Leave no room for viruses

Aerosols contaminated with coronaviruses are a problem indoors. Supplying fresh air via open windows and thereby reducing the virus concentration often remains a pious hope. In the pandemic, old certainties in ventilation systems must therefore be reconsidered. A start-up has gained new insights in this regard as part of an interdisciplinary pilot and research project.

Interview performed by Stefan Schmid

In the experimental arrangement in the classroom at the school in Lenzburg, the air is extracted from the ceiling via tubes, which has advantages.

Nano Clean Air GmbH is testing a new ventilation system in a classroom of the Rudolf Steiner Special School in Lenzburg AG. The effect of ceramic filters against the corona virus is to be researched as part of a pilot project. The installed system is also intended to provide fundamental new insights into the design of ventilation systems and the handling of aerosols.

At the start-up, which has been active since spring 2020, specialists with many years of experience are working and researching. In an interview with Baublatt, Heinz Burtscher, physicist and professor emeritus at the University of Applied Sciences and Arts Northwestern Switzerland, and Andreas Mayer, mechanical engineer specialising in pollutant emissions, give their views. The research project is also supported by the Federal Office for the Environment and monitored by the Swiss Federal Commission for Air Hygiene.

Which filter systems for clean air in rooms are currently used primarily in buildings?

Heinz Burtscher: Apart from actual clean rooms or operating theatres and the like, the ventilation air in buildings is either not filtered at all or relatively coarsely filtered, primarily pollen filters. Small particles such as viruses or fine dust from road traffic are usually not removed at all. Fibre filters are mainly used for this purpose.

What are the basic types of filter technology used in ventilation systems?

Andreas Mayer: The filters are usually pleated 'papers' made of fine fibres like the intake air filters in cars. The quality of the filters is regulated by SIA and DIN standards. The highest classes are the High Efficiency Particulate Absorbing or HEPA filters, which achieve a separation of 99.999 per cent from a particle size of 300 nanometres. However, no standards are defined for smaller particles such as viruses with a size of 50 to 150 nanometres or soot particles, and very often these filters fail in the nano-meter range.


The nebulizer is used to spray saline particles. This simulates the mode of action and the spread of aerosols in the room

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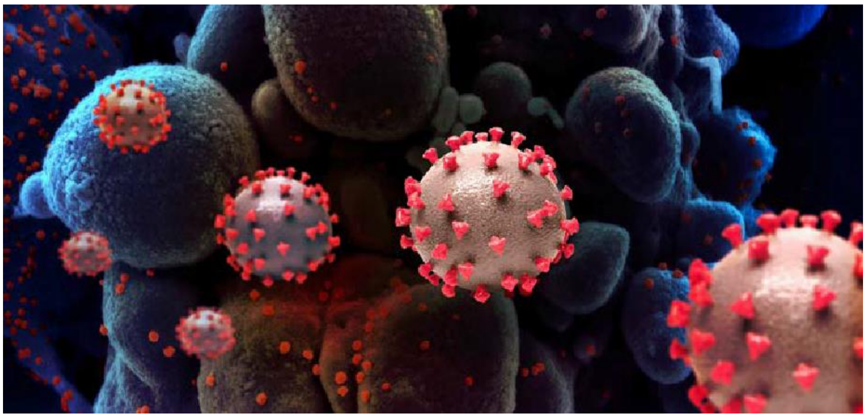
What are the differences here?

HB: The better the HEPA filters are, the lower the velocity of the air flowing through must be. In order to absorb the pressure drop, larger filters and more energy for the fans are needed. With the higher requirements, the installation space and the costs increase. The frequency of replacement also increases, because the filters cannot be cleaned.

What are the respective advantages and disadvantages of the different types of filter techniques?

HB: One advantage of simple filters with a certain degree of separation is the low counterpressure in the air flow. This is associated with low operating costs. The choice of filter is therefore always a compromise between efficiency, size and cost, depending on the situation due to the pressure drop.


