EVALUATION OF INDOOR AIR HYGIENE

Current challenges for specialists and experts:

- Aerosols as vehicles of infection
- Evaluation of air exchange and air purification
- Useful aids: Aerosol generator and spectrometer

For many years, public discussions on the topic of "air quality" have focused on the quality of outside air. However, as the Covid-19 pandemic has progressed there has been growing awareness of the importance of air hygiene in indoor areas. While initial efforts to prevent infection at the start of the crisis were aimed particularly at avoiding infection via droplets and contaminated surfaces, it has now become clear that airborne infections play a major role in the spread of the virus. It is urgent now for us to get a clear handle on air quality in indoor areas. This is the basis for the development of suitable air hygiene concepts.

1. INITIAL SITUATION

In the current health crisis – which is unlikely to be the last of its type – the challenge for experts in indoor air quality and specialists in ventilation and air-conditioning technology is the assessment of the risks posed in indoor areas in relation to airborne infections. What is new about this situation is that the people who are present in the room can be the source of hazards.

The air that people exhale while breathing or talking carries aerosol droplets which can contain bacteria and viruses if the person in question has been infected. These droplets are predominantly smaller than 1 µm. Larger droplets will rapidly shrink down to this size range as the water contained evaporates in dry indoor air. This means that these droplets are so small that they can float in the air permanently and can be inhaled by other persons.

Due to their small size, potentially infectious particles suspended in the air can only be detected with special measuring devices.

The latest research results show that some of the Covid-19 sufferers exhale a much higher number of aerosol particles. A single so-called "super emitter" can release as many viruses as a hundred average people. This can go unnoticed if the person is not subjectively affected by the disease. It can be assumed this group of people is responsible for significant levels of transmission. It is particularly challenging to secure indoor spaces against this case. Three mitigating measures can reduce the concentration of potentially infectious aerosol particles in the room air and thus reduce the risk of infection through inhalation:

1. Dilution of exhaled aerosols with fresh air ("ventilation")
2. Removal of particles by stationary or mobile filter devices ("purification")
3. Use of personal protective equipment (PPE), in particular masks ("protection")

No general statement can be made here on the third point, as the effectiveness of personal protective equipment is subject to a large number of material and person-specific factors.

2. CHALLENGES IN PRACTICE IN THE DEVELOPMENT AND IMPLEMENTATION OF AIR HYGIENE CONCEPTS

Assuming that the air is well mixed, here is a simple example of room air purification: An infected person in the room inhales and exhales about 0.5 m^3 of air per hour. A filtration device located in the room processes around 500 m^3 of air per hour, removing aerosol particles. The concentration of the aerosols given off by the infected person would be reduced by about 1000 times. Adequate mixing of the room air prevents a high concentration of infectious aerosols from building up locally.

In order to achieve the same effect by dilution with fresh air, a constant cross ventilation in winter would in many cases either lower the room temperature close to the outside temperature, unacceptable under workplace regulations, or increase heating costs to significantly exceed the costs of air purification appliances.

The rule currently proposed for schools to ventilate every 20 minutes for 5 minutes[1] results in only about two air changes per hour. As soon as there is no more ventilation, the room air quickly becomes enriched with aerosols again.

Rather ventilate than filter?

Five air changes per hour in a classroom with a volume of 200 m^3 means heating 1300 kg of air from outside to inside temperature every hour. This corresponds, for example, to the calorific value of 3 m^3 of heating gas. With 6 hours a day and 100 heating days per year, this means 1800 m^3 for a single room. This is expensive and harmful to the environment - it is really not a good idea to increase heating to allow for opening windows in winter.

Please also note: Opening windows is an organizational measure that can be omitted due to human error. Automated ventilation systems can be locked to prevent unauthorized access and can be monitored in real time, but they are also associated with high costs. So it depends ...

The result is that with intermittent ventilation, short phases of good air quality alternate with long phases of poor air quality. The risk of infection is hardly reduced. The process may allow a CO_2 concentration to be maintained that does not yet lead to reduced attentiveness or tiredness. Studies show that measured CO_2 levels are generally an aid in everyday office or school life, but are not a sufficient basis for effective mitigation measures against airborne diseases.[2]

In practice, experts will often be confronted with rooms that can only be ventilated to a very limited extent, be it due to windows that cannot be opened or the location inside a building. The only alternative is to evaluate the contribution of the given air exchange and to include it in the overall concept.

Modern buildings can be equipped with ventilation systems that allow high air exchange rates (> 5/h). If heat recovery is used, then a solution involving maximizing the fresh air supply can be sufficient and cost effective.

