WHITEPAPER HUMIDITY

Understanding relative humidity and indoor climate

Swegon

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Abstract

Humidity is a crucial factor in a lot of areas - from agriculture, construction, manufacturing, transportation, and also heating, ventilation, air conditioning and refrigeration (HVACR). Humidity affects people, properties and materials and water vapour is a key factor in weather and climate.

Humidity definition dates back to the 1300s and is widely proved to be one of the important factors in buildings. Together with temperature, relative humidity is always given in absolute or relative terms (in percentage or water content, as dew-point, dampness or with humidification/dehumidification, etc.). However, the requirements for relative humidity in current building standards are very limited. More focus needs to be paid in controlling humidity in buildings and naming relative humidity as one of the main signals to ensure comfortable indoor conditions in buildings.

Indoor climate conditions significantly impact the health, comfort and well-being of people and humidity is one of several conditions to consider. When focusing on creating the optimal comfort of occupants in buildings the target of relative humidity should not be below 30% RH. Research also shows that relative humidity is an important factor in controlling the spread of various diseases in buildings.

Background

Definition

Humidity is the amount of water vapour in the air, and it can be measured in absolute or relative terms.

Humidity is defined as:

- State or quality of being humid
- A quantity representing the amount of water vapour in the atmosphere or in gas
- Atmospheric moisture

Humidity is the presence of water vapour in the air (or in any other gas).

Humidity is the most formal and common word to describe the amount of water vapour in the air. And as synonyms, the word humidity is commonly used in reference to weather (precipitation) or climate (fogginess, humidness, and moistness), cooking (steam, vaporisation, and evaporation) and buildings (dew point or condensation, moisture, dampness or damp, indoor relative humidity), etc.

Origin

Humidity is the amount of water vapour in the air, and it can be measured in absolute or relative terms. Water vapour is usually invisible and behaves like a gas, except when it condenses to form water or ice. Even without condensing, water vapour can react with surfaces and penetrate materials. The ability of a gas (or space) to retain water vapour depends on its temperature: the higher the temperature, the more water vapour it can contain.

The word humidity dates back to the 1300s.

The origin of word "humidity" comes from late Middle English, and it was derived from Latin (**humiditatem**, with the nominative **humiditās**, and from **humidus**, meaning "damp") or from Old French (**humidité**, meaning "to be moist").

Hygrometry and psychrometry (or psychometrics) are used in the field of engineering dealing with the thermodynamic and physical properties of gas-vapour mixtures.

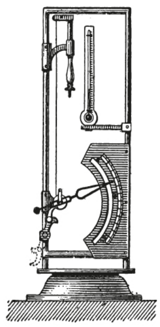
- The words hygrometry comes from the Greek **hygro+**, meaning "wet, moist, moisture";
- the term **psychro+** is from the Greek + meaning "cold";
- and **+metron** meaning "means of measurement".

Many devices were invented in connection with the measurements of water vapour in the air, soil or various spaces in buildings and materials. Invented measuring devices are hygrometer, psychrometer, dew-point hygrometer, etc.

- Hygrometer is from the French hygromètre and the Greek **hygro+**, meaning "instrument for measuring atmospheric moisture,"
- Psychrometer takes the meaning of "cold measure" in the Greek language.
- Dew-point originates from the Middle English **deaw**, **deu**, and Old English **deaw**. And dew+point thermometer is hence "that temperature of the air at which the moisture present in it just saturates it".

History

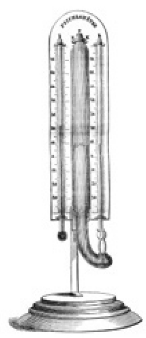
From the 1300s – Humidity and the invention of the hygrometer



In the 1400s, Leonardo da Vinci, the great Italian scholar, built the first crude hygrometer (an instrument used to measure the amount of water vapour in the air, soil or confined spaces).

F. Folli from Italy invented a more practical hygrometer in 1664. And in 1783, the Swiss physicist and geologist H. Bénédict de Saussure built the first hygrometer using human hair.

1800-1900 – Inventions of psychrometer and dew-point hygrometer

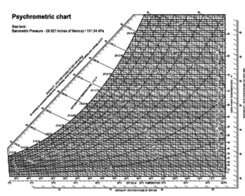


In meteorology, relative humidity has been used since the 1820s as a measure of moisture in the air compared to the amount needed to saturate it under current conditions. And in 1818, the German E. F. August created the psychrometer (a hygrometer based on dry and wet-bulb thermometers). Later, Sir Isaac Newton, the English scientist, improved his hygrometer, it was regarded as the first mechanical hygrometer, used the husk of oat grain that curled and uncurled depending on the humidity of the air.

In 1820, the British chemist and meteorologist J. F. Daniel invented the dew-point hygrometer, which was widely used to measure the temperature at which moist air reaches the saturation point.

1900-1930 – Humidity and air-conditioning, psychrometric charts and Mollier diagram

In 1902, W. H. Carrier, the inventor of modern air-conditioning, designed the first system for controlling temperature and humidity in a printing plant in the USA. Since then, air-conditioning has been defined as a system that must have four basic functions: temperature regulation, humidity control (based on relative or absolute terms), air circulation and/or ventilation, and air purification (filtration) (L. H Cetnerova, 2018).



