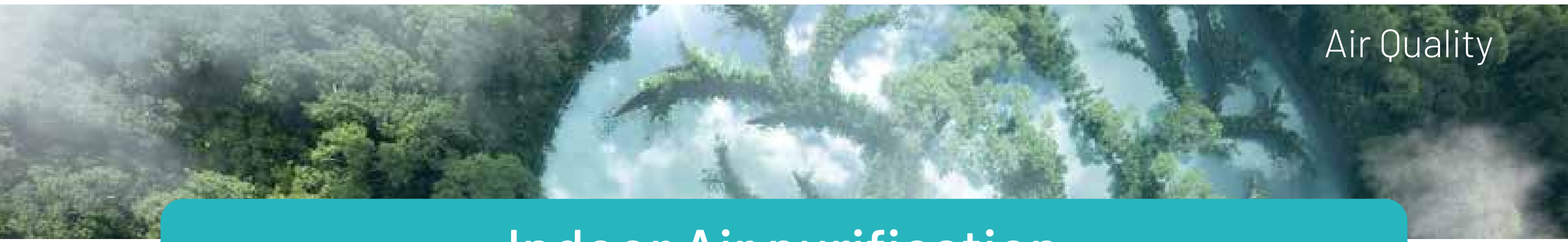

Indoor Air purification in the Fight Against Covid-19

Proceedings

June 1, 2020
Niel, Belgium

Acknowledgements

On June 1st 2021, the European Respiratory Cluster Antwerp (eu.reca) and VITO hosted an online symposium on 'Covid-19: the opportunities of indoor air purification as an additional layer of protection against airborne transmission of viruses'. Over the past year we have all learned to comply with the many measures suggested to keep our businesses and organizations at low Covid-19 risk. Social distancing, mask wearing and routinely disinfecting our hands have become our new way of life. Yet, one crucial element has long been overlooked: air. Coronavirus travels through the air in ultra-small droplets called aerosols. When we talk, cough, sneeze and even more when we sing or shout, these aerosols are dispersed throughout the room, potentially contaminating every person in their path at distances beyond 1,5m. By ventilating adequately we can dilute airborne infectious aerosols and reduce the infection risk indoors, this might prove challenging in windowless offices or small rooms in which several people congregate. In such situations it remains unclear how we can protect ourselves, our employees, our customers or our patients in the most effective way. VITO and eu.reca joined hands to inform you on (1) what is considered to be a safe indoor environment and (2) how ventilation and air purification can provide an additional layer of protection.

We are grateful to the expert speakers who participated in the event. In particular to dr. Marianne Stranger (VITO), prof. dr. Giorgio Buonanno (University of Cassino and Southern Lazio) and Mr. Hannu Salmela (VTT Technical research centre of Finland) who gave compelling presentations on ventilation & air purification, on assessing the airborne risk of Covid-19 and on existing air purification technologies, respectively.

Also many thanks to the other expert contributors in the panel discussion, namely prof. dr. Erika Vlieghe (University Hospital Antwerp - UZA), dr. Wouter Arrazola de Oñate (Association for Respiratory Health and Tuberculosis Control – VRGT), dr. Hanna Leppänen (Finnish Institute for Health and Welfare – THL), dr. Peter Wouters (Belgian Building Research Institute - BBRI), and Mr. Bart Boutmans (Flemish Agency for Care and Health – AZG).

Also, we are most thankful to our sponsors Vinçotte and VLAIO (SIRRIS/Agoria industry partnership).

▶ SUMMARY

At the start of the Covid-19 pandemic, most prevention guidelines focused on direct and near contact transmission of the virus, such as hand washing, cough hygiene and social behavior. It was not until July 2020 that the WHO recognized the possibility of airborne transmission of SARS-CoV-2. That is why measures to prevent this transmission route, such as wearing a mouth mask and increasing ventilation were eventually added

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to the internationally recommended prevention guidelines. In addition, air purification is now being considered an effective mitigation strategy, providing an additional layer of defense.

Like any other indoor air contaminant, airborne virus transmission should be tackled by a dedicated source reduction strategy, followed by an effective exposure reduction plan. Whilst source reduction in terms of Covid-19 implies limiting room occupancy and wearing masks, exposure reduction implies reducing the indoor concentration of airborne aerosols indoors, which can be achieved by ventilation or by means of air purification.

