that they will reach another host, rehydrate, and cause infection.

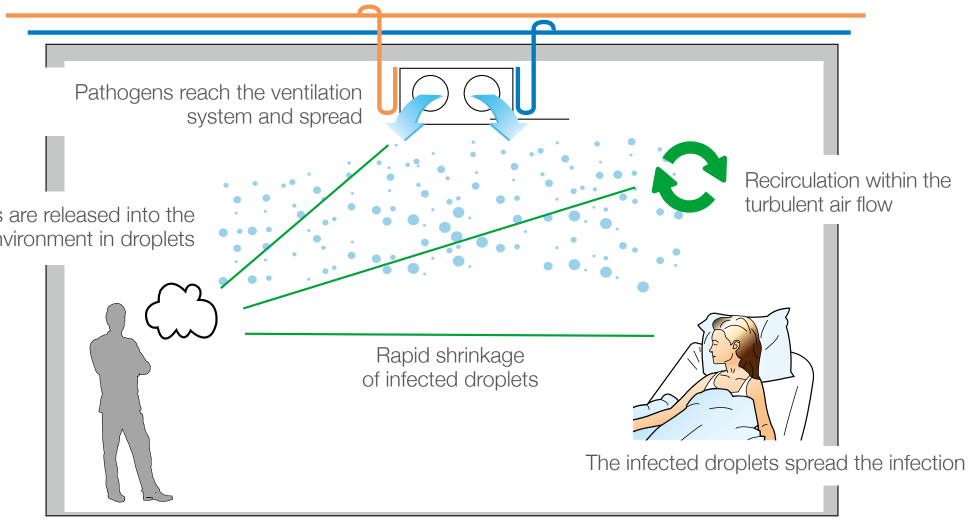


Figure 1. High transmissibility at RH < 40%

However, if the environment has a relative humidity between 40% and 60%, the droplets retain their size (≈ 100 µm) and settle to the ground after travelling 1–2 metres from the source of emission. There, they can be removed much more effectively using conventional surface cleaning procedures [2].

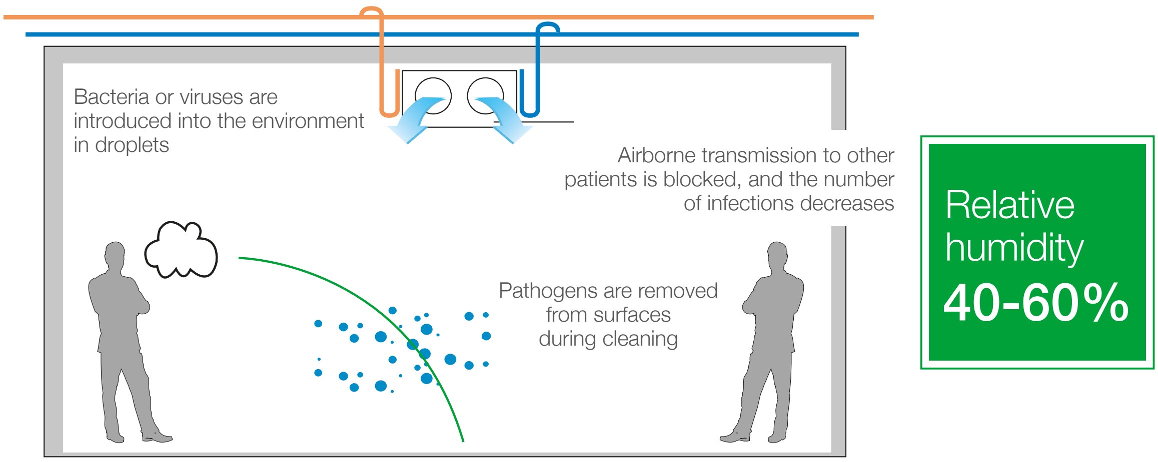


Figure 2. Significantly reduced transmissibility at 40% < RH < 60%

Numerous studies show that relative humidity, in particular, is the key factor in curbing **the airborne transmission of bacteria and viruses.**

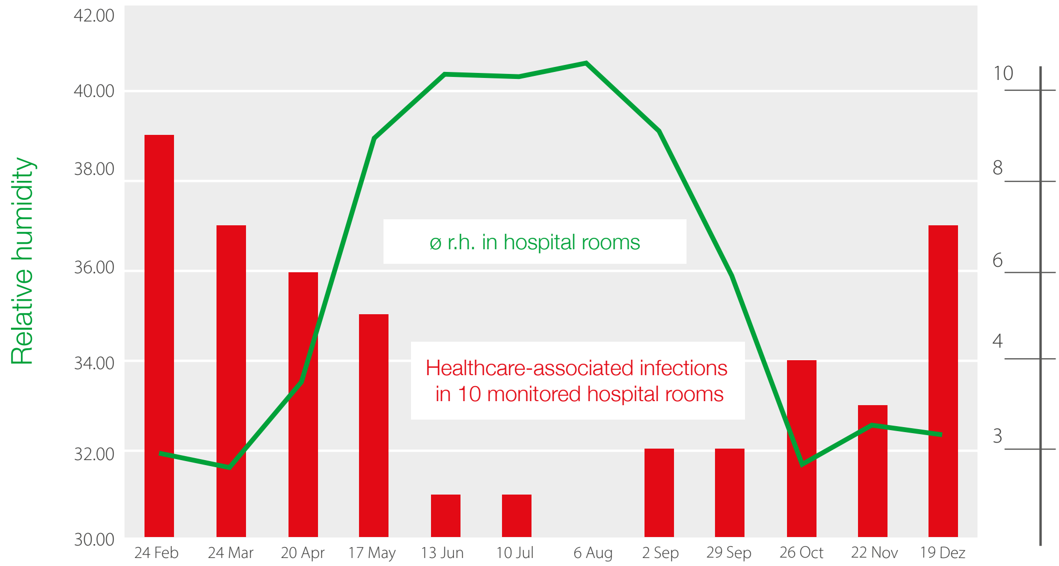


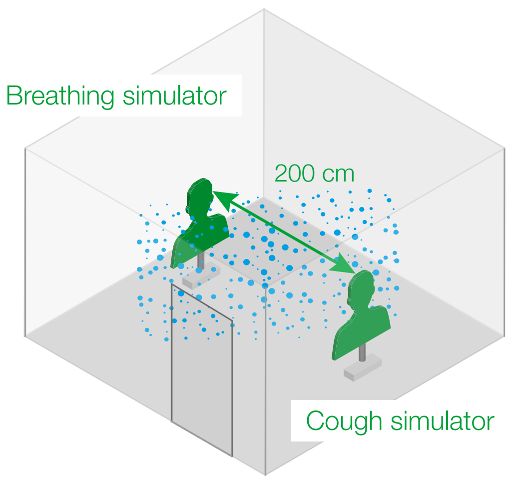
Figure 3. Relative humidity is the key parameter in reducing hospital-acquired infections

In an initial American study conducted over the course of a full year in a hospital, all environmental parameters were measured in ten patient rooms, along with the medical conditions of the patients occupying them [2]. Among the variables analysed, relative humidity showed the strongest correlation with the number of new infections. At relative humidity levels above 40%, the number of infections decreased from a peak of nine per month to zero.

A further study was carried out using specialised test mannequins to simulate the coughing of a person infected with influenza and the inhalation of a recipient at a distance of two metres [3]. By taking air samples near the recipient's mouth at different times and measuring the infectivity of these samples, the following results were obtained.