Viruses are relatively simple in structure. They consist of one or more molecules, and they are sometimes surrounded by a protein coat.

What should be paid special attention to when it comes to filter technology for classrooms?
AM: If it is not only about filtering coarse dirt or pollen, the risk of infection with viruses must be considered. Here, a very small dose can cause infection with the coronavirus. In concrete terms a few 100 or 1000 viruses once. One must bear in mind that an infected person can exhale several million viruses per cubic meter of breathing air. This means that filters must be able to separate particles far below 1000 nanometers so that they cannot escape from the filter under any circumstances. Filters must therefore achieve a very high degree of separation, in any case more than 99 percent. Instead of a filter, viruses can also be deactivated with UV light. This can also achieve a very high efficiency with a relatively low pressure drop. However, this only applies to viruses. Fine dust entering from outside, for example from traffic, must be filtered effective

What does this mean for air circulation in rooms?
AM: In addition to the filters, the type of airflow also plays a very important role. This should be designed in such a way that there is as little lateral air exchange as possible from one person to another. If the air flows downwards from the ceiling, as is very often the case, exhaled viruses will be captured and distributed across the width. This immediately creates a risk of infection for all people in the same room. If the air comes from the window, this virus distribution mechanism is even stronger and you have to ventilate for longer time until the air in the room is replaced by the outside air through dilution. With mobile air purifiers, vortices and a horizontal air exchange also occur.

Bilder: zvg

How does the Nano Clean Air system differ from common solutions in air filtration technology?
AM: The Nano Clean Air system guides the air laminarly from the floor to the ceiling. Exhaled viruses are sucked upwards. This movement of the air flow is supported by body heat. At the ceiling, the air is sucked away over a wide area and fed to a nano-filter. The two essential elements are efficient nanofiltration and laminar displacement flow from bottom to top.

To avoid noise emissions as much as possible, the filter fan is located in an adjacent room. It generates the air flow in the ventilation system.

What can the filter technology of the Nano Clean Air do that conventional filter systems cannot?
AM: We use a completely different filter derived from the diesel particulate filter. This filter is specially built for the separation of nanoparticles. It uses the principle of diffusion and therefore achieves a separation efficiency of almost 100 percent even for very small particles of 10 to 100 nanometers. The development has led to this filter separating even the smallest viruses better than soot particles, 99.9999 percent were measured. For this purpose, we set up special test rigs at the beginning of the pandemic and conducted this research under the supervision of Swiss virologists at the University of Fribourg. In addition, the filter is very small, robust and insensitive to humidity and temperature. In addition, it has a low back pressure. Cleaning is simple and has been tried and tested in vehicles, and the service life is around 20 years. Viruses are completely de-activated in this filter within 48 hours. The filter comes from the large series and is correspondingly cost-effective. If problems arise with bacteria or fungi, which often form a kind of nest in conventional fiber filters, the ceramic

filter can be heated periodically for sterilization. The filters are scalable, and suitable for both lift cars and large rooms.

What is the new approach?

HB: The new approach is to realize air recirculation via laminar displacement by means of vertical flow and highly efficient filtration. In this way, four to six air changes per hour can be achieved. Because the heating heat is not dissipated with every air change, there is also a significant energy advantage. A little fresh air is still necessary to control the carbon dioxide content. But the air is nano-filtered and the heat can be exchanged with the exhaust air in the usual way.

How are possible germs and viruses filtered out?

AM: In the ceramic cell filter, the air must flow from one cell through the porous wall into the neighbouring cell. Therefore, this type of filter is also called a wall flow filter. The air then passes into the open air. The pores are on average only about 10 micrometres in size, and the speed is in the range of centimetres per second thanks to the very large inner surface area, so that all viruses reach the inner surface through Brownian motion. There they are bound very tightly by van der Waals forces. Because a biological host such as cells of humans or animals is missing, viruses cannot reproduce. Within 48 hours, viruses lose their activity and the danger of infection is averted.