Although opening a window is the most obvious way to introduce fresh air into a building or room and thus reduce indoor levels of potentially infectious aerosols, it is not always applicable nor desirable, such as in winter, or in noisy, heavily polluted environments. Mechanical ventilation will in such case provide a constant and controlled supply of fresh air. Yet the majority of our buildings is not equipped with mechanical ventilation, and further, the capacity or performance of mechanical ventilation systems have been demonstrated to not always function in an optimal way. Air purification offer a solution in these cases, by filtration, captation or inactivation of infectious aerosols. However, it is important to carefully consider this case by case. Research shows that virus emissions increase dramatically from just breathing through physical activity to speaking loudly. In addition, ventilation systems and air purifiers perform differently and use different technologies. Therefore, room dimensions, occupancy and physical activity must be taken into account when assessing the risk of airborne virus transmission and consequently choosing the optimum mitigation solution.

In order to avoid a false sense of security, it is important to be able to correctly assess the impact of ventilation and air purification. Today, there are still some hurdles. In the case of natural ventilation, a sustainable, long-term implementation on a large scale is a challenge. With regard to mechanical ventilation both actual performance and maintenance are well-known problems. And in relation to air purifiers, it is necessary to get a better idea of their performances both inside and outside of lab chambers. In general one could conclude that although ventilation is now part of the guidelines, we are far from an effective implementation; the industry, the government, the public in general have to be educated on the determinants of safe indoor environment and how to obtain and maintain it.

New research, developments of new technologies and multidisciplinary collaborations are necessary and will lead to innovative solutions for better indoor air quality at an affordable price. Due to the Covid-19 pandemic, there is political and societal support to create a paradigm shift include wellbeing into a crucial parameter when judging an indoor environment in addition to thermal comfort and energy efficiency.

▶ WEBINAR COMPONENTS

The webinar consisted of 2 main parts, being an informative session with 3 lectures and a panel discussion.

Lectures :

"Lessons learned from the current pandemic related to a healthy indoor climate." **Dr. Marianne Stranger (VITO, indoor air quality expert)**

"How Covid-19 spreads through the air: understanding the transmission to mitigate the risk." **Prof Dr. Buonanno (University of Cassino and Southern Lazio, professor of applied thermodynamics)**

"An overview of the existing air purification technologies and the scientific evidence in view of Covid-19." **Mr. Hannu Salmela (Technical Research Centre of Finland, research team leader clean air solutions)**

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Panel :

In the second part of the webinar, a panel discussion followed on different mitigation strategies for the reduction of airborne transmission of SARS-CoV-2, including ventilation and air purification. Members of the panel were the key note speakers with the addition of prof. dr. Erika Vlieghe (University Hospital Antwerp, Chairman GEMS expert group, Belgium), dr. Hanna Leppanen (Finnish Institute for Health and Welfare, Finland), dr. Wouter Arrazola de Oñate (VRGT, Belgium), Mr. Bart Bautmans (AZG, Belgium) and dr. Peter Wouters (BBRI, Belgium). This debate was moderated by dr. Marianne Stranger.

▶ INTRODUCTION by Jade Verrept, coordinator of eu.reca.

In her welcome word, Jade Verrept, cluster manager at the Science Park of the University of Antwerp and coordinator of eu.reca, introduced the European Respiratory Cluster Antwerp (eu.reca) as a young ecosystem that focuses on everything that affects the human lung. By bringing together scientific and medical experts, entrepreneurs and other stakeholders, eu.reca enables the advancement of respiratory innovations.

During the Covid-19 pandemic eu.reca has had ample opportunity to play its part as a multidisciplinary network, hosting round table discussions on both vaccine and treatment development. But from the onset of the pandemic many eu.reca stakeholders expressed a concern regarding the underestimation of the risk of airborne transmission. Therefore in June 2020, eu.reca hosted a symposium on airborne transmission of the SARS-CoV-2 virus, presenting evidence and trying to steer the debate towards the importance of mask wearing, adequate ventilation and air purification as mitigation strategies for this transmission route. This symposium was one of the reasons why in Belgium the administration released guidelines for sensitive populations such as schools emphasizing the importance of ventilation and insisting on the use of CO_2 measuring devices. With regard to air purification the general position back then was that further research was necessary to indicate the effectiveness of technologies and devices, to demonstrate the absence of any harmful side effects and to be able to issue clear and unambiguous guidelines with regard to the use of such devices, necessary to avoid a false sense of security.