[1] https://www.umweltbundesamt.de/richtig-lueften-in-schulen#konnen-mobile-luftreiniger-in-klassenraumen-helfen(Abrufdatum: 11.01.2021)
[2] Julia Szabadi, Jörg Meyer & Achim Dittler (2020) „Untersuchung der Minderung der Partikelkonzentration in geschlossenen Innenräumen durch einen hoch wirksamen Innenraumfilter".

3. BEST APPROACH – AND THE CONTRIBUTION EXPERTS CAN MAKE

The task of the expert is to assess the behavior of aerosols in a given room and, if necessary, to make a recommendation for improvement measures. Interiors differ from one another in terms of geometry, furnishings, areas where people spend time, windows and forced ventilation. Their evaluation is therefore a complex task; In particular, the expert must identify areas with insufficient mixing based on experience and with suitable tools.

The **first step** is to investigate how the concentration of aerosol released in the room - measured as the number of particles per volume of air - changes under the influence of the existing technical properties of the room ("actual state"). Depending on the room characteristics mentioned above, it can decrease faster or slower.

It is particularly important here to identify areas with poor flow due to being located unfavorably in relation to ventilation or air circulation devices.

Aerosol generators enable the simulation of realistic load scenarios.

A suitable generator can be used to produce harmless test particles to simulate the aerosol emitted by people and distribute them in the room. The average size of the particles produced by the aerosol generator should be in the range 0.2-0.3 µm in order to simulate aerosol particles exhaled by people and to avoid a decrease in concentration due to sedimentation. In order to measure without influence of any particles randomly present in the room air or inflowing external air, the concentration must be set high enough for the test aerosol to dominate (> 10x room / external air concentration). Once the target concentration has been reached, the aerosol concentration is measured over time after a short delay to allow for even distribution in the room. The given air exchange will produce a measurable decay rate of the particle concentration. If applicable, this test should be repeated for different operating modes of the room.

A counting AEROSOL SPECTROMETER designed for the particle size range of the test aerosol is required for this measurement. Simple PM sensors are not suitable for this, as their sensitivity to detect particles below 0.5 µm is poor and usually they cannot detect particles below 0.35 µm at all.After evaluating the room in its current state the impact of an additional air treatment

Suitable measuring technology is the key:

A counting aerosol spectrometer is not to be confused with a clean room counter. Clean room counters are designed for extremely low particle concentrations, but at concentrations above approx. 50 particles / cm_3 counting errors and incorrect size determination occur because two or more particles can be in the detection area at the same time. Both indoors and outdoors, however, the concentration is usually significantly higher than that. The particle spectrum is usually only recorded above 0.3 µm and is represented only by a few size classes.

measure, such as operating a mobile air filter, can be examined in the **second step**. A study by the University of the German Armed Forces showed that mobile air purifiers with high-quality filters can reduce the indirect risk of infection via aerosols.[3]

The procedure is basically the same, only that the effect of different installation positions and operating modes of the device (e.g. "full power") in the room must now be investigated. This is required in particular if the room does not have a simple geometry and additional flow-changing furnishings, so that the optimum arrangement is not immediately clear from experience. Based on the measurements, a recommendation can be made for the installation position (s) and the air flow rate to be set.

Integrated sensors in air purifiers are often not ideal:

Why should room air purifiers not be operated in automatic mode? Their integrated sensors, usually designed for measuring PM2.5, are hardly suitable for measuring particles smaller than 1 µm, as they cannot detect particles below 350 nm (usually only from 0.5 µm with 100% efficiency) and only provide general mass concentrations. Their simple measuring principle always reacts to signals from an undefined number of particles that are simultaneously in the detection area. This is insufficient, which becomes clear when one realizes that the same PM2.5 pollution can be caused by a single particle of 2 µm or by 1000 particles of 0.2 µm in size. A realistic assessment requires counting aerosol spectrometers that recognize particles individually and measure their size.

Checking the cleaning effect of mobile air purifiers and air treatment systems makes sense

The same method can be used to evaluate a room that has been retrofitted with air cleaning in recirculation mode (acceptance test). It may be necessary to determine the capacity with which this device should be operated in order to achieve a good effect everywhere in the room.

The spreading of CO_2 in the air can differ from the spreading of aerosols. However, it can be investigated in a similar way by recording the course of the CO_2 concentration over time. For this assessment, a realistic situation must be established, i.e. either a corresponding number of people are present during the test or the breathing activity of the number of people intended for the room is simulated by releasing CO_2. It is advisable to use a measuring device with integrated recording of the CO_2 concentration; the reading of sensors that only show the current value is insufficient.

Sensible combination of the measurement of particle and CO_2 concentration to estimate the risk of infection

[3] Christian J. Kähler, Thomas Fuchs, Rainer Hain (2020): „Können mobile Raumluftreiniger eine indirekte SARS-CoV-2 Infektionsgefahr durch Aerosole wirksam reduzieren?".