To what extent do coronaviruses pose a problem in ventilation systems?

AM: Conventional ventilation systems usually work according to the principle of dilution and thus distribute the viruses in the environment of the infected person throughout the entire room. There is a risk of mass contagion. Such mass infections occurred on the cruise ship Diamond Princess or at the large slaughterhouses of Tönnies. But problem areas can also be aeroplanes, whose individual ventilation is expressly arranged completely wrongly, namely from top to bottom, which has led to the rapid worldwide spread of the virus - which is still denied by the industry, although it has been proven in numerous cases. The same applies to public transport.

Which aspects should be paid special attention to?

AM: No matter how frequent the number of air changes with good filtration of the circulating air is, it is insufficient if the immediate lateral contagion from person to person is not prevented. The fact must also be taken into account, that the air current carries the virus cloud along a long path. In such a case, people can be infected in rooms where no infected person has ever been before.

> **«The industry still often relies on systems that guide air flows from top to bottom.»**
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> ***Andreas Mayer,*** *mechanical engineer specializing in pollutant emissions.*

How often do the filters need to be replaced?

AM: From today's point of view, the cell filters used by the Nano Clean Air never need to be replaced, as they can be easily cleaned and disinfected. Fiber filters, as they are common today, cannot really be cleaned. They are replaced when they are dirty. This usually happens once a year or more. If necessary, they have to be disposed of as hazardous waste, which is costly. The loss of fibres caused by air currents can also be a health risk, depending on the material, dimensions and breakage behavior.

What precautions do the Nano Clean Air solutions take to ensure that germs and viruses are rendered harmless in the filter?

HB: The fine-cell structures of the ceramic filters can be equipped with virucidal and bacteriocidal coatings like conventional catalysts. Silver or copper coatings are possible. These technologies are already available. In addition, the ceramic filters can be periodically heated for disinfection purposes. Some of these ceramic materials have very good thermal conductivity.

What other challenges do air filtration systems face?

AM: The main reason for this is the resistance of the industry. The industry still often relies on systems that guide air flows from the top to the bottom. There is no rethinking. Incidentally, this is also the case with aircraft and railways. Moreover, it is not easy to make people aware of this danger, because the hazardous substance is not visible and cannot be smelled.

Moreover, it is not present everywhere all the time. Because it is difficult to detect viruses indoors, statistical estimates are sometimes used. So we are in the field of prophylaxis.

What new insights has the application at the Rudolf Steiner Special School in Lenzburg provided so far?

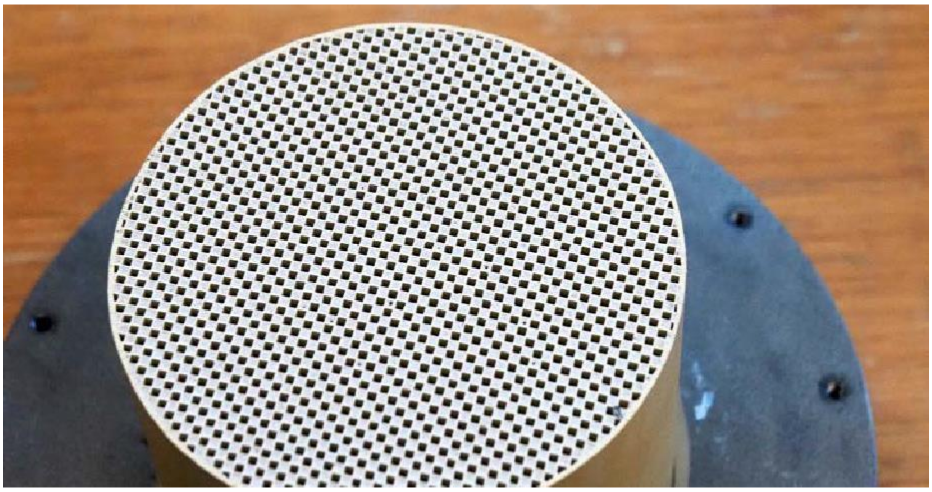
HB: Originally, we extracted the air above the tables with screens shaped like lamps. But we quickly learned that we had to extract air over a much larger area, especially from the very top of the ceiling. The decisive factor here is to design the extracted air flows laminar, so that vortex formation or lateral flow components can be avoided. This led to the solution with porous hoses, which is also cost-effective. Even better results could perhaps be achieved with porous ceilings, but that would probably only be possible with a new building. It was also important that we distributed particle sensors throughout the room and also measured the carbon dioxide levels. In this way, we achieved a high distribution of the cleaning effect step by step.