In May 2021 the Belgian federal government took steps however to not only validate the added value of air purification in the fight against Covid-19, but to actually regulate the use of air purifying technologies based on guidelines by the Supreme Health Council. It is highly commendable that the government is trying to create a framework that facilitates the safe and correct use of air purifying devices. Yet the work is not done. It is necessary to further investigate and validate other air purifying technologies, but also to harness new insights and update recommendations in total transparency. It is also necessary to educate and further advise and guide the public. How to use air purifying technologies? What is their impact on other Covid-19 mitigation strategies? When to best use them? What technology to choose? How to do maintenance? It is important that people understand the basic principles of a safe indoor air climate, as it is impossible to write guidelines that ensure safety in each and every circumstance. People should be able to correctly assess the risks.

And last but not least, it is essential to use this pandemic as a leverage towards a broader and sustained healthy indoor air strategy. Ideally, achieving and maintaining indoor air quality should be part of every company's global workplace prevention plan.

For eu.reca the aim of this webinar is to provide insight, to create awareness and to keep the importance of healthy indoor air high on the agenda.

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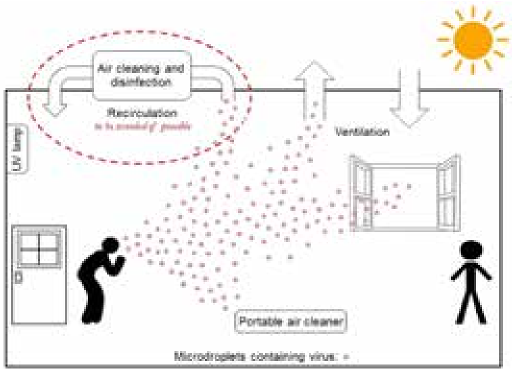
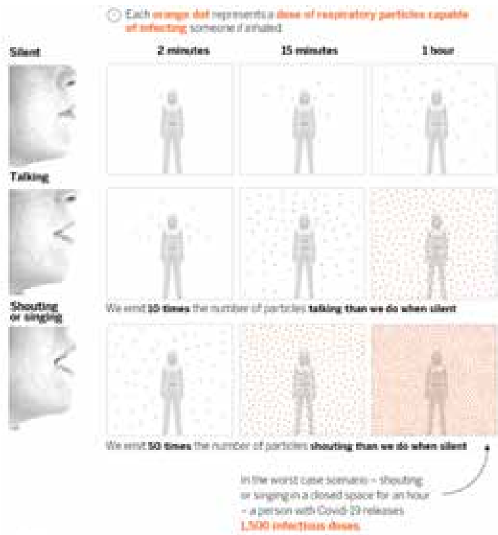
▶ LESSONS LEARNED FROM THE CURRENT PANDEMIC RELATED TO A HEALTHY INDOOR CLIMATE by dr. Marianne Stranger, VITO, Belgium

At the beginning of the pandemic most prevention guidelines focused on reducing contact transmission of the virus, stressing the importance of social distancing, hand washing and cough etiquette. It was not until July 2020 that the WHO reluctantly recognized the possible risk of airborne transmission of SARS-CoV-2, resulting in additional guidelines related to mask wearing and adequate ventilation.

During the previous eu.reca webinar, specifically on the risk of airborne transmission, prof. dr. Lidia Morawska (QUT, Brisbane Australia) discussed the principles of airborne transmission and the evidence at hand related to SARS-CoV-2. A recently infected person may emit up to 105 viral particles/min with particle sizes that vary between 0,01 µm - 100 µm and larger. The largest particles fall down as droplets, while the smallest particles remain suspended in aerosols, effectively giving them the status of indoor air pollutants. *(Figure of Morawska et al. Environment International Volume 142, September 2020).*



When discussing indoor air quality, major factors are the outdoor air quality and the ease with which outdoor air can flow into a building. This air flow can occur naturally, through windows and other openings in the building, or be mechanically induced with the help of an HVAC system. Another major factor to take into account are the sources of indoor air pollution. Think of pollutants emitted from furniture, building materials and consumer and cleaning products. The basic principles to ensure a healthy indoor air climate are simple: (1) source reduction, in other words avoid materials or products that gas out potentially hazardous pollutants and (2) exposure reduction, in other words ventilate according to use and occupancy of the room. The question is whether these principles can be applied to the current pandemic? The answer is yes. In the case of Covid-19 the source of indoor pollutants that impact indoor air quality is not of a material, but of a human nature. How then to achieve adequate source and exposure reduction? Source reduction can be achieved by wearing a mask, by limiting room occupancy and by controlling indoor activities, the latter because virus emissions vary according to the activities. *(Figure of El Pais, designed by Prof Jimenez)*