The Palas AQ Guard is equipped with a special software package for evaluating risk levels of indoor spaces on the basis of simultaneous measurement of CO_2 and aerosols. This software determines the reproduction value R, based on scientific findings on infections transmitted by air for a given situation – operation of a room under given technical boundary conditions for a predefinable, typical usage time.

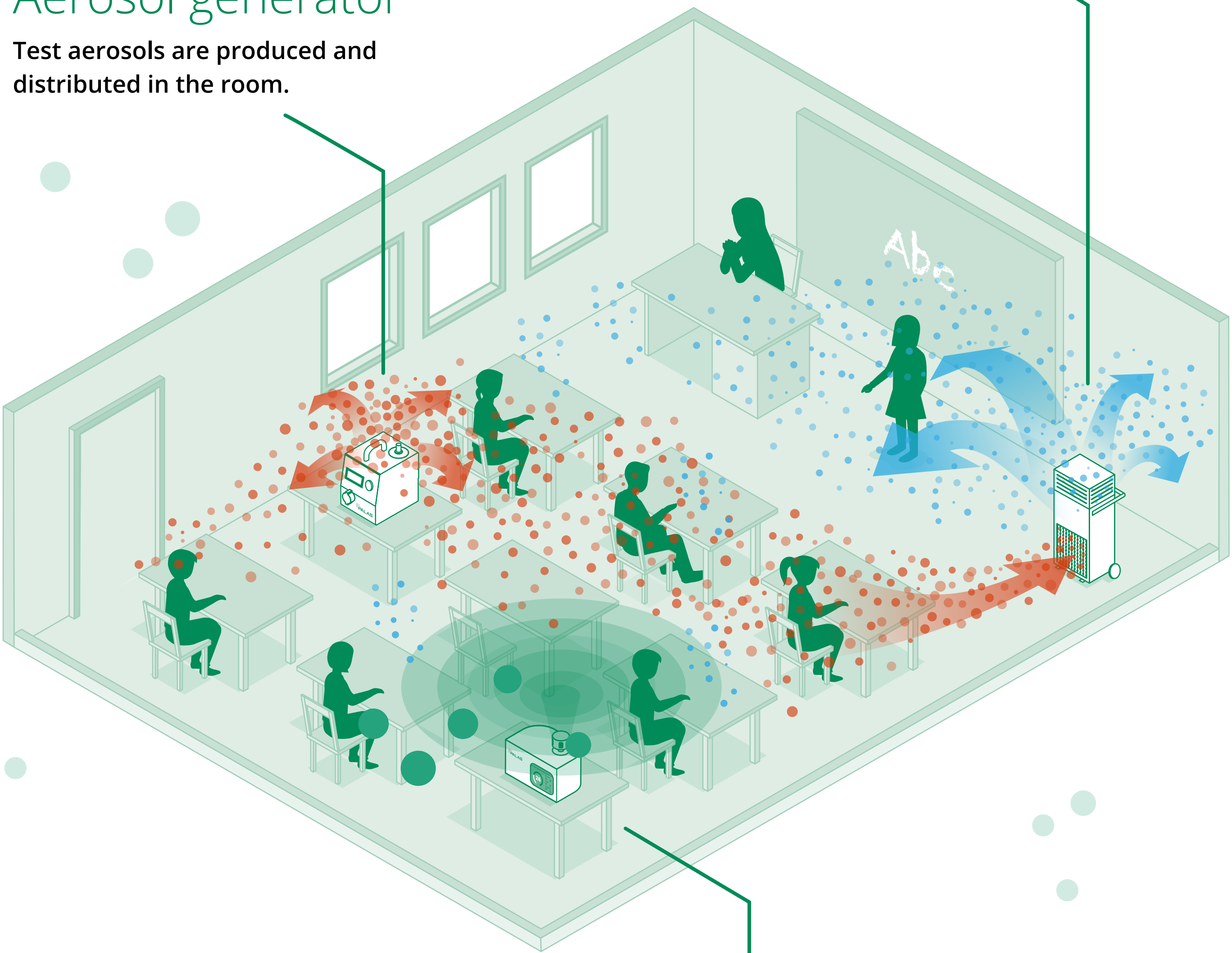
With this tool, rooms can be compared with one another, taking into account their typical use, and assessed with regard to indoor air quality.

Room air purifier

A virus filter system ensures purified air.

Aerosol generator

Test aerosols are produced and distributed in the room.