What are the most important conclusions?

A**M:** While the filter is already a standard element for us, which we know well, have validated in a specially built test stand and are available in all variants, the porous hoses or pipes are something new that can certainly still be optimised. Building physicists and architects will also have something to say about this.

Could the Nano Clean Air solution also be combined with other ventilation systems?

AM: This new ceramic cell filter or wall flow filter can actually be used in general, but will probably only be used in the upper quality segment, where really high separation rates for nanoparticles are required. The principle of vertical air flow from the bottom to the top does not necessarily have to be combined with circulation and a sophisticated filtering of the indoor and outdoor air, but then of course one loses important properties that are important for health and for the energy balance. This type of displacement ventilation can already be found in some lecture halls or concert halls.



Ceramic filters are suitable for use in ventilation systems because of the maintenance. Viruses are retained and lose their activity within 48 hours.

To what extent do you see fields of application in other areas such as hospitals and companies?

HB: Every company needs attractive meeting rooms for meetings with external persons, of whom it is not known whether they may represent a risk. Therefore, every company should be able to offer some virus-free rooms. This should become standard. The effort is no greater than in a classroom or in the waiting room of a doctor's office. In hospitals, there are numerous possible applications, for example in the area of hospital beds or during transport in lift cars. We should also consider the spatial situation in hairdressers' and dentists' surgeries, bank counters and shopping centres. In addition, public transport is also important for us. Ventilation systems should work according to the same principle everywhere. Because there is a suspicion that viruses can be caught there in just a few breaths if the concentration is high. One example is a small lift in a Chinese block of flats where 70 people have been infected who have never had any contact with the infected virus carrier. However, in the meantime, he was always riding the lift alone.

How has air filter technology changed fundamentally over the last 20 years?

AM: In our estimation, the greatest progress has been made in the area of exhaust gas filters. There are now around

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300 million of these on the roads all over the world, and the number is increasing rapidly. Their special feature is the high degree of separation of nanoparticles. The virus filters we use are derived from this new design. The major surge in the development of fibre filters is far behind. HEPA filters were first developed during the Manhattan Project because clean rooms were needed. With the advent of the semiconductor industry, the requirements were raised even higher, but little changed in the principle, except that static electricity was included with the electrostatic precipitators. They are most commonly installed in incineration plants and power stations.

What are the latest developments in this?

