MAKING BUILDINGS HEALTHIER

Protecting against the spread of infection

Humidification, dehumidification
and evaporative cooling

Reimagining buildings

Buildings were originally constructed to protect us against a hostile environment. However, thanks to the relentless pursuit of energy and operating efficiency, plus the use of artificial high-tech materials, the opposite is now true: buildings can also make us sick. The insights gained from the Covid-19 pandemic have shown just how vulnerable we now are indoors.

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In recent years, advances in building technology have enabled buildings to become more and more energy-efficient – but also increasingly airtight. High-tech insulation, lightweight building envelopes and mechanical air-conditioning systems achieve outstanding energy performance while also cutting costs. Furthermore, floor space optimization and higher user densities – following the open-plan principle, also aim to cut operational costs. Yet the consequences of these trends for the health of building users is rarely taken into account.

Indoor climate is poorly regulated
Indoor air quality is of prime importance for protecting the health of building users. In recent years, an ever-increasing body of scientific evidence has been documenting its impact on the immune system and the spread of respiratory infections. A healthier indoor climate in offices, schools, hospitals and retirement homes, for example, would simultaneously be extremely beneficial to businesses, healthcare services and the national economy. Yet there is still a lack of comprehensive standards for the factors that influence indoor air quality.

Lessons learned from Covid-19
The SARS-CoV-2 pandemic has focused public attention on the risks posed by viral transmission in buildings. Contributory factors that have been known for some time, have now been placed centre stage, emphasising the influence that fresh air, temperature, minimum relative humidity and even light all have on the spread of viruses. New technologies have also been proposed such as UV-C irradiation, although little is currently known about the risks involved in their use.

Time for a rethink and retrofit
This brochure aims to stimulate a discussion about reimagining buildings. Healthier buildings are the result of many factors, some of which also work in synergy with one another. For specific buildings, some approaches will also be unsuitable or technically unfeasible. This report is intended to promote dialogue between facility managers, users, and health and safety officers, to enable the right package of health protection measures to be put together for new or existing buildings.

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Making buildings healthier

Healthy buildings mean healthier people

Respiratory infections cause huge productivity losses and generate considerable healthcare expenses that must be borne both by businesses and society at large. The catastrophic consequences for the economy have been vividly demonstrated by the coronavirus lockdowns. Flu infections alone are responsible for more than 500 million cases worldwide every year. People are especially at risk in buildings where many individuals are present in confined spaces or where they have pre-existing conditions.

Air is essential to life

We spend up to nine-tenths of our lives indoors. This indoor climate significantly affects our health and productivity, as well as the costs incurred by businesses and public health services.

Examples: How indoor air quality affects health and productivity

	Office / workplace	School / nursery school	Hospital / care home
13,000 litres inhaled air	**Up to 9%** decreased productivity	**3%** improvement in grades	**10%** incidence of infections
Every day up to 13,000 litres of air flow through our nose, mouth and lungs. Air is essential to life	Poor-quality indoor air can be responsible for productivity losses of 6–9% [1]	Improving air quality in schools improves the success rate for pupils passing a test by around 3% [3]	Hospital-acquired infections (HAI) are contracted by around 10% of patients worldwide [5]
90% due to viruses	**16%** of days lost to illness	**2x** rate of absenteeism	**Up to 30%** airborne transmission
Around 90% of all acute respiratory infections are caused by viruses: the commonest pathogens are rhinoviruses (30–50%), followed by influenza, parainfluenza and corona-viruses	16% of days lost to illness by office workers result from respiratory infections [2]	In nursery schools where humidity is controlled, children only miss 3% of teaching days from coughs and colds, compared to 5.7 % in schools where humidity is not controlled [4]	At least 15–30% of infectious microbes in hospitals are able to spread by airborne transmission

[1] Wyon, D.P. 'The Effects of Indoor Air Quality on Performance and Productivity.' IndoorAir, U.S. National Library of Medicine, 2004
[2] Statista Research Department, Germany, 2020
[3] Haverinen Shaughnessy et al., 'Association between substandard classroom ventilation rates and students' academic achievement', 2011
[4] Ritzel, G. 'Sozialmedizinische Erhebungen zur Pathogenese und Prophylaxe von Erkältungskrankheiten', 1966
[5] 'Report on the burden of endemic health care associated infection worldwide', World Health Organisation, 2011

Making buildings healthier:

1. Reimagining buildings
2. Factors for healthier buildings
3. Open-plan office with lots of employees
4. Risk group: Older people and those with pre-existing conditions

Enclosed spaces are infectious

Viral respiratory infections are almost exclusively transmitted from person to person indoors. In the industrialised world, people interact, work, sleep and travel in enclosed spaces for nine-tenths of their lives. Transmission pathways in these settings are through direct contact, indirect contact, droplets and airborne aerosols.