Exposure reduction can be achieved through adequate ventilation, which can be monitored by measuring CO_2, a good indicator for the accumulation of indoor air pollutants and indirectly related to the risk of infection. The higher the indoor CO_2 concentration, the higher the volume of air you are literally rebreathing, exposing you to air and particles exhaled by someone else and thus increasing your infection risk. It is therefore important to keep the CO_2 level low. In Belgium, the recommended indoor CO_2 is ≤ 900 ppm, which can be obtained by ensuring ventilation at a rate of 40m^3/h of fresh air per person. However, it must be emphasized that, even with the application of these principles, the infection risk indoors will never be 0%. *(Figure by Rudnick and Milton Model, 2003).*

CO_2 concentration	Rebreath fraction	Probability of infection
1200 ppm	2,1%	29%
900 ppm	1,3%	18%
600 ppm	0,4%	5%

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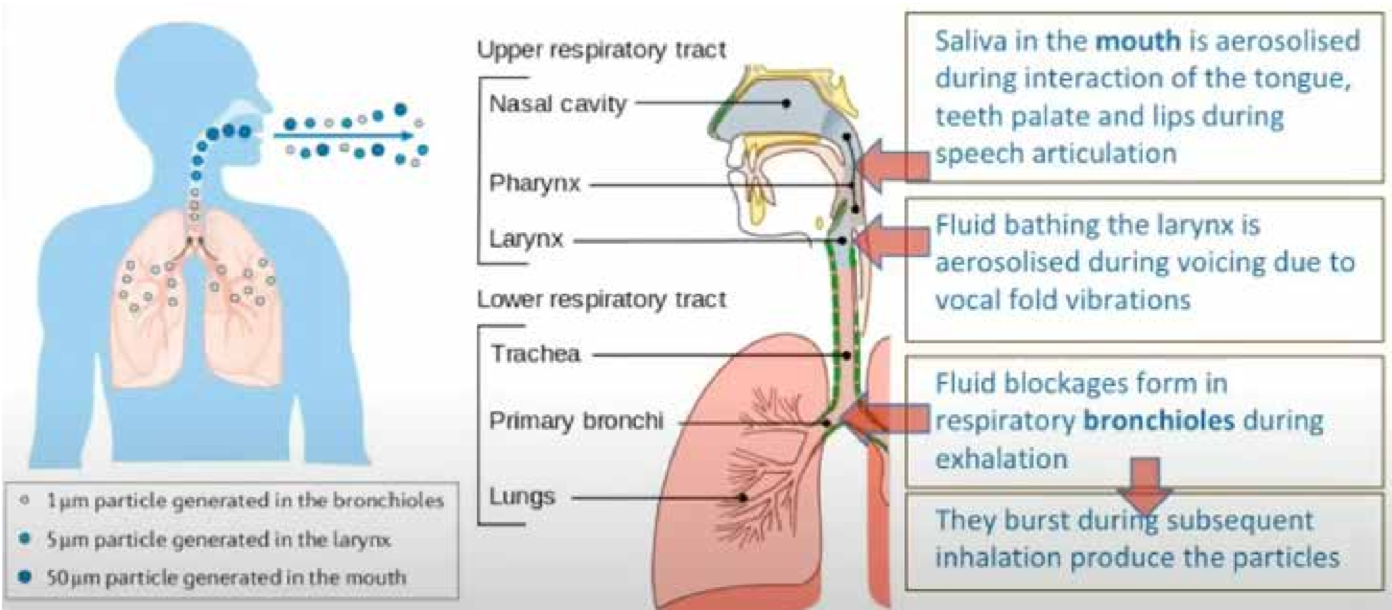
Finally, it is possible to further reduce the levels of infectious aerosols by using air purifiers. There are various methods of air purification. It is possible to (1) capture or filter infectious aerosols, effectively taking them out of the air or to (2) inactivate or destroy them, leaving them in the air but rendering them harmless or to (3) capture and destroy them. Regardless the method, an air purifier can only be effective when it has a Clean Air Delivery Rate (CADR) that can be tailored to the size of the room, its occupancy and the planned activity. Also, you want to make sure that the device does not emit undesired by-products and that it is properly installed, located, used and maintained. As air purifiers do not lower indoor CO_2 and their impact can therefore not be measured by monitoring CO_2, it is important to choose a solution that can demonstrate effectiveness and efficiency. As a general rule, ventilate first and purify when and where necessary using a validated system.