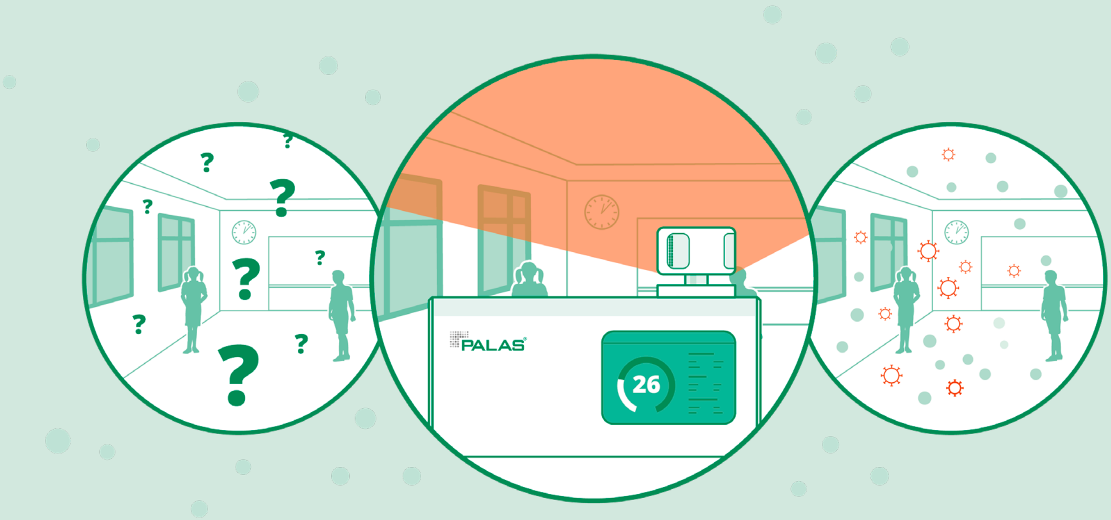


Aerosol spectrometer

Permanent monitoring of the air quality by the AQ Guard.

CONCLUSIONS

An interior room should always be supplied with fresh air in such a way that the attentiveness and well-being of those present are not impaired. For this purpose, the CO_2 content, temperature and humidity of the room air can be measured. However, aerosol-specific measurements are decisive for the hygienic assessment with regard to aerosols as carriers of infection.



These should be carried out and interpreted by authorized experts. In this way, effective air hygiene measures can be defined against the background of the actual building situation. The contribution of experts to infection protection goes far beyond general recommendations - and helps to avoid expensive bad investments.

go green
to breathe clean.

PALAS®

Palas® is a leading developer and manufacturer of high-precision devices for generating, measuring and characterizing particles in the air. With numerous active patents, Palas® develops technologically leading and certified fine dust and nanoparticle measuring devices, aerosol spectrometers, generators and sensors together with associated systems and software solutions.
Palas GmbH is a subsidiary of Brockhaus Capital Management AG, which is listed in the Prime Standard on the Frankfurt Stock Exchange (BKHT, ISIN: DE000A2GSU42).

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Effective January 2021

Technical features

Measuring principle (dust)	Single particle optical light scattering with evaluation of signal duration and shape, advanced mass conversion algorithm
Measuring range (dust)	PM_1, $PM_{2.5}$, PM_4, PM_{10}, TSP 0 – 20,000 µg/m³ Total number concentration C_N: 0 – 20,000 particles/cm³ Particle size 0.175 – 20 µm, Distribution in 128 size channels
Measuring range (gas)	Temperature: -20 – +60 °C Relative humidity: 0 – 100 % Pressure: 700 – 1100 hPa CO_2: 0 – 5,000 ppm TVOC: 0 – 60,000 ppb
Linearity (dust)	0.95 – 1.05
Accuracy (dust)	$R^2 > 0.98$ for $PM_{2.5}$ $R^2 > 0.94$ for PM_{10} (15 min. averages, vs. Fidas® 200)
Resolution (dust)	0.1 µg/m³
Zero point (dust)	0 µg/m³ based on 24 h average

Air sampling rate	1.0 l/min = 0.06 m^3/h
Response time (PM data)	Down to 1 s (user definable)
Interfaces	5“ high resolution color display with touch functionality USB, Ethernet, WiFi, 4G (optional)
Data storage	10 GB (internal)
Communication	UDP ASCII, ASCII/TCP, Modbus RTU, UIDEP, Bayern-Hessen Built-in web server for universal access
AirQualityIndex	Based on $PM_{2.5}$, PM_{10}, CO_2, TVOC
InfectionRiskIndex	Based on CO_2 and particle number concentration
Operating conditions	-20 – +50°C
Power	12 V ± 10 % DC, consumption: < 15 W (AQ Guard), PoE option 15 – 50 W (AQ Guard Ambient)
Weight	2.4 kg (AQ Guard) 3.9 kg (AQ Guard Ambient)
Dimensions (W • D • H)	280 • 140 • 175 mm (AQ Guard) 320 • 190 • 240 mm (AQ Ambient)