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With direct transmission, viruses are spread by contact with the skin or mucous membranes, without an intermediate medium during propagation. If someone with the flu sneezes into their hand, for example, the viruses will stick to the surfaces of their hand. If this person then shakes hands with other people, the virus can enter their mucous membranes via the mouth, nose or eyes. Indirect contact transmission involves transfer of pathogens deposited on an inanimate vehicle such as door handles or other surfaces that are touched by many different people.

Droplet transmission

The most common infection pathways are transmission in close range via droplets and remote airborne transmission via aerosols. Viral particles from an infected individual are breathed in by another person, and these then enter mucous membranes in the upper respiratory tract. This is called droplet- or aerosol-mediated transmission, depending on particle size. During breathing, coughing, talking or sneezing, infectious viruses present in a person's respiratory system can be emitted in droplets of saliva and mucus. These droplets are in various sizes and quantities. In medical terms, a 'drop- let' is a particle with a diameter of more than 5 µm (micrometres). These larger particles, which are responsible for droplet infections, remain airborne only briefly: after only a few seconds, these particles then fall to the floor or onto other surfaces. Droplets are only transmitted up to a distance of about 1.5 to 2 m. However, droplets can also be spread by contact with contaminated surfaces – such as when these surfaces are touched and the viruses then come into contact with mucous membranes via the hands.

Airborne transmission of aerosols

Particles with a diameter of less than 5 µm can travel over long distances through the air before infecting people. This route is considered airborne transmission of aerosols. Some of these aerosols may in fact contain very little liquid and be mostly solid matter. As a result of their low mass, these aerosols have the potential to escape gravitational forces and remain airborne indoors for several hours. Even if indoor air remains relatively still, tiny infectious aerosols can spread through the air in large spaces over a long period of time.

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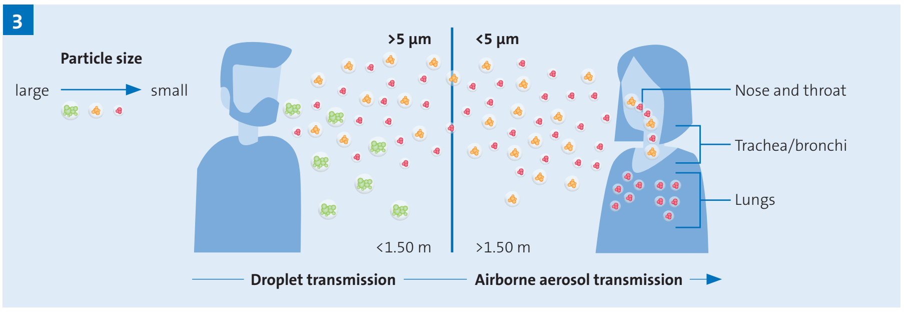

TRANSMISSION VECTORS

CONTACT, DROPLETS AND AIRBORNE AEROSOLS

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A Direct transmission by contact
B Droplet transmission
C Airborne aerosol transmission
D Indirect transmission by contact

Airborne transmission
The spreading of viruses by airborne aerosols is crucially dependent on the indoor climate in buildings. Air changes per hour, temperature and relative humidity are relevant factors for reducing the risk of infection.

Personal precautions to take
To protect against viral spread indoors, there are a number of precautions that can be taken, depending on the transmission vector. For contact and large droplet transmission, precautions such as good hand hygiene, sneezing into the crook of one's elbow, observing distancing, and wearing a mask covering the nose and mouth are all very effective means of reducing the risk of infection. These precautions are ineffective, however, for airborne transmission of tiny areosols.

Indoor climate as a factor
Beyond precautions involving good hand and surface hygiene, the spread of aerosols indoors requires the identification of indoor climate factors that can be controlled to mitigate the risk of transmission. Relevant factors are those that directly affect the capabilities of viral aerosols to shrink, remain infectious and spread through the airborne route. In an indoor environment, air quality clearly has a central role to play. Studies show that controlling air changes, temperature and relative humidity are effective strategies for reducing aerosol-mediated transmission: Optimised ventilation with plenty of fresh air reduces the risk of SARS-CoV-2 infection by diluting and removing infectious viral aerosols, for example, while excessively low levels of humidity mean that viruses may stay viable and travel farther in small aerosols.

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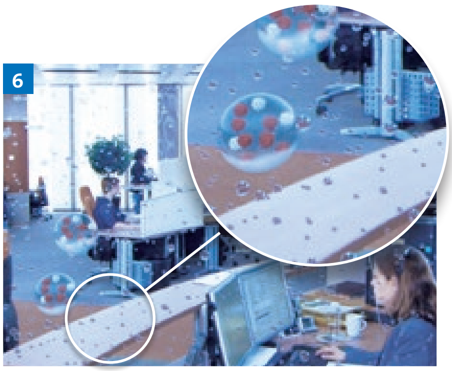

Transmission pathways:

1 Viruses in indoor spaces
2 Person to person
3 Droplet and airborne
4 Pathways in the workplace
5 Schools and day nurseries
6 Particle travel between surfaces and air

Tackling infectious aerosols with fresh air

To stay healthy, we know that we need to go outside and get fresh air whenever we can. The same principle applies indoors: the more fresh air inside, the lower the concentration of viral particles. Filters and proper ventilation are also important in removing particles and contaminated air.