▶ HOW COVID-19 SPREADS THROUGH THE AIR: UNDERSTANDING THE TRANSMISSION TO MITIGATE THE RISK by Prof Dr Giorgio Buonanno, University of Cassino and Southern Lazio, Italy

During exhalation activities, particles are formed when an airstream passes the surface of a liquid at a sufficiently high speed. These surfaces are located in the respiratory tract, more specifically in the respiratory bronchioles, the larynx and the mouth.



Morawska and Buonanno, *Nature Reviews Physics*, https://doi.org/10.1038/ s42254-021-00307-4

All breathing activities generate particles, but vocal actions give the highest emission. The majority of the formed particles are < 1 µm and the vast majority < 10 µm and are therefore light enough to remain suspened in the air for a long time. Airborne transmission of the SARS-CoV-2 virus occurs through inhalation of infectious particles. In the vicinity of an infected person, the concentrations of infectious aerosols or droplets are high, and a short exposure time is sufficient to inhale the infectious quanta, being the infectious dose capable of infecting with a probability of 63%. Further away from the infected person, concentrations are lower, and a longer exposure time is needed to inhale the same quanta. The norm is to respect a distance of at least 1.5m from a speaking person.

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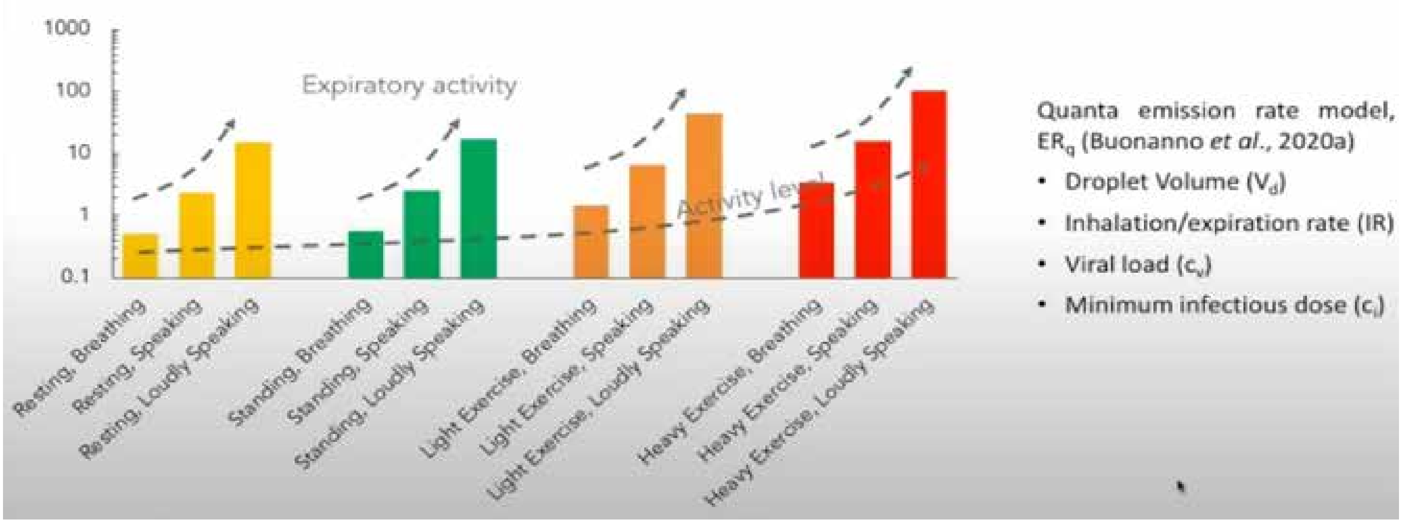
Recently, Prof Buonanno's team presented the results of a study to estimate the viral load emitted by a contagious subject on the basis of the viral load in the mouth, the type of respiratory activity (e.g. breathing, speaking, whispering), respiratory physiological parameters (e.g. inhalation rate), and activity level (e.g. resting, standing, light exercise). This information is key to engineers or indoor air quality experts trying to simulate the airborne dispersion of disease in indoor environments. The study shows a 10-fold increase in the quanta emission rate between breathing and speaking and another 10-fold increase in the case of loud speaking. In addition, there is a high quanta emission rate during heavy exercise compared to resting.