Infectivity decreases from 80% to 20% when relative humidity is maintained between 40% and 70%. This is because the influenza virus is no longer able to remain suspended in the air for extended periods, and the survival rate of many airborne bacteria and viruses is significantly reduced within this range.

Appropriate humidity control not only inhibits the growth of microbes and bacteria but also significantly reduces their transmission potential. In a hospital environment—where countless pathogens are present and patients are highly susceptible to infection—this is absolutely essential.



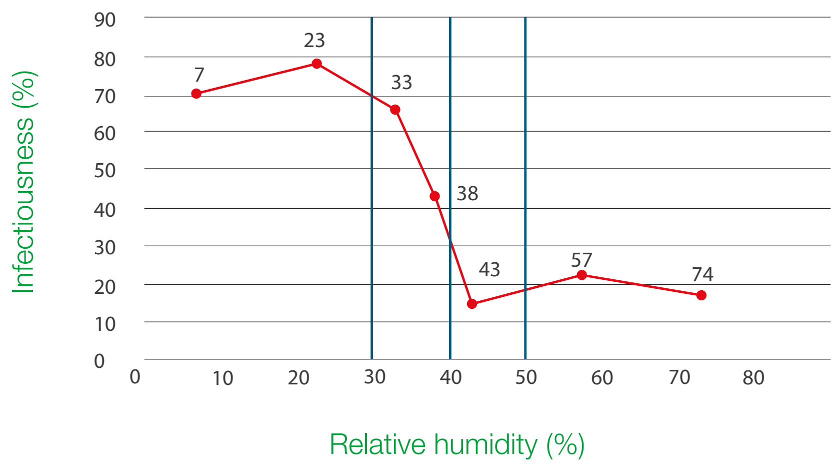


Figure 4 and 5. The infectivity and transmissibility of the influenza virus decrease significantly between 40% and 70% RH.

Humidity and the body's natural defence mechanisms

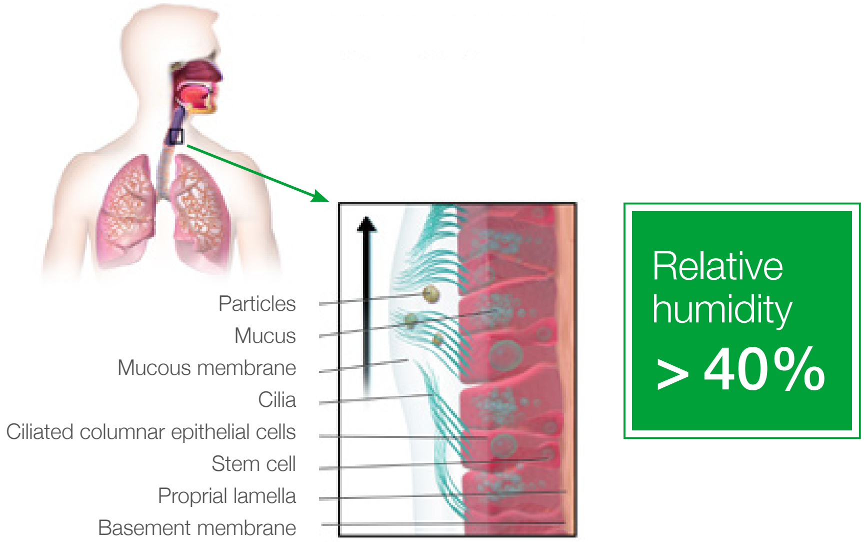


Figure 6. The process of mucociliary clearance removes pathogens that enter the respiratory system. For it to function effectively, the correct level of relative humidity is required [10].

In airborne infections, bacteria are inhaled, enter the respiratory tract and settle on the airway walls or in the alveoli. There, they can lead to pneumonia or bloodstream infections. The body's final line of defence against these attacks is provided by the walls of the respiratory system itself. From the nose to the trachea and bronchi, they constantly secrete a thin layer of mucus, which humidifies and warms the inhaled air and traps the transported bacteria. This mucus layer is continuously moved upwards by the rhythmic motion of countless cilia lining the airway walls. The mucus reaches the oral cavity, where the trapped bacteria are swallowed. They are then neutralised by gastric acids and become part of the intestinal flora. This cleansing process, known as **mucociliary clearance,** is of fundamental importance to health. Under normal conditions, it blocks the majority of inhaled pathogens. However, its effectiveness is strongly influenced by relative humidity.

If relative humidity falls below 40%, the mucus layer dries out. The cilia collapse and cease movement. As a result, viruses and bacteria can penetrate the cells of the respiratory tract and cause infection [1]. For this reason, humidity control plays a primary role in preventing most hospital-acquired infections. A relative humidity between 40% and 60% prevents the formation of bacterial colonies and mould, significantly reduces their transmission, and supports the body's natural defence mechanisms.

Economic benefits

From an economic perspective, humidity control in hospitals has an indirect impact and is therefore difficult to quantify precisely. However, the available data and the considerable costs associated with hospital-acquired infections clearly indicate that the benefits for healthcare facilities are substantial.

Each year in Germany, 3.6% of hospital patients become infected during their stay. This corresponds to a total of 400,000 to 600,000 infections per year, 10,000 to 20,000 of which result in death. The EU average is 5.5%.

Studies show that pneumonia, urinary tract infections, wound infections, Clostridium difficile infections and bloodstream infections account for almost 80% of hospital-acquired infections [4].

The costs to the healthcare system due to prolonged hospital stays and legal claims from affected patients are enormous. By maintaining properly controlled indoor humidity, the number of airborne infections could be significantly reduced - along with the substantial societal costs associated with them.

2. Humidification to ensure equipment operation

Humidification is a means of protecting equipment against electrostatic discharge (ESD) [5] [6].

Electrostatic discharges, also known as **ESD**, are electrical breakdowns that can occur when two objects with a large potential difference come into close proximity. In such cases, the electric current overcomes the resistance that normally exists between the two bodies, which is determined by their distance and the insulating properties of the materials involved.

A practical example in a hospital environment is an operator of an analytical device wearing rubber-soled shoes. By walking on an insulating plastic surface, such as a vinyl floor covering, the rubber soles release a certain number of electrons through friction and become positively charged, while the floor remains negatively charged. This behaviour is described by the triboelectric series, which lists insulating materials that tend to lose or gain electrons through friction [7].

Figure 7. Triboelectric series: in this example, the rubber soles transfer electrons to the vinyl floor.

The operator's body is therefore electrostatically charged. If they touch the analytical device with their hands, the following may occur:

- The electrostatic field generated by the static charge can create potential differences within the device, which may result in damage.
- An electrical discharge may occur through the air between the fingers and the device. The voltage can vary considerably and may even reach tens of thousands of volts. However, even a voltage below 3,500 - imperceptible to the person - can still cause severe damage to the device.

The resulting damage can range from the destruction of individual components and complete equipment shutdown to measurement errors, deletion of stored data, and the accumulation of static electricity on X-ray images. In all cases, the functionality of expensive equipment is compromised - often irreversibly.

Sufficiently high air humidity supports the dissipation of excess electrical charge from the human body into the surrounding air. This prevents electrostatic charging from reaching dangerously high levels.

Given the critical role of many devices in hospital environments, it is essential to prevent potential malfunctions caused by dry air. To minimise the risk of electrostatic discharges, it is recommended to maintain relative humidity above 40%, while also ensuring that other ESD protection measures - particularly those related to equipment design - are not neglected.