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Bringing as much fresh air into the room as possible is an effective method for removing viral aerosol particles from indoor spaces. As the proportion of fresh air rises, the viral aerosol particles in room air is increasingly diluted.

Ventilation from windows

The simplest option is just to open a window. The volume of air that flows through an open window depends on the temperature gradient, the wind speed/direction and the angle at which the window is opened. The general recommendation is short but ample ventilation, by windows being fully opened for several minutes at least every hour. This air exchange will be most effective when two windows opposite each other are opened at the same time. There are limits to the effectiveness of using windows for ventilation, however. In summer, the temperature gradient between outdoor and indoor air is often too low, and air exchange is minimal. In winter, energy losses and sharp drops in relative humidity are arguments against the constant use of open windows.

Mechanical ventilation

Ventilation and air-conditioning systems can move the required volumes of fresh air and used air into and out of the room in a controlled manner. The air change rate is an important parameter here: an ‘air change per hour’ of 1, for example, means that the volume of fresh air introduced per hour is the same as the room volume. As air changes increase, the risk of infection grows smaller. The ideal air change rate depends on building usage and the number of people present indoors. It should be noted that higher rates of change can lead to an increase in energy consumption and a lowering of relative humidity levels. Checking CO_2 levels (concentration of carbon dioxide in the air) is a practical way of establishing whether or not an occupied room is well-ventilated. Air quality is considered to be good when the concentration of CO_2 is less than 1,000 ppm (parts per million).

Filters

Specialised filters can also remove even the smallest aerosols from air. The use of filters is recommended in particular for ventilation and air-conditioning systems where air is frequently recirculated. Various classes of filters are available, which are effective at filtering out specific sizes of particles. High-quality MERV filters (class 13 or better) and HEPA filters are designed so that they can trap over 99% of particles with a diameter of up to 0.3 µm (micrometres). Their effectiveness is limited for smaller particles.

Influence of air change rate on the risk of infection from aerosol-mediated viruses[1]

		Living space	Classroom		Medium-sized office		Open-plan office		Lecture theatre	
Room volume	m^3	220	210		65		1,200		10,000	
People (max.)	–	2	35		4		33		1,000	
Timescale	h	8	5		8		8		1.5	
Air changes	**per h**	**0.5**	**0.5**	**6.0**	**0.5**	**2.5**	**0.5**	**1.5**	**0.5**	**3.3**
Risk of infection**	RR_{inf}	1x	12x	1x	3x	1x	2x	1x	5x	1x

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* Reference: ‘private domestic space’ ** Relative risk of infection versus reference

[1] Cf. D. Müller, K. Rewitz, D. Derwein, T.M. Burgholz: ‘Simplified estimate of infection risk from aerosol-mediated viruses’ (in German), RWT Aachen University (2020)

Too dry and too hot is unhealthy

The fact that waves of colds and influenza infections occur during the colder months in particular is largely dependent on a number of seasonal factors that affect the indoor climate. These are related to the air temperature, as well as a drop in relative humidity. Even in summer, however, the air-conditioning units used for cooling can cause the air circulating in these interior spaces to dry out – making life much easier for viral aerosols.

Professor Akiko Iwasaki

Professor of molecular, cell and developmental biology at Yale University, and research scientist at the Howard Hughes Medical Institute (USA)

"A low level of humidity is one of the reasons for the seasonal occurrence of flu outbreaks. The world would be a healthier place if the humidity of the air in all of our public buildings were to be kept at around 40 to 60% relative humidity."

Dry indoor air doesn't simply occur on its own but results from the interaction of seasonal factors, building properties and basic physics. Often, dry air is literally 'home-made'.

Relative humidity makes the difference

If a building were to be hermetically sealed off from the outside world, the absolute humidity inside would be constant and unchanging. However, relative humidity is the key factor for properly assessing the humidity situation. Relative humidity describes the saturation percentage of air with water vapour and is affected by the air temperature.

Warm air can hold a greater amount of water than cold air. Air will always attempt to absorb water in the form of water vapour until it reaches maximum saturation. This is why relative humidity falls when air is heated, although the absolute humidity remains the same.

Buildings in winter

When indoor air is heated and windows are then opened or fresh air is brought in by a mechanical system, this air will start to dry out. The colder the outside air, the lower its capacity to absorb water – and the drier it becomes. If this cold, dry outside air enters the building, relative humidity will drop rapidly as this air is heated further. The air then tries to restore the equilibrium: if no humidification systems are installed, the air will try to become saturated by drawing moisture from any materials, structures and human bodies present.

Correct ventilation and heating

Before a humidification system is installed, it is important to check the air change rates and temperatures. The proportion of fresh air indoors should be reduced to the minimum necessary – especially in winter. Windows that are permanently open and excessively high air exchange rates should be avoided in order to prevent the air drying out. Indoor spaces should also not be overheated: an ideal temperature here is between 20 and 22 °C.