$$ER_q = c_v \cdot c_i \cdot IR \cdot V_d = c_v \cdot \frac{1}{c_{RNA} \cdot c_{PFU}} \cdot IR \cdot V_d$$



The approach was then extended to several respiratory pathogens, several viruses and tuberculosis. A first step approach to quantify the probability of infection due to the exposure in a micro-environment where a SARS-Cov-2 infected person is present, has been developed based on (1) the evaluation of the quanta emission rate, (2) the evaluation of exposure to quanta emission in the micro-environment, (3) the evaluation of the dose of quanta received by an exposed, susceptible subject, (4) the estimation of the probability of infection on the basis of a dose-response model. The findings in terms of quanta emission rates were then adopted in infection risk models, which can be applied in a variety of settings, such as classrooms, restaurants, and gyms.

An Airborne Infection Risk Calculator (AIRC), based on this risk model, has been developed by Prof Buonanno's group in collaboration with the Queensland University of Technology in Brisbane, and the CT University of New York. Interesting about this model is not only that it can assess risks, but also that it can be easily adapted to any respiratory disease or Covid variant, as long as virologists are able to determine the infectious dose. The results of the simulations clearly show that good ventilation plays a key role in containing the virus in indoor environments. To demonstrate this approach, 2 settings were discussed.

First the risk infection in classrooms was discussed. The team (Stabile et al, 2021) worked according to the following methodology : (1) different scenarios were defined such as an infected teacher vs. an infected student or speaking vs. loud speaking. Also different mitigation solutions were simulated; (2) the team then applied virus and CO_2 mass balance equations; (3) the road of the application in the paper was from quanta concentration to the risk (R) and then to the reproduction number of the event; (4) and finally the condition to be guaranteed was the reproduction number of the event < 1.

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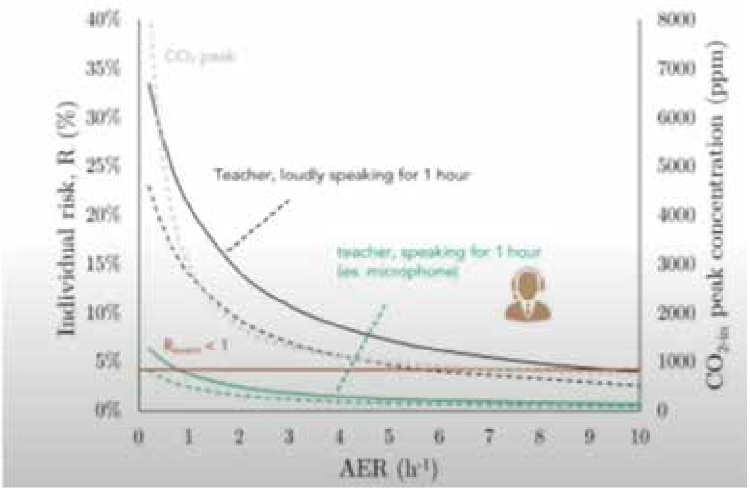
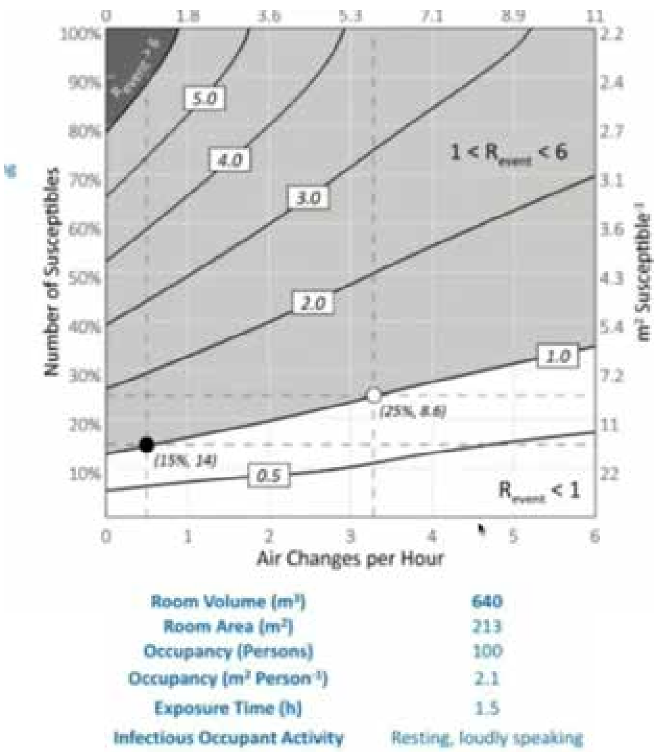
Reducing the risk to acceptable levels with ventilation alone, leads to a high and inconvenient value represented by the black line in the figure below, where you would need an Air Exchange Rate (AER) of over 10 volumes an hour. An integrated approach on the other hand, for example by mitigating emission by using a microphone, would have the advantage of a limited AER (see the green line).