3. Humidification to ensure thermal comfort

The main reasons why humidity control is essential in hospitals are the reduction of infectivity, the limitation of bacterial transmission, and the protection of equipment.

In addition, humidification plays a key role in ensuring the well-being and thermal comfort of occupants, as well as in preventing health conditions associated with excessively dry air.

Humidification and comfort conditions

Comfort conditions refer to the state of physical and mental well-being experienced by an individual in a given environment. The overall sense of comfort is influenced by:

- thermal comfort, defined by temperature, relative humidity and air velocity
- air quality, defined by fresh air supply, CO_2 concentration, and levels of VOCs and micro-organisms
- noise levels

According to European Standard EN 15251, thermal comfort in hospitals (Category II) is considered acceptable when the percentage of dissatisfied persons (PPD) remains below 10%. In addition, various national and international regulations (see Chapter 3) define the target ranges for temperature, humidity and air quality in different environments.

Ambient temperature is the primary factor influencing discomfort. However, relative humidity also plays a decisive role. It affects our perception of air temperature, influences skin perspiration and impacts the body's internal energy balance.

Maintaining appropriate relative humidity helps to prevent dryness of the skin, eyes and respiratory tract. It facilitates breathing and perspiration, ensuring that the body's thermoregulation system is not placed under excessive strain, thereby avoiding discomfort.

Correct humidity control also reduces airborne dust, which tends to remain suspended much longer in dry environments and intensifies the sensation of dryness and discomfort.

If low humidity conditions persist over extended periods, frequent occupants may develop a range of related symptoms, including Sick Building Syndrome. All of these factors negatively affect indoor air quality and, consequently, the health of the people present.

Sick Building Syndrome

Sick Building Syndrome (SBS) describes a situation in which occupants of a building experience symptoms of illness that appear to be linked to the time spent within the building, yet no specific cause can be identified.

The causes of this condition are often associated with faults or improper operation of HVAC systems, insufficient fresh air supply, the presence of volatile organic compounds (VOCs), mould, and materials or substances that release pollutants.

Some studies have shown that SBS symptoms are either caused or exacerbated by excessively low relative humidity. These include deterioration of the tear film, dry eyes, irritation of the nose and throat, asthma, dry or sensitive skin, headaches, fatigue and irritability.

Insufficient humidity levels alone have been shown to result in a 3–7% reduction in the performance of office workers, for example when reading or processing documents or carrying out simple calculations. When low humidity is combined with additional factors such as high temperatures and air pollution, these symptoms are further intensified [7].

The optimal range of relative humidity for comfort lies between 40% and 60% RH. This range coincides with the levels that reduce hospital-acquired infections (40–60% RH) and overlaps with the thresholds for preventing electrostatic discharge (RH > 35%) and mould growth (RH < 80%).

Taking into account all the effects of relative humidity on the human body and on hospital operations, it can be concluded that the ideal operating range for comfort conditions also lies between 40% and 60% RH.

This raises the question of when these ideal conditions can actually be maintained, and which factors prevent them from being achieved - thereby making continuous humidity control necessary.

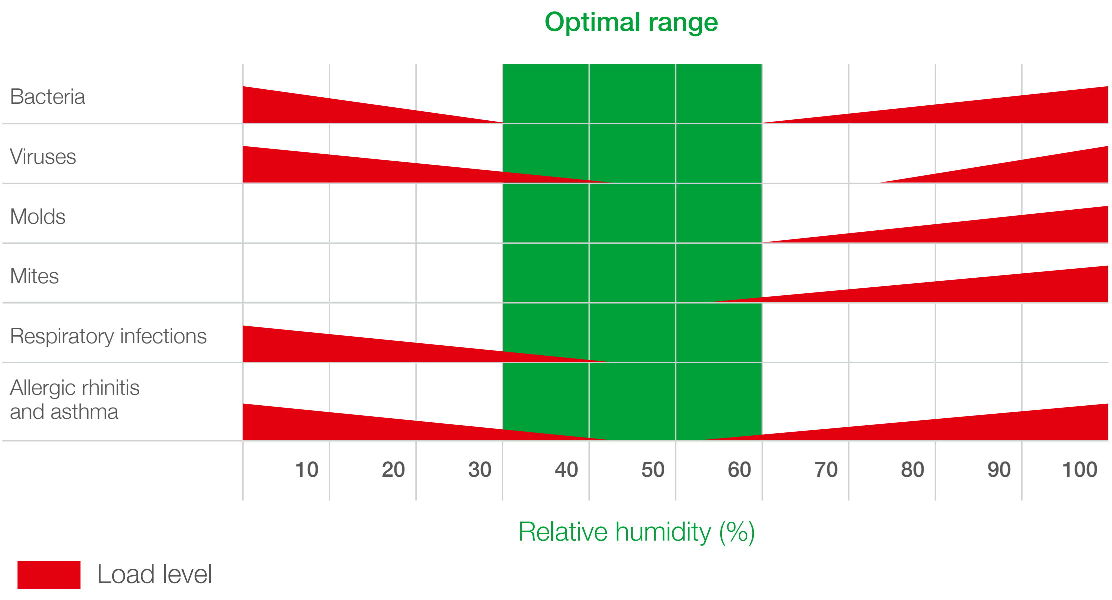


Figure 8. Optimal range of relative humidity for thermal comfort and human health.

What prevents us from achieving optimal humidity conditions?

Having recognised the indispensable benefits of humidification in hospitals - and therefore the importance of maintaining ideal humidity levels - it is important to examine whether and why environmental conditions often deviate from these optimal values, and whether the installation of a humidification system is ultimately essential.

Regular air exchange reduces relative humidity

In hospital facilities, indoor air must be renewed regularly in order to achieve the recommended air quality. This air contains pollutants generated by occupants, materials or anaesthetic gases during surgical procedures, which cannot be fully removed by filtration. Therefore, indoor air must be replaced with large quantities of **fresh outdoor air.**

However, before the fresh air can be supplied to the environment, it must be heated to an acceptable temperature, typically between 20 and 24 °C.

In winter, for example, outdoor air is very cold and humid (point A: temperature –5 °C, **relative humidity 80%**). It is heated by a heating coil in one of the hospital's air handling units. While the temperature increases, the specific humidity (i.e. the absolute water content in a given volume of air) remains constant (point B: temperature 22 °C, **relative humidity 12%**).

As a result, the relative humidity of the heated air (the ratio between the actual water content and the maximum possible water content before condensation occurs) decreases from 80% in the outdoor air to around 12% under indoor conditions - even though no moisture has been removed. This is because air can hold more water vapour as its temperature increases.