Absolute humidity =
actual quantity of water in the air, in the form of water vapour.

Relative humidity =
quantity of water contained in the air compared to the maximum possible quantity of water that could be absorbed.

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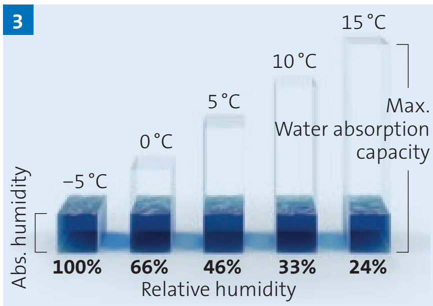


Importance of air quality

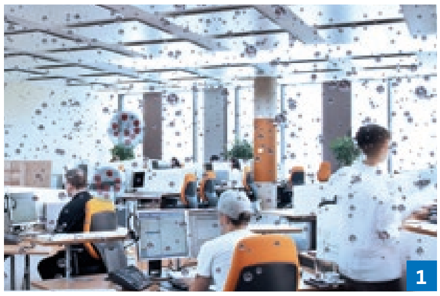
1 Fresh air reduces the risk of infection

2 Buildings in winter

3 Absolute and relative humidity

Viruses prefer dry conditions

The airborne transmission and viability of viruses is also significantly influenced by the relative humidity of indoor air[1]. The lowest risk of transmission is achieved with a relative humidity of 40 to 60%. At the same time, this is also the range in which the human immune response is most effective.



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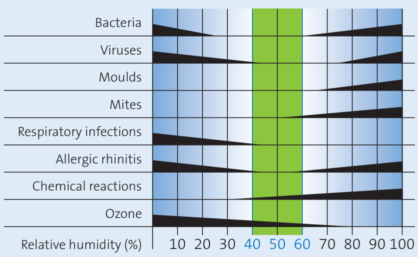
Relative humidity decisively affects the ability of viral aerosol to remain suspended in indoor air. Unlike the larger and heavier infectious droplets produced by coughing or sneezing, which fall to the ground after a few seconds, lighter and smaller aerosols can stay suspended in the air for hours at a time.

Dry aerosols stay in the air for longer

Aerosols consist of water, dissolved salts and proteins. At a relative humidity of under 40%, aerosols are unable to retain this water and there-fore dry out. This produces dry aerosols, which are smaller and lighter, and which can float through indoor air for longer. Unlike larger droplets, their lower water content also makes them less 'sticky' and so they cannot bond together so readily.

Humidity and the danger posed by microorganisms 2



Air flows and the movements of people in the room also mean that dry aerosols are swept off surfaces more quickly, and can therefore spread further[2].

Viruses stay viable for longer

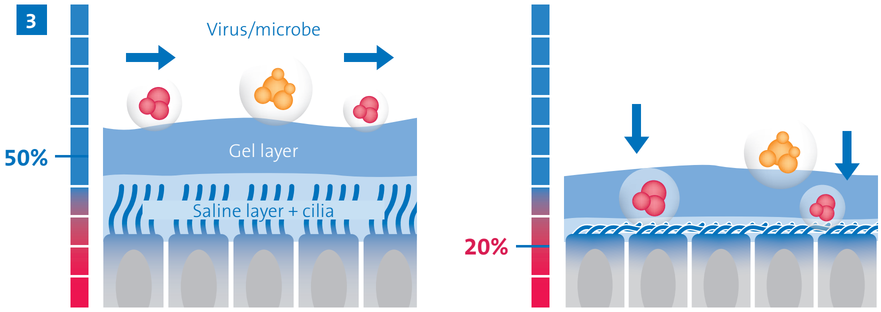
Apart from its effect on suspended particles, humidity is also hugely important for the contagiousness of these pathogen rich droplets. At less than 40% relative humidity, aerosols dry out so much that the salts they contain crystallise. These salts protect the viruses and they remain infectious for longer. When breathed in, the crystallised salts dissolve once more in the moist environment of the respiratory tract. The viral particles, still infectious, are released onto the mucous membranes, where they can trigger an infection. If relative humidity is within the optimum range of 40 to 60%, however, particles only dry out to an extent where salt concentrations rapidly inactivate viruses rather than protecting them.