In order to reduce the virus transmission potential, air procedures were defined. In this particular case (natural ventilation), feedback control strategy was included and the design parameter was not just the AER, but also Revent <1 (the event reproduction number less than 1), which informed scheduling of the manual airing procedures. These were continuously checked and if necessary rescheduled by monitoring CO2 concentrations. The monitoring allowed for evaluation of the actual ventilation rate during the airing cycles and inform problem adjustments to the airing period.



The same approach was applied to restaurants; critical micro environments because of the high emission as a result of load speaking, the large crowd and the high exposure time. As seen in the figure below, also in this case a high ventilation rate is required to reduce the risk. The reproduction number is higher than 6 (!) with natural ventilation. An AER greater than 12 volumes per hour would be required for a reproduction number less than 1. It is difficult in such a setting to dramatically reduce the source emission, but an important factor will be the number of vaccinated people. If 80% of the people is vaccinated, you can reduce the number of susceptible persons to 20% and a ventilation rate of only 3 is then required to maintain our life style.



These findings as well as the recognition that Covid-19 is an airborne infection, led to an international call demanding universal recognition that infections from airborne viruses like Covid-19 can be prevented through improving indoor ventilation systems. In the journal Science, 40 researchers from 14 countries called for a 'paradigm shift', demanding the WHO to extend indoor air quality guidelines to include the control of airborne transmission of respiratory infections by changes in ventilation standards. In order to be effective, flexible ventilation systems are necessary, dependent on the buildings purpose. Ventilation airflow rates must be controlled by the number of occupants in the space and their activity. To date, the focus of engineers has been primarily on energy efficiency, thermal comfort, odor control and other issues, but preventing respiratory infections was neglected. When we open a water tab we do not have to worry about transmitting disease; it is high time to start thinking the same about the indoor air.

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▶ AN OVERVIEW OF THE EXISTING AIR PURIFICATION TECHNOLOGIES AND THE SCIENTIFIC EVIDENCE IN VIEW OF COVID-19 by Hannu Salmela, Technical Research Centre of Finland

Different technologies are used in air cleaners as indicated in the figure. Only mechanical filtration, electrical filtration and ionization remove particles from the air, while optical radiation targets the inactivation of bioaerosols. Mechanical filtration is an established technique with a high Clean Air Delivery Rate (CADR), but which requires a lot of energy. Likewise, for electrical filtration, which has the added disadvantage of requiring more maintenance. It also should be noted that removing SARS-CoV-2 from the air with filtration techniques is challenging as most filters, including HEPA filters, are less efficient in capturing the individual virus as its size is only 0,1 µm. Once the virus is part of an expiratory droplet, it is part of a larger particle which can be stopped by various filters. Optical radiation is less efficient because the air velocity through the device is often high, limiting the exposure time to the pathogens which is needed to destroy them.

Technology	Main impurity
Mechanical filtration (fibre filtration)	Particles
Electric filtration	Particles
Adsorption (e.g. active carbon)	Organic and inorganic gases
Optical radiation (e.g. UV)	Bioaerosols
Photocatalytic oxidation	Organic and inorganic gases
Plasma	Organic gases
Ionization	Particles
Ozonation	Organic gases
Botanic plants	Organic and inorganic gases

Technology	CADR (Clean Air Delivery Rate)	Energy consumption	Byproducts (e.g. ozone, UFP, HCHO)	Cost vs. performance
Mechanical filtration	+ ... +++	+ ... ++	+++	++ ... +++
Electric filtration (ESP)	++ ... +++	++ ... +++	0 ... ++	++ ... +++
Optical radiation (UV)	0 ... +	+	0 ... ++	0 ... ++
Air ionisers	0 ... +	++	0 ... +	0 ... +

Finally, air ionisers have low CADR efficiencies and require energy. Some techniques produce by-products, but this can be tolerated with the implementation of additional solutions such as gas filtration, lamp coatings or low-emitting solutions.