And in 1904, Carrier pioneered the psychrometric chart, a graph of the thermodynamic parameters of moist air at constant pressure. It displays these parameters: dry-bulb temperature, wet-bulb temperature, dew-point temperature, relative humidity, humidity ratio, specific enthalpy and specific volume. This became the basis for the fundamental calculations in the air-conditioning industry and helped to determine the exact relationship between indoor & outdoor temperature and relative humidity to regulate the indoor climate throughout the year.

In 1914, a health report published by the Chicago's authorities concluded that temperature with proper humidity control was desirable in artificially heated living rooms and "that from the standpoint of health, relative humidity is one of the important factors in ventilation".

In 1923, R. Mollier from Germany invented an enthalpy-humidity chart (known as the Mollier diagram), which was used to investigate changes in the state of moist air and to provide values for enthalpy and wet bulb temperature.

In 1936, C. P. Yaglou from the USA considered the effect of temperature and humidity in on people and the ventilation requirements in a study by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) (Yaglou, 1938). And both parameters are still considered to be the most important elements impacting the satisfaction of the building's occupants.

1960-1980 – Relative humidity and building-related illnesses

In the 1960s, research focused primarily on allergies, allergens, pathogens, chemicals and ozone, also with respect to relative humidity. E. Sterling from Canada published the Sterling chart in 1986, and ASHRAE further updated it. After a standard reference for building design criteria was developed, the medium-range humidity of 30-60% RH was found to be optimal for occupancy (Sterling, Arundel, & Sterling, 1985). And it can be stated that the paper with a Sterling chart has put humidity on the indoor air quality map.

After the oil crises in the 1970s, many countries began looking for ways to improve the energy efficiency of buildings, and building airtight and insulated buildings led to problems with humidity, condensation, dampness and mould in buildings. Besides, moisture problems were caused by increased relative humidity, in addition to poor ventilation and enhancement of various activities of the building's occupants.

Around the 1980s, problems in buildings began with radon, dust mites, allergies, and sick building syndrome (SBS) and building-related ill nesses (BRI). And studies from 1992 revealed that high humidity could also cause concerns about health effects of building's occupants, such as allergic and respiratory problems (Spengler, Burge, & Su, 1992).

Towards the 21st century – What is the impact of relative humidity?

At the beginning of the 21st century and further on, P.O. Fanger and his colleague P. Wargocki from the Technical University of Denmark focused on the sensory load of pollution sources (besides persons), such as building materials, carpets, and computers, and the impact of ventilation and indoor air humidity in buildings.

In the first quarter of 21st century, many environmental variables such as temperature, relative humidity, air velocity, radiation and others are taken into account as various indoor thermal comfort indicators to provide the best thermal comfort for building's occupants.

Current building standards still focus on rather a simple linear relationship between the outdoor temperature and indoor comfort temperature, assuming to sufficiently explain the effect of all other variables, e.g. relative humidity (RH) and air velocity. However, the lack of a signal for relative humidity is particularly surprising, given its well-known impact on comfort.

Terminology

Humidity

- Relative humidity (RH, in %) indicates the present state of absolute humidity relative to the maximum humidity at the same temperature (%), i.e. how saturated the gas (or space) is with water vapour.
  - For example, RH of 30% means that the air contains 30% of moisture, which can maintain at that particular temperature.
  - When the air cannot hold any more moisture at a given temperature (i.e. the RH is 100%), the air is said to be saturated.
- Absolute humidity (AH, in g/m^3 or g/kg) is the mass of water vapour per unit volume of air containing water vapour, also known as water vapour density.
- Specific humidity (SH, in g/m^3 or g/kg) is the ratio of water vapour mass to the total mist air parcel mass, also known as the moisture content

(Wikipedia. Humidity, 2020).

Psychrometric properties

- Dry-bulb temperature (DBT, in °C or F) is the temperature indicated by the thermometer exposed to air in a place sheltered from direct solar radiation (Wikipedia. Psychrometrics, 2020).
- Wet-bulb temperature (WBT, in °C or F) is the temperature read by a thermometer covered in the water-soaked cloth (wet-bulb thermometer) over which air passes.
- Dew-point or dew-point temperature (DPT, in °C or F) is the saturation temperature of the moisture present in the air sample, it can also be defined as the temperature at which the vapour changes into liquid (condensation).
  - Dew-point shows what temperature to keep a gas, to prevent condensation.
  - Dew-point relates directly to the amount of water vapour present (partial pressure of water vapour).

Other parameters

- Specific enthalpy (h, in kj/kg of air) quantifies the total energy of both the dry air and water vapour per kilogram of dry air.
- Specific volume (in m3/kg of dry air) quantifies the total volume of both the dry air and water vapour per unit mass of dry air.
- The psychrometric ratio is the ratio of the heat transfer coefficient to the product of mass transfer coefficient and humid heat at a wet surface.
- Enthalpy is the energy content of the air.

The dew-point temperature is a simplified definition is the temperature at which water vapour turns into "dew"

Chamunoda Zambuko 2012

Basic physics and applications

Temperature with moisture content and relative humidity

The moisture holding capacity of air increases dramatically with increased temperature (Figure 1). This is a simplified version of the psychrometric chart (Engineering Toolbox. Moisture holding capacity of air., 2020).

Note – the moisture holding capacity of air at 38°C is 10 times greater than the ability to retain moisture at 0°C.

In general, it is a good energy economy to increase air temperature! The increased moisture transport capacity of air at higher temperature outweighs the increased energy consumption for heating dry air to the higher temperature.