Humidity range	Effect on suspended particles	Persistence	Risk of infection
60–100% rH	Low Large infectious droplets fall to the ground and settle quickly	Low Short persistence in room air	High Microbes remain infectious due to the low concentration of salt in the water
40–60% rH	Low Average-sized infectious droplets that do not stay airborne for long	Low Short persistence in room air	Low Microbes killed off by high salt concentrations
0–40% rH	High Small infectious aerosols remain suspended in air	High Long persistence in room air	High Salts crystallise out, preserving the microbes

[1] Miyu Moriyama, Walter J. Hugentobler, Akiko Iwasaki: 'Seasonality of Respiratory Viral Infections, Annual Review of Virology' (2020)

[2] W. Yang et al, 'Dynamics of Airborne Influenza A Viruses Indoors and Dependence on Humidity', PLoS ONE, Issue 6 (2011)

Self-cleaning abilities of mucous membranes at different levels of relative humidity



Mucous membranes: our first line of defence

We humans are not entirely defenceless in the face of attacks from viruses and bacteria: the response mounted by our immune system will decide whether or not we become ill and – if we do – the speed of our recovery. We are protected from infection by the self-cleaning mechanisms used by the mucous membranes in our airways. The surfaces of these mucous membranes are covered by fine motile hairs (cilia), which move freely within a fluid secretion (saline layer). Covering this is a sticky gel layer, on which most of the viral, bacterial and pollutant particles breathed in remain stuck. As long as the cilia remain highly motile, they can transport the secretions together with these microorganisms towards the larynx, where this secretions can then be swallowed or coughed out.

A weakened immune system

As humidity drops, this removal system for pathogens becomes less effective[3]. At lower levels of relative humidity, the saline layer starts to dry out. This has the effect of collapsing the cilia, which therefore lose their motility. The increasing viscosity of the mucous membrane works to block the flow of mucous and the risk of infection increases from viruses invading mucous membrane cells. Once relative humidity has fallen to 20%, this self-cleaning process comes to a complete standstill. Experiments have shown that the fastest pathogen transportation rate – and therefore the lowest risk of infection – is achieved at 45% relative humidity.

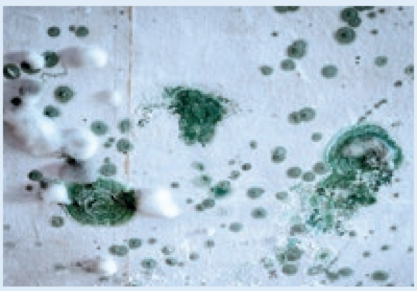
Use additional humidification

With humidification system, any building can now keep relative humidity within the safe range of 40 to 60%, using an approach that is both hygienic and energy-efficient. Depending on building conditions and requirements, centralised systems can be installed in the ventilation and air-conditioning system or local, direct room humidification systems can be used.

Damage to mucous membranes

When air is too dry, two other mechanisms also have a direct impact on the immune system and hamper the effectiveness of our adaptive immune response. Epithelial cells form a physical barrier underneath the mucous membrane layer, which prevents viruses penetrating into host cells. Breathing in air that is very dry damages these cells and therefore impairs the repair processes used by respiratory tract epithelia (lung cells). Secondly, low relative humidity can also reduce the formation of interferon in lung tissue. Interferons trigger the production of proteins that combat invading viruses and thereby prevent virus multiplication[3].

[3] Kudo E et al, Low ambient humidity impairs barrier function and innate resistance against influenza infection, PNAS (2019)



Mould isn't a problem

Moulds are not able to draw moisture out of the air: instead, they take up moisture from the material they are growing in and where their roots are anchored. Mould cannot grow on dry, well insulated masonry – whatever the relative humidity in the room.

Keep humidity in the safe range

1 Dry aerosols stay in the air for longer

2 Scofield/Sterling diagram

3 Dry air weakens the immune response

Prevention needs measurements

Without a sound set of data, it is difficult to decide which particular parameters need to be changed to achieve a healthier indoor climate. Buildings are made healthier and more productive by systems that consistently collect data on the relevant air quality parameters and suggest actions to take. Sensor systems and monitoring solutions can be integrated into any building with very little effort.

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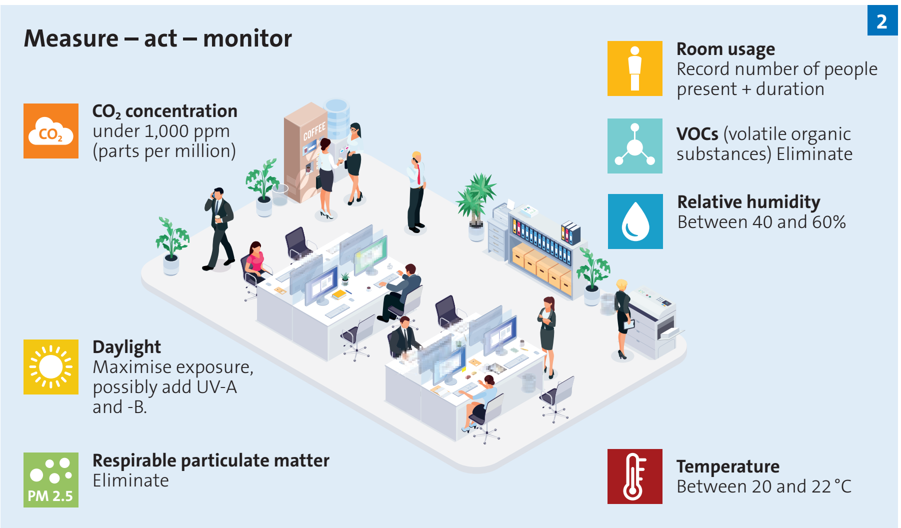
CO_2 levels that are too high, excessive heating, very low levels of humidity and air pollution from fine particulates and volatile organic compounds (VOCs) are all health hazards that also reduce productivity. Without proper measurements, it's hard to identify the underlying reasons for 'sick building syndrome', days lost to illness or the rapid spread of respiratory infections.