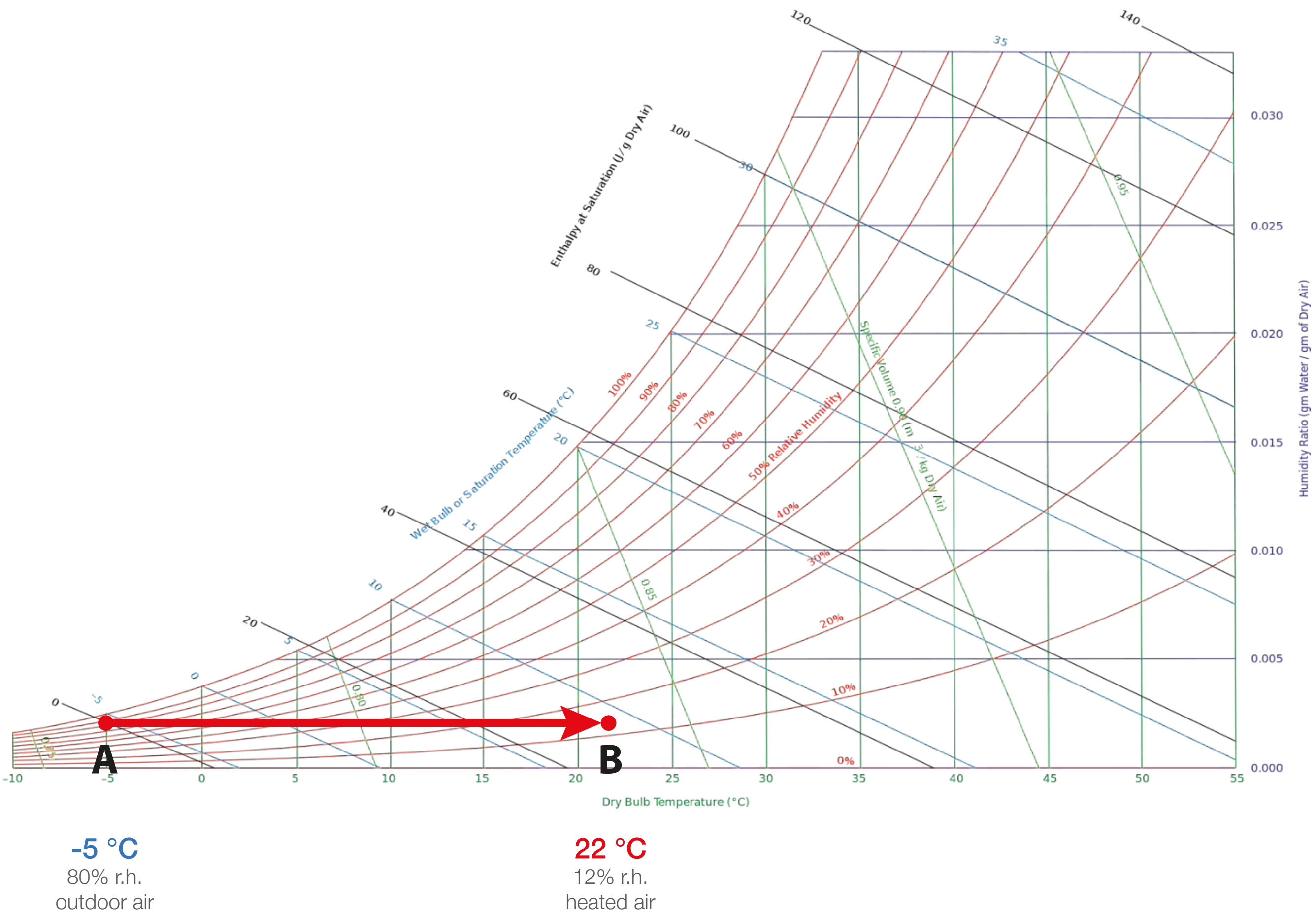


Figure 9. The psychrometric chart illustrates why heated air is too dry for hospital applications.

Given the importance of maintaining an appropriate level of relative humidity, a humidification system must be installed to restore relative humidity (and temperature) to the correct ranges. The technology used may involve adiabatic humidification (1), achieved through the atomisation of fine water mist into the air, or isothermal humidification (2), in which water is boiled to produce steam that is then absorbed by the air.

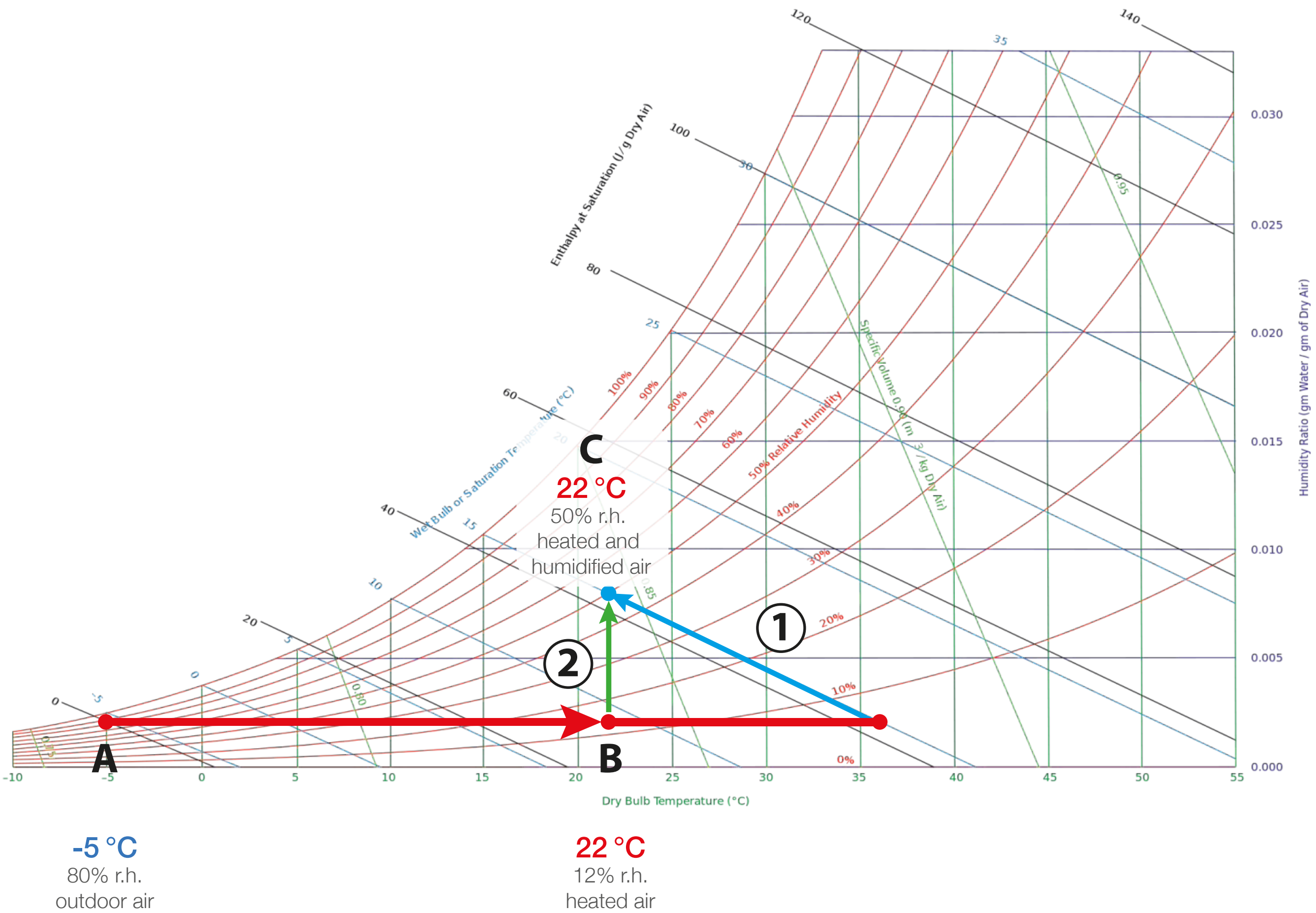


Figure 10. After heating, the air must be humidified to ensure optimal conditions of approximately 22 °C and 50% RH.

Regardless of the humidification technique used (see Chapter 4), the humidification system operates more intensively in winter and less in summer, due to the drying effect caused by heating.