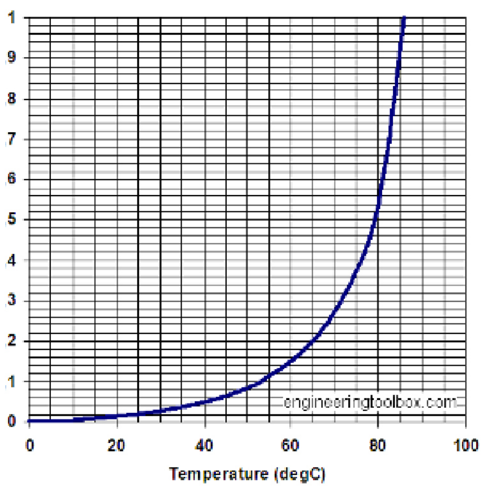


Figure. 1: Moisture holding capacity of air – kg water per kg dry air

For example, in the range of normal temperatures, the air at 20°C and 50% relative humidity will become saturated if cooled to 10°C, its dew-point. And 5°C air at 80% relative humidity heated to 20°C will have a relative humidity of only 29% and will feel dry (Figure 2).

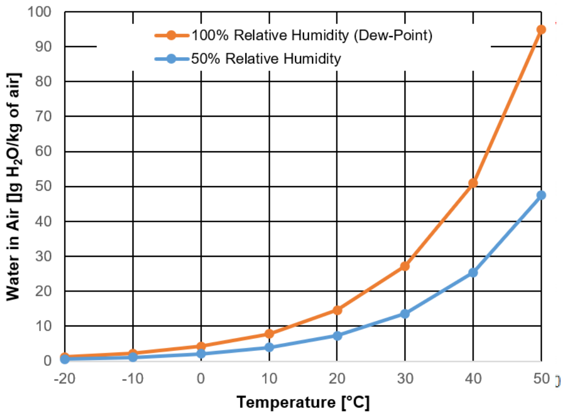
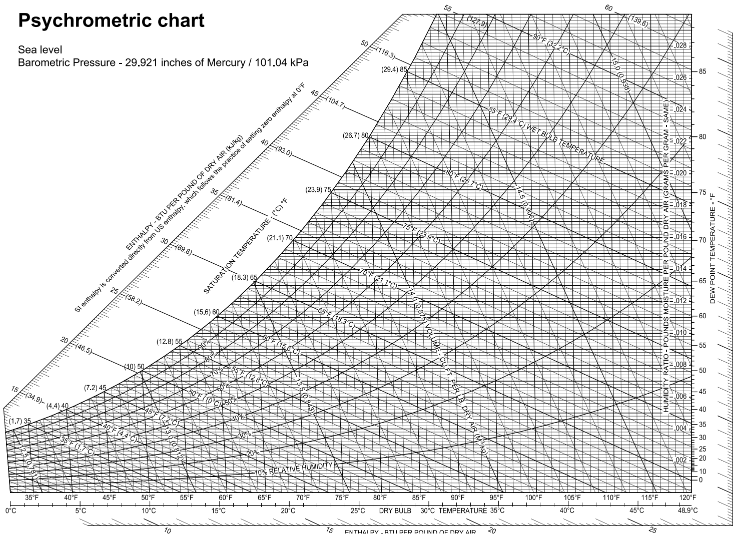


Figure 2: Amount of water in the air at 50% and 100% elative humidity across a range of temperature

A rule of thumb: the maximum absolute humidity doubles for each 11°C increase in temperature. Thus, the relative humidity decreases by a factor of 2 with each 11°C increase in temperature, assuming conservation of absolute moisture.

Psychrometric charts

The psychrometric chart (Figure 3) is a graph of the thermodynamic parameters of moist air at constant pressure, often referred to at elevation relative to sea level. It is a graphical equation of state with the following parameters: dry-bulb temperature (DBT), wet-bulb temperature (WBT), dew-point temperature (DPT), relative humidity (RH), humidity ratio, specific enthalpy and specific volume. There are other versions of psychrometric charts (Figure 4 and Figure 5) (Wikipedia. Psychrometrics, 2020), (Cushman-Roisin, 2020).



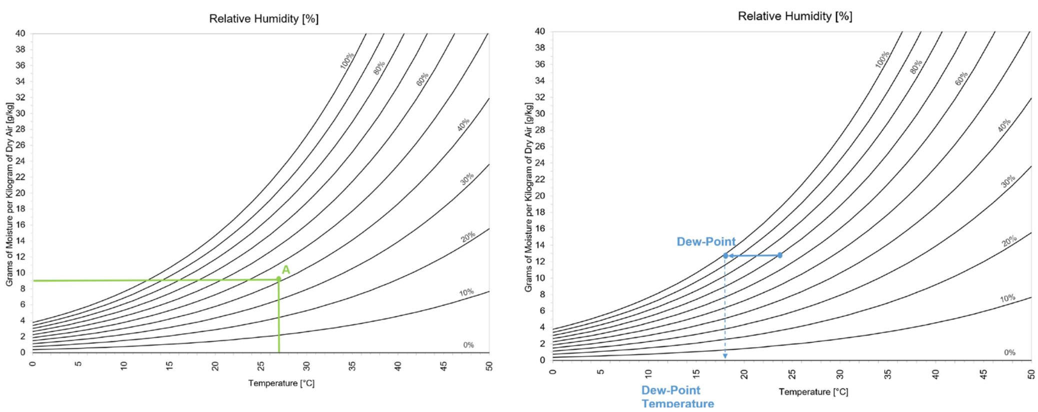


Figure 4. Humidity as a function of temperature - saturation value (A) and dew-point (B)