Prevention with building automation

To ensure the continuous monitoring and quantification of air quality, sensor and monitoring systems can now be easily retrofitted to any building. The systems are deployed either as an integrated part of building automation or as a simpler, standalone solution. Typically, relevant parameters – such as temperature, CO_2 concentration, humidity, and VOC levels – are measured using a multifunctional sensor system contained in just a single unit. When coupled with movement sensors, fully integrated systems can even detect the numbers of people using a particular room. Fresh air, temperature and humidity are adjusted automatically well before the indoor air starts to become a hazard to the health of people present.

Certified air quality

Proof of managed indoor air quality by continuous sensor measurement is an important requirement for many types of building certification programs. The leading standards for building sustainability and health are the US LEED program, the UK BREEAM assessment method, the German DGNB and the international WELL certificate. The WELL Building Standard is the first assessment system that concentrates on one single objective, namely: designing buildings and interior spaces to ensure that they have a positive influence on the health and well-being of their users. Fulfilling the requirements for monitoring as set out by these standards usually requires collecting statistics on ventilation performance and the resulting improvements to indoor air quality that this achieves. These standards also stipulate various exposure limit values and benchmarks in terms of air exchange rates, concentrations of particulate matter and ozone, VOC emissions and relative humidity.



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Natural light is healthy

Maximising sunlight makes people healthier. One reason for this is the formation of vitamin D in response to exposure to sunlight. Daylight is a freely available resource that can be applied actively in buildings to protect human health while also boosting productivity. However, the important UV-A and UV-B components of sunlight are blocked by glass windows.

Our bodies trigger the production of healthy levels of vitamin D in response to UV-B rays from the sun. Investigations have shown that the higher the levels of vitamin D in blood, the lower the likelihood of contracting a respiratory infection. Each incremental increase of just 10 nmol/l (nanomoles) reduces the risk of illness by 7% [1]. The lack of sunlight and the fact we spend most of our time shut away in buildings contribute to the seasonal occurrence of respiratory infections in autumn and winter.

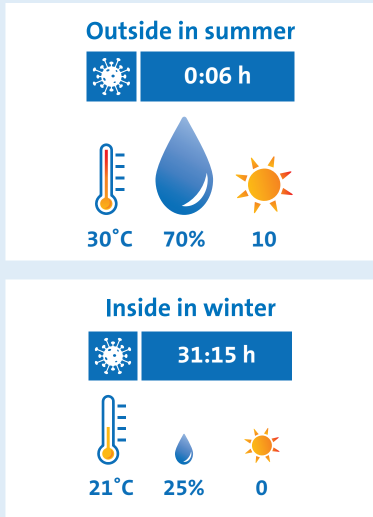
Letting the sun into the building

Sunlight also plays an important role as an active line of defence against viral infections. The UV component of sunlight stimulates the body's immune system on the one hand, while also enhancing the formation and mobility of the natural killer cells that tackle viruses and bacteria. Sunlight also reduces the period during which many pathogenic microorganisms can remain viable. Investigations conducted on flu viruses show that the time taken for half of the viral particles to become inactive drops rapidly in sunlight from around 32 minutes to under 3 minutes. Natural UV-A and UV-B light is absent from our buildings, since window glass (and thermally insulating glass in particular) absorbs and reflects up to 100% of UV radiation. UV-LED lighting, which can reproduce both UV-A and UV-B light, makes it possible to simulate full-spectrum sunlight within a building. This would reduce the propagation of pathogens while also boosting our immune system.

A biological boost

Light is a stimulus that controls our hormones, which in turn regulate our biological clock and ultimately decide how productive, attentive and focused we are during the day. Alongside natural daylight, dynamically controlled lighting systems in buildings can adjust the colour temperature and intensity of lighting to people's needs, thereby ensuring it has a stimulating or relaxing effect.

Influence of sunlight and humidity on the time taken to inactivate 90% of all Sars-CoV-2 viral particles



SARS-CoV-2 survival period
Sunlight (UV index)
Rel. humidity
Temperature

Source: Department of Homeland Security (US, 2020)

[1] Hyppönen et al.: Vitamin D status has a linear association with seasonal infections and lung function in British adults, British Journal of Nutrition (2011)

Caution is advised with UV-C

The continuous application of UV-C light as a defence against pathogens is not appropriate in buildings intended for normal use. UV-C does not form part of natural sunlight, and can be carcinogenic as well as hazardous for the eyes and skin. UV-C light must not be used in any rooms where people are present. In ventilation ducts, UV-C light is applied to air after extraction (circulating air). UV-C irradiation can cause viruses to mutate into resistant forms and is potentially harmful to the human immune system.