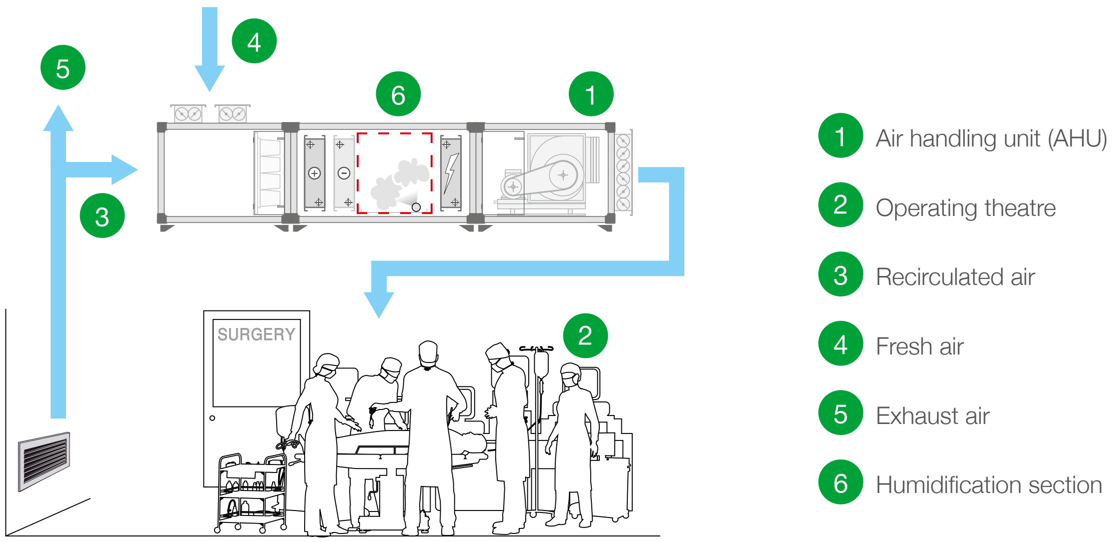
Humidification systems for hospitals

Humidification systems for hospitals are primarily based on duct-based humidification rather than direct room humidification.

Due to the sensitive and life-critical nature of processes in healthcare facilities, specialised technical design measures are often required to ensure hygienic safety and the reliability of the installation.

Various technologies are suitable for humidification in hospitals.
Each system consists of the following components:

- **Humidifier**
  This may be either adiabatic (water mist generation) or isothermal (steam generation).
- **Distribution system**
  This is used to distribute the generated moisture. In hospitals, air is almost always supplied from outside, conditioned, and distributed throughout different areas via air ducts. The humidifier distribution systems are installed downstream of the heating coils and positioned within the air ducts. These systems are connected to the humidifier and may consist, for example, of perforated distribution pipes with small nozzles that atomise pressurised water, or larger perforated pipes that release steam directly into the air duct. In some cases, the humidifier itself is installed directly within the air duct.
- **Droplet separator**
  This component is used only with adiabatic humidifiers and is installed in the air duct at the end of the humidification section. It captures droplets that are not absorbed by the air, thereby preventing water stagnation.
- **Water treatment system**
  This is used to condition the supply water at the humidifier inlet. Although it is not a mandatory component, it is strongly recommended for hospital applications.



4. Isothermal humidifiers

Isothermal humidifiers humidify the environment using steam. The steam is generated by boiling water and is introduced into the air. The energy required for the phase change -approximately 750 W per litre of evaporated water - is provided by the humidifier itself (via its power supply). The term isothermal means that the air temperature remains unchanged during the humidification process.

Isothermal humidifiers are easy to install. The use of steam ensures a high level of hygienic safety, which is why they can be used both for direct room humidification and for duct humidification in air handling systems. They are also suitable for very low output capacities.

The main limitation of steam-based systems is their high energy consumption. For very high humidification loads, operating costs may become significant.

In general, there are three types of isothermal humidifiers:

- Electrode steam humidifiers
- Heater type steam humidifiers
- Pressurised steam systems

Electrode steam humidifiers

Electrode steam humidifiers are cost-effective and simple systems. Electrodes heat the water to boiling point. The control accuracy of electrode steam humidifiers is typically ±5% RH. They operate using conductive water (potable water) with a conductivity of 200-500 µS/cm and preferably low total hardness. Their maintenance requirements increase with higher salt content in the supply water.

Heater type steam humidifiers

In these systems, electrically heated elements immersed in water bring the water to the boiling point. These humidifiers achieve very high levels of precision (up to ±0.5% RH) and operate across the full capacity range, as the output of the heating elements can be finely modulated.

They can be supplied with either standard tap water or treated water. When operated with treated water, they are particularly well suited for 24/7 operation and require minimal maintenance.

Pressurised steam humidifiers

Pressurised steam systems are connected to an existing steam network and utilise this steam for air humidification. They introduce condensate-free saturated steam into the ventilation system. Pressurised steam systems offer a wide capacity range, are highly economical both in terms of operation and investment and require minimal maintenance.

5. Adiabatic humidifiers

Adiabatic humidifiers enable the direct evaporation of water into the air without the need for an external energy supply. The heat required for evaporation is provided by the air being humidified, which consequently cools down.

These systems create a large contact surface between air and water in liquid form, allowing spontaneous evaporation to occur. The main advantage of adiabatic humidification lies in its extremely low energy consumption: energy is only required for atomising or nebulising the water into very fine droplets (in the micrometre range).

In winter, the heating coil must preheat the air more than in the case of steam humidification. This is necessary to compensate for the evaporative cooling effect. Nevertheless, the overall energy consumption remains extremely low and ranks among the most cost-efficient of all technologies. In summer, the evaporative cooling effect can be used to achieve additional energy savings when both cooling and humidification are required.

The most common types of adiabatic humidification technology are:

- Spray nozzle systems
- Ultrasonic humidifiers

Spray nozzle systems

Spray nozzle systems (low-pressure and high-pressure systems) are equipped with a pump to increase water pressure to levels between 5 and 15 bar (low pressure) and 25 and 75 bar (high pressure). The water is atomised into a fine mist via a distribution system installed within the air duct, using small nozzles. This mist is then absorbed by the air.

These humidifiers achieve excellent precision (up to ±1% RH), even at very high humidification loads. They have extremely low power consumption, and the water is not recirculated. They represent a hygienic, chemical-free solution and are compliant with VDI 6022 standards. When operated with fully demineralised water, maintenance requirements are minimal.

Ultrasonic humidifiers

Ultrasonic humidifiers use high-frequency vibrations from piezoelectric elements to atomise water into even finer droplets than high-pressure systems.

They can achieve precision levels of up to ±1% RH and modulate output across the entire operating range. These humidifiers are suitable for both direct room humidification and duct humidification. They offer high absorption efficiency and are ideal for small to medium-sized installations.

Despite higher initial investment costs compared to other compact humidifiers, their performance levels, low energy consumption, and minimal maintenance requirements ensure rapid return on investment - particularly in retrofit applications replacing steam-based systems.

6. Requirements for humidification systems

All components of a humidification system - and humidifiers in particular -must meet specific requirements in order to be suitable for use in critical and sensitive environments such as hospitals. These requirements include:

- Hygienic safety
- Reliability
- Energy efficiency
- Connectivity

Hygienic safety

The humidification system must ensure that neither bacteria nor contaminants are able to accumulate or spread within the environment.