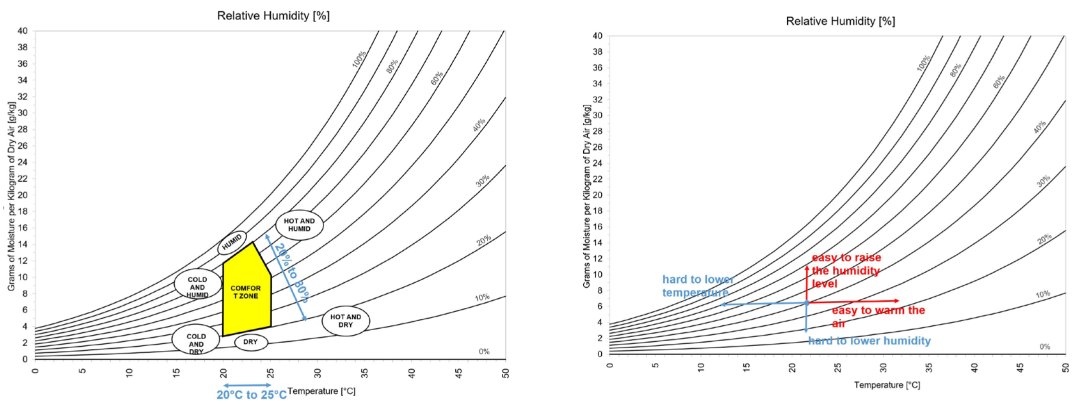


Figure 5. Humidity as a function of temperature - saturation value (A) and dew-point (B)

A psychrometric chart is commonly used in the USA and Britain.

NOTE: How to read psychrometric charts?

- In the metric system of units (i.e. SI units), visit www.engineeringtoolbox.com/psychrometric-chart-molier-d_27.html
- In the imperial system of units (i.e. I-P units), see wikihow.com/Read-a-Psychrometric-Chart

Mollier diagram

The Mollier diagram (Figure 6) is a graphic representation of the relationship between air temperature, moisture content and enthalpy - and is an essential design tool for engineers and designers. The Mollier diagram (enthalpy-humidity mixing ratio) is preferred by many users in Europe and Russia (Engineering Toolbox. Psychrometric chart by Mollier, 2020).

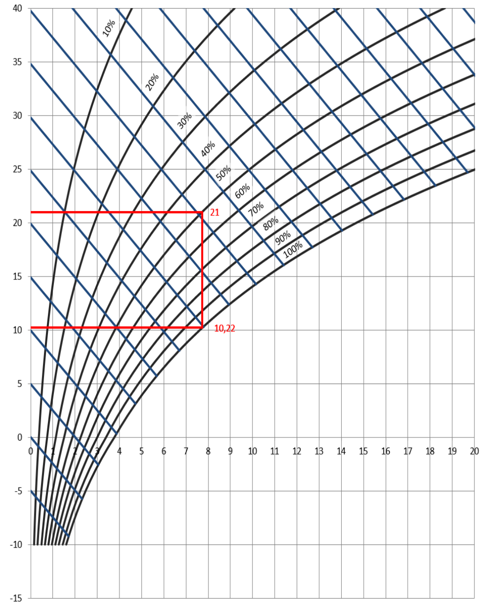


Figure 6: Mollier diagram as a variant of the psychrometric chart

Sterling chart

The Sterling chart (Figure 7) established that both high and low relative humidity levels had a deleterious and costly effect on the health and productivity of the building's occupants concerning bacteria, viruses, fungi, dust mites, respiratory infections, allergies, asthma, and ozone in the workplace, at school and home. The Sterling chart was used extensively for years by building owners, designers, developers, as a guideline for new and retrofit construction, but is not an official standard for building design (Sterling, Arundel, & Sterling, 1985).

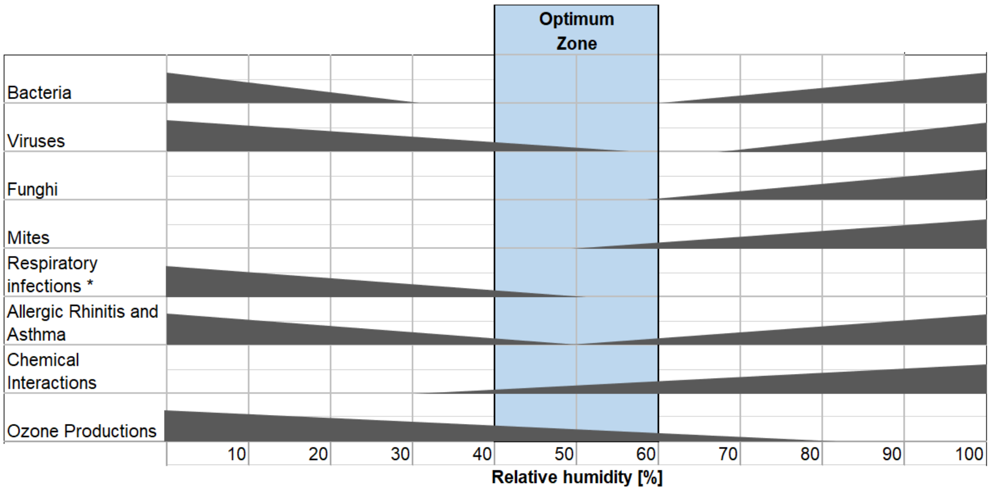


Figure 7: Sterling chart – optimal humidity range for minimising adverse health effects