Monitoring and light

1. Monitoring of air quality indicates need for action
2. An integrated approach is necessary

Microbes belong in buildings

Surprisingly, keeping things ultra-hygienic and germ-free is harmful to our immune system. Our buildings must also enable interaction with the good microbes (e.g. viruses and bacteria) present in our environment. Choosing the right materials is important to suppress the microbes that make us sick while boosting the health of building users, through allowing exposure to healthy microbes.


1

Our immune system interacts continuously with its environment and can distinguish between harmless and harmful microbes. Harmless microbes – the 'old friends' that have accompanied humans for millennia – support the immune response and limit the spread of pathogenic microorganisms. In many buildings, however, this multitude of microbes is increasingly absent, resulting in a greater incidence of infectious disease and allergies.

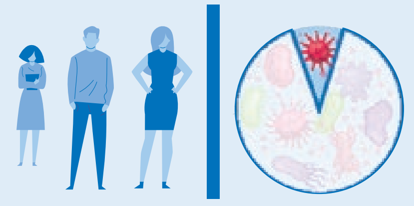
Stress due to dryness

Demands for better energy efficiency has brought one high-tech material after another into our buildings and also resulted in a rise in average temperatures. To produce an airtight building shell, insulation and interior fit-outs increasingly use steel, glass and various plastics, all of which have an impact on moisture levels. Unlike natural building materials such as tiles, plaster, clay or wood, industrial synthetic materials are smooth and non-porous, and are unable to absorb water or nutrients. In particular, our beneficial 'old friends' microbes cannot survive in the dry and nutrient-free environment created by these industrial materials. With no competitors for water and nutrients, pathogenic, multi-resistant microorganisms can propagate unopposed. As microbes are subjected to greater levels of stress and the diversity of these microorganisms is reduced, resistance to substances such as antibiotics can develop more easily.

A healthy mix of materials

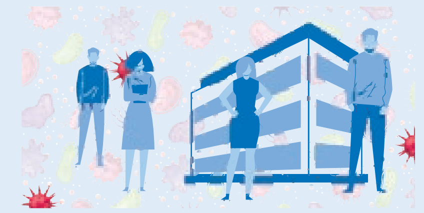
Buildings need to be understood as living ecosystems, able to achieve a balanced diversity of microorganisms. To ensure this, porous-free, smooth synthetic materials should be used sparingly and only for surfaces that are frequently touched and therefore need to be routinely cleaned – such as handrails, door handles, taps and keyboards. For walls, ceilings and furniture, natural materials with porous surfaces are preferred, offering an amenable environment for diverse communities of microbes. On these natural surfaces, water and nutrients are in plentiful supply for bacteria and viruses. With our 'old friends' in the majority, they suppress pathogenic microorganisms. With the exception of hospitals, surfaces should be cleaned with detergents and chemicals only in exceptional circumstances: soap and water is perfectly adequate.

2 Traditional approach to hygiene



A world free of microbes is healthy. However: only a small number of microbes are pathogenic.

3 Modern approach to hygiene



Harmless microbes are part of our building environment and essential for our good health.

4

Many ways to better well-being

Alongside technical systems and structural materials, the ability of a building to protect against infectious diseases also depends on its usage and facilities. The ways in which space is partitioned in buildings affects the intensity of person-to-person contact and therefore the spread of microbes. Floor coverings and plants can also have a positive effect on air quality.

5

The specific use of a building will influence its floorplan and layout. One crucial factor here is the degree of social interaction required between building users. Office buildings will have other requirements than public buildings with high levels of footfall or facilities such as schools and day nurseries. Whatever the type of building, the risk of transmission for pathogenic organisms increases when many people share the same space.

Spatial arrangement

The number of interconnected rooms, doorways and hallways influences communication and movements within a particular building. In recent years, many buildings have tended to adopt the kinds of layouts that emphasise openness, transparency and spaciousness. However, these positive moves to facilitate teamwork and personal interaction also have the effect of increasing the risk of transmission: spacious rooms with large numbers of people are proven to encourage the diversity and occurrence of microbes. The spread of pathogens can be contained, however, by reducing the number of high-occupancy rooms, and ensuring a mix between open and closed spaces.

Choosing a floor covering

The choice of floor covering can also influence indoor air quality. Unlike hard floors, coverings like rugs and carpets reduce levels of fine particulates within a room. Textile floor coverings trap dust particles in their fibres and prevent re-suspension into the air. Organic fabrics also store water molecules while helping to reduce noise levels in the room.

Green is clean

Plants filter impurities out of the air and boost microbe diversity while producing oxygen. Under the influence of light, photosynthesis removes carbon dioxide from the air: the plant retains the carbon and the oxygen is released into the room. Plants are also capable of releasing up to 90% of water they are given into the air, which means they are also moderate contributors to humidity.

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Room layout	Office type	Microbe transmission vectors	Microbe concentration (light = low, dark = high)
	Office for one or a few persons		
	Large office		
	Open-plan areas		

Building fabric

CHECKLIST

PROTECTING AGAINST THE SPREAD OF INFECTION

How does my building match up?