This requirement is particularly important in hospitals, as patients are often weakened and highly susceptible to new infections.

Special precautions must be taken to prevent the growth of Legionella bacteria, which are associated with very high mortality rates and have historically been responsible for numerous deaths in hospital-related outbreaks.

For this reason, isothermal humidifiers are typically the preferred choice. They boil water at 100 °C to produce steam that is virtually free of germs and therefore hygienically safe. In certain hospital areas, such as operating theatres, the use of isothermal humidifiers is even required by law. These systems prevent the spread of pathogens - such as Legionella - via the humidification system. Legionella bacteria are immediately inactivated at temperatures above 70 °C and are completely eliminated by isothermal humidifiers [8].

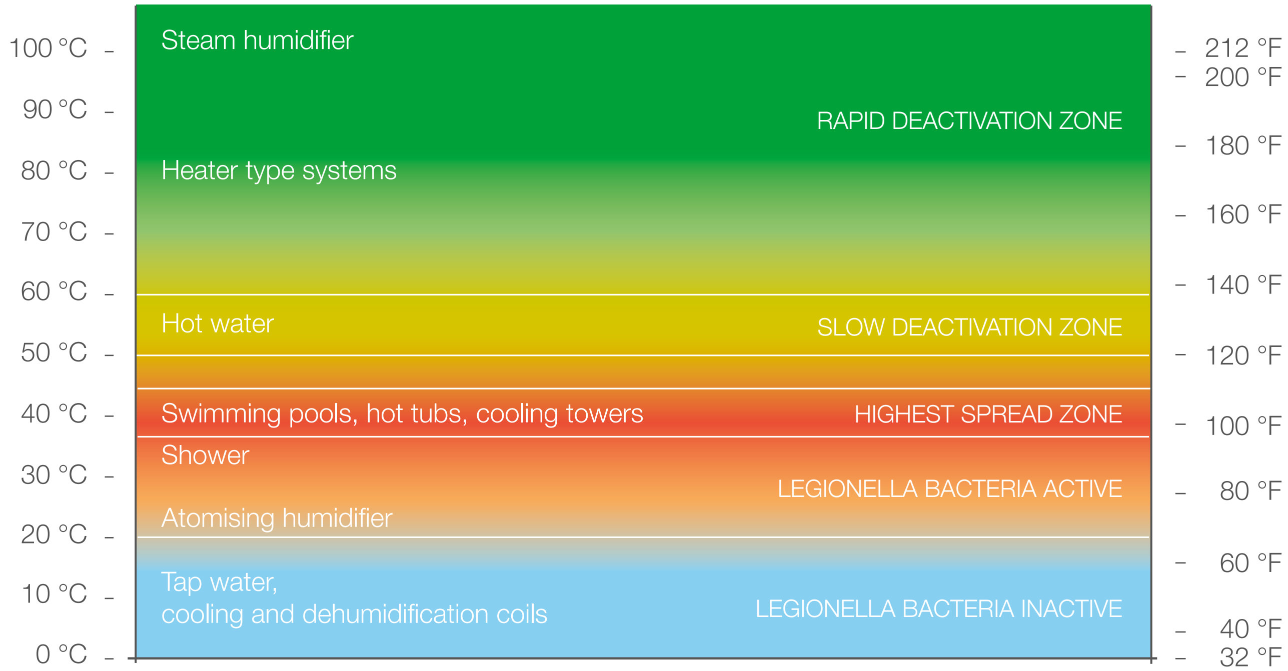


Figure 11. The diagram illustrates the behaviour of Legionella bacteria at different temperatures from 0 to 100 °C.

Certain adiabatic humidification technologies, such as high-pressure spray systems or ultrasonic humidifiers, can also be used in hospital environments, provided that appropriate design measures are implemented to ensure hygienic safety.

No humidifier must allow water to stagnate; systems must be drained during idle periods and regularly flushed, otherwise conditions conducive to bacterial growth may develop.

In addition, the quality of the mains water supply must be carefully monitored. Excessive mineral content and the presence of microorganisms can be dispersed into the environment if not properly filtered in advance. It is therefore recommended to use demineralised water supplied via reverse osmosis systems. This commercially developed technology ensures optimal filtration performance.

Another advantage is offered by humidifiers constructed from corrosion-resistant and dirt-repellent materials. Furthermore, UV disinfection systems should be considered to eliminate any bacteria that may survive the reverse osmosis process. Chemical biocides can be used as an alternative to UV disinfection; however, they are very costly and require special measures for water disposal, as well as frequent microbiological testing. In the event of a malfunction in the biocide dosing and distribution system, the humidifier could be supplied with microbiologically contaminated water. Consequently, this is not an intrinsically safe solution and is therefore not suitable for hospital applications.

An additional safety feature is the use of a high-limit humidity sensor. Installed either within the air duct or in the room, this sensor detects when humidity exceeds a predefined threshold. When the limit is exceeded, it stops humidification output, thereby preventing the formation of condensate. Condensation poses hygienic risks if it leads to water stagnation.

The most advanced systems support modulating control: as the humidity approaches the limit value, they gradually reduce output in fine increments, avoiding abrupt system shutdowns. Some humidifiers are also equipped with a remote ON/OFF function to prevent condensation. This function stops humidification if a fault occurs in the ventilation system within the air duct.

Finally, all technical solutions must be verified for compliance with relevant industry certifications (such as the German VDI 6022) to ensure manufacturer-guaranteed system hygiene.

Reliability

Hospitals are facilities of critical importance that must remain fully operational, even in the event of malfunctions, maintenance activities or challenging climatic conditions. In winter, even a single hourly air change without humidification can cause relative humidity to drop below critical threshold levels.

The humidification system must therefore be highly reliable and designed to minimise downtime as far as possible, ensuring uninterrupted operation at all times.

Preference should be given to systems capable of reducing maintenance-related downtime. In general, humidifiers supplied with demineralised water require less maintenance, as limescale deposits are avoided - these would otherwise need to be removed periodically and may necessitate component replacement.

High reliability means that the humidifier can deliver greater operational continuity. In the case of isothermal humidifiers, solutions that allow preheating of the water within the steam cylinder are particularly advantageous.

Additional benefits can be achieved when rotation and redundancy functions are implemented within the humidifiers. The rotation function enables alternating operation between units, balancing operating hours and extending maintenance intervals. The redundancy function ensures continuous operation: if one humidifier fails due to maintenance or malfunction, humidification is not interrupted, as another unit compensates for the missing capacity.

A humidification system incorporating both features - operation with demineralised water and integrated rotation and redundancy functions - represents the most reliable solution. In such systems, humidity production is not interrupted even during minor maintenance interventions.

Energy efficiency

Efficient systems that consume less energy help to reduce operating costs while ensuring compliance with the latest building climate control regulations. Certain technologies and humidifiers available on the market incorporate advanced features that justify higher initial investment costs through greater long-term savings.

From an energy consumption perspective, isothermal humidifiers are at a disadvantage compared to other technologies. Their operating principle is based on boiling water, requiring approximately 750 W per litre of evaporated water.

Humidifiers with electric heating elements or immersed electrodes deliver their output electrically and therefore incur high operating costs, particularly at large humidification loads.

Adiabatic humidification systems are among the most energy-efficient solutions, as the power consumption of high-pressure pumps and ultrasonic piezoelectric elements is extremely low. In addition, during winter operation, the energy required for evaporation can be supplied directly from the existing heating system.