Relative humidity

Humidity affects all living organisms, such as people, animals and plants. Water vapour is a key agent in both weather and climate, and it is also an important atmospheric greenhouse gas. Humidity affects people's thermal comfort and the indoor air quality, and it is essential for the indoor environmental quality. Humidity or rather water content is also essential to meeting environmental requirements for machines (vehicles, electronics, aviation), sensitive materials (for example, historic) and technical processes. Humidity levels between are 40-60% RH also key for building constructions, materials and equipment in buildings.

A little water goes a long way.

Sources of humidity

From people and household

- People (metabolic processes – respiration and perspiration) on average 1.25 l/person/day.
- Household activities (showering, washing, clothes drying, cooking) 2.4–3 l/person/day
- Other potential sources are houseplants, appliances, saunas, firewood, etc.

In a new home in the first year, the total moisture input from occupants (family of four) and other sources may average to combined load of 18–20 l/day or more during the winter, if all moisture-producing activities were to occur on the same day (Labenvironex, 2020). As everything dries out, the total moisture input rate in second year may drop down to 15 l/day and settle eventually to a rate about 10 l/day. Therefore, many of the issues needs to be addressed in order to control humidity levels in new and retrofitted homes.

In a home, one third of the total moisture input is generated by sources other than the occupants and his activities.

From buildings, construction, materials, equipment to activities

- Construction moisture, for example from new materials (wood, concrete, etc.), so-called retained moisture in building materials after installation, etc.
- Building equipment and processes can affect relative humidity.
- Various activities can have a significant effect in commercial buildings (offices, factories), educational (schools, entertainment, sport venues), etc.
- Specific types of activities require a specific level of relative humidity – low RH (museum, historical buildings), high RH (sports, ice hockey, swimming pool) or specific level of RH (hospital, laboratories), etc.
- Other errors causing dampness and leakage (damp ground, water leakage, plumbing leaks), etc.

A person who sits down and engages in light work will release about 40 g of moisture per hour into the air and about 200 g per hour when carrying out more strenuous physical work.

Effects of humidity

Human body's response to the levels of humidity, whether outdoors or indoors, can hugely affects people's health, comfort and well-being. Human body consists of 65% water and the prevention of dehydration is critically important, as many human mechanisms exist to maintain overall fluid balance.

Low humidity

- Maintaining healthy skin as a barrier is critical to well-being, as the water content in the innermost cells of skin is around 70%.
- The importance of proper humidification for wellness and breathing. If the humidity is low, small particles are more likely to be inhaled deep into lungs. Low humidity can increase the creation of smaller exhaled aerosols that can re-transmit microbes.
- The mechanics of infections in relation to relative humidity show that infectious particles survive longer in dry air and human bodily defence is less effective in dry air.
- When relative humidity is below 30% RH, the skin becomes dry and symptoms of dry skin include: itching, cracking and chapping. Skin conditions such as psoriasis may become aggravated and worsen at lower relative humidity (Sunwoo, 2006).
- Low humidity causes the tear film in the eyes to break down. Discomfort to the eye increases with time if the dew point is below 0°C (Laviana, Rohles, & Bullock, 1988).
- Very dry air can cause dryness and discomfort in the nose. Membranes in the nose dry out faster at low humidity. Low humidity is a common cause of nosebleeds.
- Humidity above 30% RH is needed for the mucous membranes in the nose to properly filter the air that people breathe (Guggenbichler, Husterand, & Geiger, 2007). And it has an even more significant impact on the seniors and compromises their health.
- Relative humidity below 30% RH can irritate the vocal chords, resulting in dryness of throat, increased hoarseness or laryngitis.
- Low humidity can cause sensations of "static" when people are touching things. Static electricity is a build-up of electrical charges inside or on the surface of a material (for example carpet or vinyl) and it can be a nuisance or hazard. Static problems are reduced with relative humidity large than 20–45% RH (Hearn, 2020).

High humidity, damp air

- Very moist air will make people feel chilled in cold weather, and hot and sticky in warm weather.
- Damp air facilitates the growth of fungi (mould) and bacteria that can cause respiratory problems and/or allergic reactions.
- Dampness provides the conditions for dust mite populations to grow, which can affect people with asthma.
- Fungal growth can result in odours in poorly ventilated spaces.
- High humidity will result in condensation forming on windows, walls and ceilings that are colder than air temperature and can potentially damage building materials.
- High humidity can make a person feel tired and sluggish. In extreme cases, it can cause nausea and excessive sweating.

Drink water (six to eight glasses a day) and keep the relative humidity above 30%. Recommendation of the National Institute for Health (NIH).

Humidity – health, infections and viruses

The effects of humidity on health are mainly due to biological pollutants. The following outline describes the health problems most often associated with biological pollutants, such as infectious disease (pathogens) with bacteria (streptococcus, legionella), viruses (common cold, flu), allergic reactions (asthma, rhinitis), dust mites (dried body parts and fecal excreta), fungi and non-allergic immunologic reactions (hypersensitivitypneu-monitis) and bacteria (myctoxicosis fungi).