Facility managers and occupants can use this checklist to take stock of the current situation, and discover the extent to which their building protects against the spread of infections and where improvements can be made. The checklist aims to promote dialogue among stakeholders, to identify the need for outside consulting services and surveys.

	Actions to take	Implementation		
		is possible 3 points	not known 1 point	not possible 0 points
	Outdoor air ventilation **Goal:** Open windows to their fullest extent for several minutes every hour (intensive ventilation/ventilation from opposite windows). Avoid windows being permanently open. **Reason for action:** Fresh air dilutes the proportion of viral particles in the air. In winter, permanent or frequent ventilation with windows causes a drop in relative humidity.			
	Mechanical ventilation **Goal:** Improving air exchange, and adjusting this rate to room usage and the number of people present. Avoid recirculating room air or keep to a minimum. If air is changed too frequently, this causes a drop in relative humidity. Avoid infectious aerosol particles being swept up into the air again. **Reason for action:** The more fresh air there is inside, the lower the concentration of viruses in the air. The recirculation of used air (partially or mixed with fresh air) distributes viral particles over the entire building. Displacement ventilation or local ventilation systems reduce the risk of particles being swept into the air.			
	Filters **Goal:** If possible, use MERV filters (class 13 or better) and HEPA filters to trap microscopic particulates. **Reason for action:** If recirculating building air, reduce the viral load in air that is being reused in the building.			
	Relative humidity **Goal:** Use technical systems to keep humidity between 40 and 60% all year round, either in the whole building or in rooms with high occupancy. Integrate with the building's ventilation and air-conditioning system or install as a local, direct room humidification unit. **Reason for action:** This is the range where the human immune response is most effective, while also keeping viral viability and presence in the air as short as possible.			
	Temperature **Goal:** Do not overheat rooms, and keep temperatures constant between 20 °C and 22 °C. **Reason for action:** As indoor temperatures rise, this automatically causes a drop in relative humidity. Temperatures above 23 °C also stress the circulatory system and reduce productivity.			
	Monitoring **Goal:** Deploy sensor and monitoring systems to ensure continuous measurement of relevant parameters for air quality. **Reason for action:** Excessive levels of CO_2, high temperatures, very low humidity and other airborne pollutants (VOCs) are identified in real time together with action areas.			

CHECKLIST

PROTECTING AGAINST THE SPREAD OF INFECTION

	Actions to take	Implementation		
		is possible 3 points	not known 1 point	not possible 0 points
	Sunlight **Goal:** Ensure that plenty of daylight gets into the building. Install LED lighting with controlled levels of UV-A and -B. **Reason for action:** Natural light (with UV-A/UV-B) stimulates the body's immune system while also reducing the number of pathogenic microbes.			
	Natural materials **Goal:** Porous, natural materials should be chosen for walls, ceilings and furniture. **Reason for action:** Natural materials absorb water and nutrients, and therefore help to increase the diversity of harmless microbes in the building. A balanced community of microorganisms helps our immune systems and limits the spread of pathogenic microbes.			
	Cleaning strategy **Goal:** Use disinfectants and chemicals only in exceptional cases or for special-use buildings (e.g. hospitals). **Reason for action:** Disinfectants also kill harmless microbes. With no competitors for water and nutrients, pathogenic, multi-resistant microorganisms can propagate unopposed.			
	Spatial arrangement **Goal:** Create a balanced mix of open and closed spaces, which is carefully tailored to the kinds of room usage expected as well as user behaviour. **Reason for action:** Large, high-occupancy spaces with many people present increase the risk of infection. The spread of pathogens can be contained by partitioning off spaces, reducing room occupancy and ensuring distancing rules are properly applied.			
	Plants **Goal:** Use plants to make the building 'greener': these can also be used as part of room decor and for room partitioning. **Reason for action:** Plants improve ambient air by reducing levels of impurities and carbon dioxide, producing oxygen, contributing to good levels of humidity and diversifying microbial communities.			
	Floor coverings **Goal:** Use textile floor coverings that contain natural materials. **Reason for action:** Textile floor coverings trap dust particles in their fibres and prevent resuspension into the air. Organic fabrics also store water molecules. Textile fabrics help to reduce noise levels in the room			

Points	Risk
0 – 5	**HIGH** The building is a serious health risk for its occupants. Urgent consultation with experts is advised, in order to assess and implement potential courses of action.

Points	Risk
5 – 25	**MEDIUM** The building's current level of risk can be further reduced by implementing the available measures and assessing the feasibility of other options for improving health.

Points	Risk
>25	**LOW** The building is a low health risk for its occupants if available measures are implemented. Further action can be taken to improve the level of protection offered to the health of building users.

Making buildings healthier

Condair Group AG
Gwattstrasse 17
8808 Pfäffikon/SZ, Switzerland
Phone: +41 (0) 55 416 61 11
E-mail: info@condair.com
Internet: www.condairgroup.com