If the evaporative cooling effect is to be utilised in summer, adiabatic humidifiers are the preferred choice. This approach offers the greatest potential in warm and dry climates, as the air is simultaneously humidified and cooled, maximising energy savings. The cooling effect is approximately 0.7 kW per litre of evaporated water, with very low energy consumption.

Indirect evaporative cooling further reduces electricity consumption in summer: by humidifying and cooling the exhaust air before it passes through a heat recovery unit, the load on the air handling system is reduced.

Connectivity

Although connectivity features are not strictly essential in humidification systems, they are becoming increasingly important, particularly in complex installations with multiple setpoints - such as those found in hospitals. They support the need for data acquisition, monitoring and system management.

As a result, HVAC systems supported by building management systems (BMS), with centralised multi-site management and humidification system control, are becoming increasingly common. It is therefore essential that humidifiers are equipped with widely used communication protocols such as Modbus and BACnet.

HygroMatik humidifiers can be remotely monitored via a gateway within a local network or via LTE. This enables the operation and configuration of the entire humidification system via a PC or tablet. When connected to a central monitoring system, the installation can also be managed remotely. This significantly simplifies the management of the numerous units installed across hospital facilities.

Hygienic safety	Reliability	Energie efficiency	Connectivity
• steam humidification • no water stagnation • periodic flushing • demineralised water • corrosion-resistant materials • UV disinfection • high-limit humidity sensor • enable signal from the AHU fan • hygiene certification	• rotation and redundancy functions • reduced downtime due to maintenance • demineralised water • water preheating and reduced blowdown cycles for dilution purposes	• adiabatic humidification • evaporative cooling • lower operating costs for gas-fired humidifiers	• integrated communication protocols (Modbus, BACnet) • BMS compatibility and remote control

7. Distribution systems for steam / water mist

In hospital applications, moisture distribution systems are installed within air ducts. They consist of perforated distribution pipes and differ primarily in whether they are supplied with high-pressure water or steam.

Their effectiveness is expressed in terms of absorption efficiency. This key parameter measures the amount of water effectively absorbed by the air in relation to the total amount of water introduced into the air duct. Atomised droplets that are not fully absorbed, or steam that condenses upon contact with surfaces, contribute to energy losses and pose a risk to the hygienic safety of the air duct system.

High-pressure water distribution systems must be constructed from stainless steel and designed to suit the dimensions of the air duct. The nozzles should be small, sufficiently numerous and properly spaced to cover most of the cross-section, without requiring excessively long absorption distances.

Steam distribution systems typically achieve higher absorption efficiency. However, they may lead to recondensation when steam comes into contact with cold metallic surfaces within the distributor. Several measures are taken to limit this effect: condensate separators at the steam distributor inlet; nozzles that extract steam from the centre of the lance; insulation layers or air cushions that protect external surfaces from excessive temperature drops.

Another component of the distribution system is the droplet separator, which is used exclusively with adiabatic humidifiers. For hospital applications, it should be made of stainless steel and designed for easy removal and cleaning.

The air duct must incorporate a sloped drain pan with an outlet to prevent water stagnation. In addition, a range of design solutions may be considered to ensure that the air handling system can be effectively disinfected. These include distribution racks and panels that prevent infiltration and provide thermal and acoustic insulation of the duct, as well as specialised antibacterial surface treatments.

8. Water treatment systems

The purpose of water treatment systems is to improve the quality of the supply water for humidifiers in order to optimise humidifier operation and enhance air quality in the humidified environment. For this reason, adiabatic humidifiers and certain types of isothermal humidifiers used in hospital facilities must always be combined with a water treatment system.

Water treatment for humidification primarily involves **water softening** and **reverse osmosis.**

Water softening

Water softening reduces the temporary hardness of water; however, it does not purify it. The calcium and magnesium salts responsible for limescale formation are replaced by sodium through regeneration. This reduces limescale build-up in isothermal humidifiers that operate with water at high temperatures. The overall salt content is not reduced. Softened water is recommended for the operation of heater type steam humidifiers.

Reverse osmosis

Reverse osmosis reduces water conductivity by decreasing the concentration of dissolved salts. This treatment not only prevents limescale formation within the humidifier but also purifies the water. Through reverse osmosis, humidifiers can operate under optimal conditions, improving air quality in the humidified environment to the benefit of both occupants and equipment.

Water treatment systems must have the following features: easy maintenance, an integrated UV disinfection function to eliminate all bacteria, and a high desalination ratio (which indicates how much ‘pure water’ is produced in relation to the water consumed).

9. Humidifier selection criteria

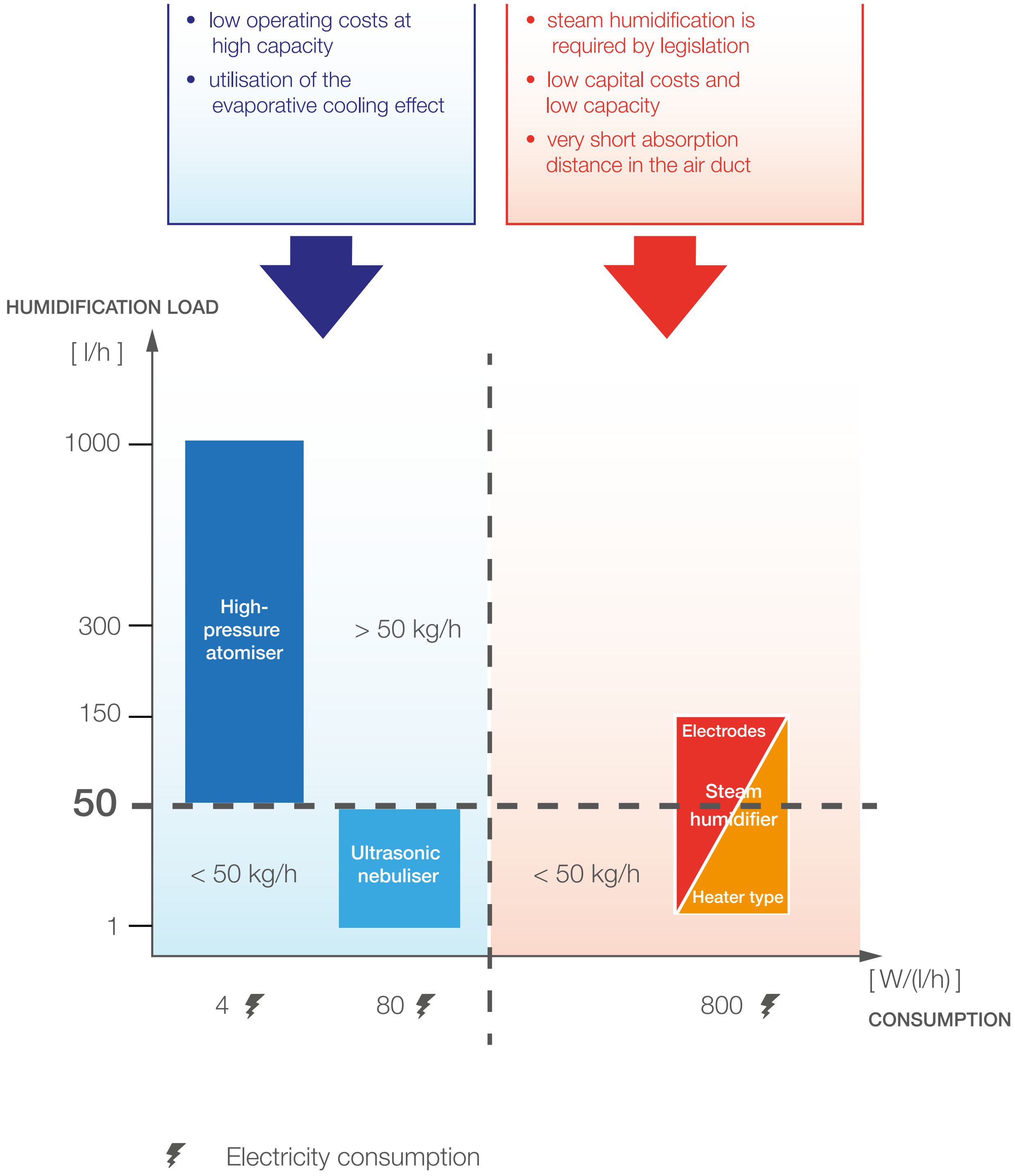
The most suitable humidification system for a given hospital area depends on the specific characteristics of each installation. However, a number of general technical selection criteria can be taken into account.