The seasonal impacts of viruses on health with respect to relative humidity are also of great importance as influenza is more common in the autumn and winter months, as studies show that higher humidity reduces the infectivity of influenza.

Research studies show that as relative humidity decreases, infections and bacterial spread increase ($t<0.02$ to $t<0.01$). For example, research indicates that 1 hour after coughing, the influenza virus is 5 times more infectious at 7-23% RH than when relative humidity is higher than 43% RH, i.e. the virus is most stable at lower levels of relative humidity (Lax, 2016).

The mechanics of infections show that droplets can travel a certain distance in the air based on the droplet's size. A droplet with a diameter of 100 μm can travel up to a distance of 1 meter and float for about 6 seconds, but a droplet of 0.5 μm can travel up to 5+ meters with a float time of 41 hours.

Humidity in buildings

Humidity affects the performance of buildings, the durability of building envelope materials, the longevity of the building's equipment and good indoor environmental conditions.

Controlling humidity

When the temperature is low, and the relative humidity is high, the evaporation of water is slow. When the relative humidity approaches 100% RH, condensation can form on surfaces, leading to problems with mould, corrosion, decay, and other moisture-related deterioration (Designing buildings. Humidity, 2020). Condensation can pose a safety risk (mould growth, mildew, staining, slip hazards, damage to equipment and the corrosion, freezing emergency exits shut). As it also leads to decay of building envelope materials as well as poor performance of insulation.

When the temperature is high, and the relative humidity is low (below 30% or less), evaporation of water is fast (everything dries quickly). If the air in the building gets to be dry because the relative humidity drops as the air heats up. Static electricity, which is caused by friction, increases proportionally with speed. And dry air causes problems in buildings and provides an uncomfortable environment.

Climate control in buildings

Climate control refers to the control of temperature and relative humidity in buildings, vehicles and other enclosed spaces to ensure human comfort, health and safety, and to meet environmental requirements for machines, sensitive materials (for example, historical) and technical processes.

Also, if the conditions vary too much, this can affect everything tremendously. Materials swell and shrink as they absorb and lose water. Humidity, therefore, affects the dimensions and weight of the materials. The effects of this ever-changing moisture content can damage building materials and equipment in the long term.

Using heating, ventilation and air-conditioning (HVACR) system is the key is to keep the relative humidity in a comfortable range - low enough to be comfortable, but high enough to avoid problems associated with very dry air.

Humidity control

Humidity can be controlled by limiting or removing moisture at the sources, raising the temperature, humidification or dehumidification, and ventilating.

- Passive ventilation by opening windows. For example, opening windows for just 10–15 minutes every day can lower the moisture levels inside the house. Windows should preferably be on opposite sides of the building to ensure good cross airflow.
- Raising the indoor temperature by heating. For example, houses heated to 18°C experience far fewer periods of high humidity (Alsmo & Alsmo, 2014).
- Condensation can be avoided by increasing surface temperature. For example, improving glazing and insulation.
- Mechanical ventilation. For example, the use of extract fan in the bathroom, the use of a range hood in the kitchen, and a dehumidifier, etc. And the use of HVACR as a more demand-controlled system (raising temperature, increase of ventilation rates).

However, manufacturing, technical processes and treatments in special factories, laboratories, hospitals, and other facilities require specific relative humidity levels to be maintained using humidifiers, dehumidifiers and associated control systems.

Ventilation and humidification

Indoor temperature and humidity are affected and controlled by ventilation rates. Significant energy in the HVACR may go into cooling the air (to remove water vapour) or, on the other hand, adding humidity (humidification) if it is too low. Humidity levels need to be monitored through the monitoring system, both to achieve correct environmental conditions and to minimising energy cost (Seppanen & Kurnitski, 2009).

Ventilation usually reduces indoor moisture levels.

Humidification or dehumidification of indoor air is necessary when the usage of the building requires the humidity of the air to be kept within narrow limits. This is often the case in museums, printing works and laboratories (40–60% RH). An even stricter requirement (45–55% RH) might be necessary for special laboratories and historical buildings.

Humidification of the air in the room can be carried out by either humidifying supply air in the air handling unit or direct humidification of indoor air. There are two basic methods that can be used: one is based on the introduction of moisture that has been pre-vaporised, i.e. humidification by the use of steam, and the other based on direct vaporisation, so-called evaporative humidification (circulating water, spray humidification, ultrasonic humidification).

Thermal comfort and relative humidity

People can be comfortable in a wide range of humidity depending on the temperature – from 30-70% RH – but ideally between 50-60% RH. Although relative humidity is an important factor for thermal comfort, people are more sensitive to variations in temperature than to changes in relative humidity (Fanger, 1970). Relative humidity has a small effect on thermal comfort outdoors when air temperatures are low, a slightly more pronounced effect at moderate air temperatures, and a much stronger influence at higher air temperatures (EN 16798 et al. Humidity in European regulations, 2020), (Brode, 2011)

Two types of thermal comfort standards currently prevail in the literature: steady-state and adaptive.

The steady-state model, pioneered by P.O. Fanger in the late 1960s, is a heat-balance model based on indoor environmental variables (air temperature, mean radiant temperature, air movement, relative humidity, clothing and metabolic heat by human activity) that will provide acceptable thermal conditions to the majority of occupants. These variables create the predicted mean vote (PMV) for thermal comfort.