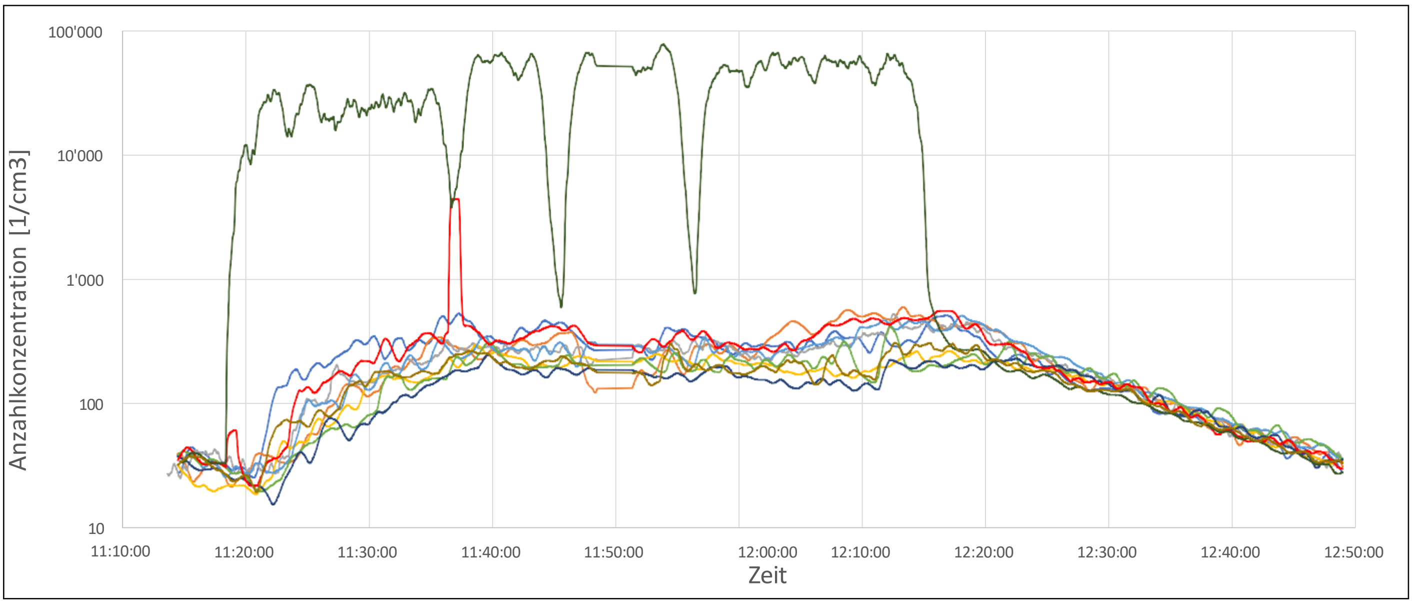
AM: In the true sense, it is these extruded ceramic cell filters that are now offered with cell densities of up to 300 cells per square inch.

What would be the new needs in filter technology and in which direction could further developments go in this regard?

AM: The decisive factor is that in the 1990s it was recognised, especially in the field of occupational medicine, that the smaller the pathogenic or inert pollutant particles, the more dangerous they are. Particles smaller than 500 nanometres penetrate the alveolar membrane and within a few hours pass through the brain barrier and the placental barrier and via other pathways, ultimately into all organs. The WHO has not yet implemented this. It still uses particle sizes of 2,500 to 10,000 nanometres for its limit value definitions, but drew attention to the significance of these ultrafine particles in its latest publication of September 2021. In the case of exhaust gas limits, the requirements for particulate filters in Switzerland were first reduced to a particle size of ten nanometres in 1998. In the meantime, this has been adopted by all industrialised countries except the USA. This realisation has still not been adopted in the standards for air filters in buildings. In general, the lowest particle size for which measurements must be taken is 300 nanometres, in some standards even 1000 nanometres, which completely underestimates the health risk. Impaction filters, which are smaller and cheaper, are still preferred to diffusion filters, which are needed for very small particles.

How much do you estimate it costs to retrofit a classroom with an efficient air filtration system?

HB: We cannot say for sure at this early stage. The cost of the components should be below 3,000 Swiss francs, in projects with several rooms probably below 2,500 francs, but the labour costs for the installation are difficult for us to estimate, and we are looking for cooperation partners in the industry. n



The diagram shows the concentration at the nebuliser (green curve) and at the individual desks (other colours). The nebuliser is switched on at 11:20 and switched off at 12:15. The concentration at the consoles is more than 100 times lower than at the source and approximately the same everywhere in the room.