As explained in the following chapter, legislation may require steam humidification in certain hospital areas. Otherwise, key selection criteria include the required humidification capacity, available space within the air duct, operating costs and investment costs.

In general, adiabatic humidifiers offer very low operating costs, higher initial investment costs, and require longer absorption distances within the air duct. Due to their lower hourly operating costs per litre of water mist, high-pressure spray systems are more suitable for higher humidification loads than ultrasonic humidifiers. Some models are also capable - using a single pump - of providing direct humidification of supply air (in winter) and indirect humidification of exhaust air (in summer).

Isothermal humidifiers have lower initial investment costs but higher operating costs. They are particularly suitable for small to medium humidification loads or in applications where their use is mandated by legislation.

Regardless of the technology selected, it must be ensured that the solutions meet the technical requirements for hygienic safety and reliability, and that they provide energy-efficient and connectivity features appropriate for hospital applications.


low operating costs at high capacity
utilisation of the evaporative cooling effect
steam humidification is required by legislation
low capital costs and low capacity
very short absorption distance in the air duct
HUMIDIFICATION LOAD
[l/h]
1000
300
150
50
1
High-pressure atomiser
> 50 kg/h
< 50 kg/h
Ultrasonic nebuliser
< 50 kg/h
Electrodes
Steam humidifier
Heater type
4
80
800
[W/(l/h)]
CONSUMPTION
Electricity consumption

Regulatory framework

The characteristics of HVAC systems and humidification systems are governed by regional, national and international legislation, both in Germany and internationally.

Due to its critical importance, Legionella risk management is regulated separately.

Regulatory parameters

Air treatment, and humidification in particular, are strictly regulated by regional, national and international legislation, depending on the specific hospital environment. Operating theatres require the most stringent thermohygrometric and air quality conditions. Other areas, such as wards, consultation rooms, changing rooms and pharmaceutical storage rooms, are subject to different requirements.

Numerous parameters are regulated. The most important include:

- the acceptable temperature and humidity range within the space
- the number of air changes per hour in occupied areas

Additional parameters relate to permissible contamination levels, filter type and efficiency, decontamination time, airflow type, the design and positioning of air diffusers, air velocity, the maximum temperature difference between supply air and room air, the presence of anaesthetic gases, and acceptable noise levels.

Regulations often vary from country to country. However, the most recent and stringent requirements are aligned with the thermohygrometric specifications outlined in this document.

Legionella risk management is governed by specific legislation in each country. This typically includes:

- design requirements to mitigate Legionella risks
- factors that promote Legionella proliferation (water temperatures between 20 and 50 °C, low-flow pipework, seasonal or intermittent system use, water quality, the use of rubber in fittings, etc.)
- requirements for when and where Legionella risk assessments must be carried out
- sampling and analytical methods
- disinfection procedures
- cleaning and routine maintenance

These parameters define both the target values and the design characteristics of HVAC systems. Both international and German standards impose restrictions on the types of humidifiers permitted in specific environments.

Operating theatres are the most strictly controlled environments. They are generally required to be supplied via air handling systems using exclusively isothermal humidification systems. Current reference standards for the German market include DIN 1946-4, VDI 6022-3 (2002) and the report Legionella and Legionellosis (05/2005) [source: AiCARR].

In the United States, since 2013, the use of adiabatic high-pressure spray systems has been permitted in operating theatres, provided that strict measures are implemented to ensure hygienic safety. These include the use of reverse osmosis systems with UV disinfection for water treatment, droplet separators and high-limit humidity sensors, the prohibition of water recirculation, and interlocked system operation allowing humidification only when the air handling unit fan is running. Many of the hygienic safety features described here are mandated as minimum requirements by legislation.

10. German legislation

Regulatory parameters		DIN 1946-4
Thermohygrometric conditions	Supply air temperature, relative humidity	19–26 °C, adjustable; RH in acc. with DIN 13779
	Maximum Δt between supply air temperature and room temperature	Not specified
Contamination classification	Mandatory ISO class	classification according to RKI: Classes Ia, Ib, II
	Contamination measurement	Bacterial count and particle concentration
Minimum floor area (operating theatre)		Not specified
Fresh air and recirculated air	Recirculation permitted?	Yes, using air from the same room group
	Outdoor air supply rate	1200 m^3/h outdoor air
Filtration	Filter requirements	Stage 1: F5 (F7 recommended) Stage 2: F9 Stage 3: H13 within 0.5 m of the rooms
	Filter positioning	Stage 1: upstream of the AHU Stage 2: in supply air Stage 3: in supply air
Decontamination times		Not specified
Airflow types	Recommended airflow	displacement flow for Type A rooms; displacement or mixed flow for Type B rooms
	Dedicated equipment	Not specified
Air velocity	Maximum permissible turbulence level in operating theatres	Not specified
	Air velocity limit in operating theatres	Not specified
	Air velocity at diffuser outlet	minimum 0.23 m/s downstream of filter
Room subdivision	Subdivision of operating department	reference to Table 2 of the standard
	Rooms with varying contamination levels	Room Class I (high microbiological control requirements, e.g. operating theatres)
	Contamination control methods	Airflow between rooms defined via cross-tabulation to determine flow direction
Air terminal arrangement	Supply air	Not specified
	Extract air	above (recirculated air) and below (exhaust air)
Anaesthetic gases	Concentration limits in operating theatres	N_2O = 25 ppm; Halogenated gases = 2 ppm; (upper limit based on NIOSH values)
Minimum airflow (standby mode)		Minimum 2 m/s in ducts upstream of HEPA filters
Maximum permissible noise level		48dB(A)

Data source: AiCARR

11. Conclusions

Humidification is more important in hospital operations than it may initially appear. It influences:

- the development of pathogens and the transmission of infections between patients
- the protection of medical equipment against electrostatic discharge
- thermal comfort for patients and the performance levels of medical staff

Numerous studies demonstrate that the optimal range of relative humidity lies between 40% and 60% RH. The same regulations that govern the design and construction of HVAC and humidification systems for hospitals require these values to be maintained.

For this reason, humidification systems are a mandatory component in hospital facilities. Their components must meet application-specific requirements in terms of hygienic safety, reliability and connectivity. Where possible, the selection of high-performance adiabatic or isothermal humidifiers makes it possible to balance humidification needs with energy efficiency goals in energy-intensive environments such as hospitals.

These decisions have a significant impact not only on the medical condition of hospital patients but also on the associated societal costs.

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