The adaptive model by ASHRAE (and the European counterpart) is based on the idea of the range of acceptable indoor temperatures in buildings and dependent on the external temperature. The model derives a linear relationship between indoor and outdoor temperatures.

In general, higher temperatures will require lower relative humidity to achieve thermal comfort compared to lower temperatures; all other factors will be constant. For example, with clothing level = 1, metabolic rate = 1.1, and airspeed 0.1 m/s, the change in air temperature and mean radiant temperature from 20°C to 24°C would lower the maximum acceptable relative humidity from 100% RH to 65% RH to maintain thermal comfort conditions (Schiavon, 1996).

Relative humidity in building standards

Most of the building standards state that the recommended range of indoor relative humidity is generally 30-60% RH. However, it is not mandatory (it is not a legal requirement), only a recommendation for maintaining the relative humidity in the indoor air with the temperature in the room and the season.

European building standards

EN 16798:2019 (which replaced EN 15251:2007) focuses on parameters for the thermal environment, indoor air quality, lighting and acoustics (parameters are defined for category I, II, III and IV levels, i.e. levels I being the best and IV the worst). EN 16798 provides a number of specifications for air humidity in rooms, in ventilation systems and in buildings (European Committee for Standardization, 2019).

- Relative air humidity is defined for four categories (minimum and maximum values of between 20% and 70% RH) depending on weather, room temperature and type of use.
- Recommends an absolute indoor air humidity of less than 12 g/kg at all times.
- Humidity is concerned with the prevention of condensation and hygienic aspects.
- Humidity control on the supply air side of the HVACR is mandatory to exclude the possibility of condensation forming.
- Humidity and all parameters must be recorded, tested and evaluated (EN 16798 et al. Humidity in European regulations, 2020).

American building standards

ASHRAE Standard 55:2017 recommends relative humidity between about 30–75% RH at room temperature of 21°C (ASHRAE, Standard 55. Thermal environment conditions for human occupancy., 2013).

ASHRAE 62-2019 is moving towards dew-point targets over relative humidity for humidity control requirements ((ASHRAE, Standard 62. Ventilation for acceptable indoor air quality, 2019). Thanks to HVACR systems and airtight building envelopes, buildings have significantly lower sensible heat loads. As a result, temperature set points can be satisfied, but humidity levels remain high in the building (Systemair. What the latest ASHRAE 62.1 means for you, 2020).

- ASHRAE recommended levels of 30–60% RH.
- Humidity control requirements are now expressed as dew-point instead of relative humidity. As dew-point measures only the moisture level in the air, whereas relative humidity assesses both temperature and moisture.
- Dew-point measures can accurately predict the temperature at which moisture will condense, which can reduce the risk of mould growth.

Humidity around the world

Different climates

Relative humidity depends on temperature: the more the air is heated, the lower the relative humidity. Keeping in mind that relative humidity is defined as the percentage of water vapour the air can hold at the given temperature, whereas absolute humidity is the actual amount of water present in a unit of air (Table 1).

Temperature (°C)	Grams of water vapour per kg of air (g/kg)
-40	0.1
-35	0.2
-30	0.3
-25	0.51
-20	0.75
-10	1.8
0	3.8
5	5
10	7.8
15	10
20	15
25	20
30	27.7
35	35
40	49.8

Table 1: Specific humidity of a kg of air (at average sea level pressure)

Winter, cold and dry climate

Colder air is capable of holding less absolute moisture. That air may well be saturated (100% RH), but it only takes a small amount of moisture to make that happen at cold temperatures (Table 1).

Cold air is dry air. The lower the temperature, the less water can exist in the vapour state.

In other words, human discomfort caused by low relative humidity in cold climates is caused by the outdoor temperature with a lower capacity of water vapour. Although it may be snowing and the relative humidity outdoors is high, once that air enters the building and heats up, its new relative humidity is very low (meaning the air is very dry), which can cause discomfort (Wikipedia. Humidity, 2020).

- In buildings located in northern European climates, the relative humidity of indoor air often falls to around 10-15% RH in winter.
- In northern Europe, the humidity ratio of outdoor air varies between about 1 and 10 g/kg during the year. It only becomes dryer or more humid than this a few percent of the time.
- For example, in winter outside air at 0°C on a foggy day (100% relative humidity) heated indoors to 22°C gives a relative humidity of 23% RH.
- In places with very dry winters, with an outside temperature of 0°C and relative humidity of 30% RH and when the air is heated to 22°C, the relative humidity plunges to 7% RH.

Summer, hot and humid climate

- In Nordic climates in summer, the relative humidity indoors is rarely more than about 60-70% RH.
- In buildings located in humid climates (for example in Miami, USA), it is seldom dryer than relative humidity about 30% RH. Although the corresponding level would be about 90% RH if the air were not mechanically dehumidified.
- In southern Europe, the corresponding interval is about 2 to 20 g/kg. In Florida, USA, the humidity ratio is rarely less than 4 g/kg, but can quite often rise to about 20 g/kg.
- Dehumidification will most probably be needed to prevent problems caused by moisture and mould growth within building structures.

It a building in Rome or Miami, without any dehumidification, the relative humidity would rise to nearly 100% RH, if the room air were kept at 26°C (Table 2). If the room temperature were allowed to rise, for example, to 30°C, the relative humidity would still be close to 80% RH. This suggests that there is quite a massive need for dehumidification in buildings located in such climates (C. Nilsson, 2008).

	Humidity ratio of the outdoor air [g/kg]		Relative humidity in the room	
Location	Winter	Summer	Winter (22 °C)	Summer (26 °C)
Stockholm, SE	0.8	11.5	12%	60%
Paris, FR	1.9	13.2	19%	68%
Rome, IT	2.3	19.1	21%	95%
Miami, USA	4.5	20.3	34%	100%

Table 2: Example of limit values for outdoor air humidity ratios in different locations (source Climate Data: ASHRAE Handbook Fundamentals

Feeling hot or cold

There is a physiological effect of humidity that is often neglected: the effect on the feeling of hot or cold. Perspiration/sweating is an essential part of the organism's thermal control mechanism: the evaporation of sweat removes heat, thus making people cool.

Figure 8: Diagram of relative humidity (% RH) – from low to high
(* for 80% or more of the occupants in a space)

In summer, when it's hot, increased perspiration tends to return skin temperature to comfortable levels. High humidity stops the evaporation process (sultriness), while dry air promotes evaporation and subsequent cooling. High humidity makes hot days feel even hotter.

In winter, drier air helps evaporation and thus cool the skin. The most immediate effect of this phenomenon is that for the same temperature: the drier the air, the colder people feel.

A small amount of fresh air that enters a house when, for instance, opening a window has a negligible effect on the room temperature and yet causes a significant drop in relative humidity. In other words, water vapour "escapes" much more quickly than heat, due to the physical properties of gases. The paradox is that letting in the fresh air in the winter without adding moisture may
actually reduce air quality and make it too dry.

What is the best relative humidity then?

Optimal humidity in all buildings is no longer exclusively a feel-good factor – it can have a direct impact on the health, comfort, well-being and performance. The results of various studies can be applied more broadly as infections organisms are found everywhere, and thus controlling humidity is essential in all buildings: offices, schools, homes, hospitals, etc. There are only limited legislative and mandatory requirements in building standards in relation to relative humidity, or water content.

Importance of proper relative humidity for people's well-being has been documented for a long time. However, the relative humidity still left a little bit behind. The lack of a signal for relative humidity is particularly surprising given its well-known impact on comfort.

In countries with more temperate and wet climates, the problem will naturally be that the humidity levels are seasonally too high. But too low levels is also a problem. Measurements show that in the cold and dry winters of northern Europe, indoor RH-levels can drop to 5-15% for extended periods of time. This is especially clear in offices and other working places which are lacking natural sources of humidity. On the other hand, indoor environments with too high humidity levels result in growth of microorganisms that cause other illnesses, and may cause mold problems which are not just harmful to the house itself, but to its inhabitants. In other words, we need to control the humidity levels, so they are not too low, and not too high.

Global climate, the greenhouse effect

Humidity affects the energy budget and thereby influences temperatures in two major ways. First, water vapour in the atmosphere contains "latent" energy. During transpiration or evaporation, this latent heat is removed from the surface liquid, cooling the Earth's surface. This is the most significant non-radiative cooling effect at the surface. It compensates for roughly 70% of the average net radiative warming at the surface.

Second, water vapour is the most abundant of all greenhouse gases. Water vapour, like a green lens that allows green light to pass through it but absorbs red light, is a "selective absorber". Along with other greenhouse gases, water vapour is transparent to most solar energy, as one can literally see. But it absorbs the infrared energy emitted (radiated) upward by the Earth's surface, which is the reason that humid areas experience very little nocturnal cooling, but dry desert regions cool considerably at night. This selective absorption causes the greenhouse effect. It raises the surface temperature substantially above its theoretical radiative equilibrium temperature with the sun, and water vapour is the cause of more of this warming than any other greenhouse gas.

Unlike most other greenhouse gases, however, water is not merely below its boiling point in all regions of the Earth, but below its freezing point at many altitudes. As a condensable greenhouse gas, it precipitates, with a much lower scale height and shorter atmospheric lifetime- weeks instead of decades. Without other greenhouse gases, Earth's blackbody temperature, below the freezing point of water, would cause water vapour to be removed from the atmosphere. Water vapour is thus a "slave" to the non-condensable greenhouse gases.

While humidity itself is a climate variable, it also overpowers other climate variables. Humidity is also affected by winds and by rainfall.

Humidity can be an asset

We have known for a long time that humidity can have a positive impact on our health. Humidified air and water vapor inhalation has been a popular self-care treatment and used also in hospitals for quite some time for respiratory illnesses.

Our strive to avoid sick building syndrome, especially in the Nordic countries, has given humidity a negative ring to it. To avoid sick building syndrome and mold, high ventilation rates have been recommended, but there have been no requirements for humidity levels to act as a counterbalance, resulting in extremely dry indoor environments.

We use heat recovery in ventilation systems to save thermal energy. Besides that, control systems automatically adjust the recovery based on whether we want to keep the thermal energy inside the building or remove it. We should treat humidity like an asset and recover in the same way as we do with thermal energy.

Too dry air is bad for our health and is a problem we need to put more attention to in order to create healthy indoor environments for all. We need to look at the actual cost of too dry air, in terms of sick leave rates, not to mention the human cost of poor health.

We should treat humidity like an asset and recover in the same way as we do with thermal energy.

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