There are also several standard test methods for air purifiers, but only a few are suitable for purifying air from microbes. In a study by Curtius et al, 2021, testing 4 air purifiers, it was shown that air purifiers can be an appropriate measure to significantly reduce the risk of the airborne transmission of SARS-CoV-2. For a 2-hour stay in a confined space with a highly infectious person, it was estimated that the inhaled dose is reduced by a factor of six when using air purifiers with a total AER of 5.7 h-1. A study by Salo Satu, 2020, showed that another air purifier, type Genano 5250M, is efficient in eliminating viable microbes in the air in a 30m^3 pilot scale room. This room was contaminated with aerosols containing a microbial mixture, including the MS2 virus, which is considered a surrogate for coronaviruses. Subsequently, the number of microbes was analyzed as a function of time and this in both settings, respectively with and without the use of the air purifier. Also the IQAir Cleanroom 250 air purifier's effectiveness was confirmed in a test report showing a 99,9% reduction of airborne viruses in less than ten minutes in a room of nearly 30m^3.

Although these are promising results of air purifying techniques, there are some important considerations and concerns. First of all, it is important to think about the positioning of the devices in the room as well as the number of air purifiers per room, which may vary depending on the size of the room, the required CADR, etc. Moreover, it is important to weigh the efficiency of the different techniques against the cost of the required devices as well as their energy consumption. Finally, portable indoor air purifiers efficiently reduce the indoor air particulate matter (PM2.5) by 40-82%, but few health improvements could be demonstrated

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in mainly healthy adults. The WHO suggests careful thought should be given to indoor air filtration and recirculation during the pandemic, but in areas where outdoor air pollution is high, this may be better than increasing ventilation rates. (WHO, Roadmap to improve and ensure good indoor ventilation in the context of COVID-19, 2021)

▶ PANEL DISCUSSION ON THE IMPORTANCE OF AIR PURIFICATION TO REDUCE THE RISK OF AIRBORNE TRANSMISSION OF SARS-CoV-2

In order to start the discussion on ventilation and air purification as a preventive strategy to combat Covid-19, the following three remarks must be made. Firstly, the fight against Covid-19 is not only about ventilation and air cleaning. Social distancing, wearing masks, hand and cough hygiene, vaccination and all other preventive measures are equally important. Secondly, the transmission risk will never be 0%, but the risks can be assessed and reduced by taking appropriate combinations of mitigation strategies. Thirdly, the quality of the indoor air is related to the quality of the outdoor air, which of course is a topic of necessary improvement as well.

When the discussion is specifically about indoor air quality and airborne transmission of SARS-CoV-2, the general consensus is that ventilation, either naturally or mechanically, is the most important first line of defense in reducing the airborne transmission risk. Though natural ventilation has the obvious advantage of being easy to obtain, disadvantages are that it is not very energy efficient, not always comfortable, invites outdoor air pollutants into the room and difficult to maintain over a longer period of time. Therefore, mechanical ventilation might be the more interesting choice, though recirculation – often integrated to ensure energy efficiency – has to be avoided, because it further disperses pollutants throughout the building.

Dr. Hanna Leppänen and Mr. Hannu Salmela shared their opinions on the effectiveness of air purifiers in reducing the impact of the airborne transmission of SARS-Cov-2. Dr. Leppänen indicated that in Finland mechanical filtration with HEPA or ULPA filters and adsorption (e.g. an activated carbon filter) to remove particulate impurities (including viruses) is generally preferred, as it is both effective and has the added benefit that these techniques do not generate any hazardous by-products. What you have to take into account when using air cleaners is that the air flow from the air cleaner should be set according to the basic ventilation of the space, with a general rule of thumb being that it should be approximately 2 times greater than the supply air flow. Also important is a sufficiently high CADR. A thing to avoid is a bypass in the air cleaner; all the air should always pass through the filter. Dr. Leppänen went on to stress that the number of air cleaners should be chosen in function of m^3 of the room, and that all corners of the room should be acknowledged. The difficulty here is that both number of purifiers and their placement are very case dependent. And finally, regular maintenance and filter changes are crucial. Dr. Leppänen went on to explain that the problem with certain techniques is that they produce hazardous byproducts such as ozone. This is not necessarily a problem if the manufacturer can prove based on independent and validated research by a trustworthy laboratory that these byproducts or secondary impurities do not exceed any thresholds. Techniques that should be approached with such caution are (1) electronic filtration that can generate charged particles and new contaminants such as ultra-fine particles and ozone, (2) ultraviolet radiation that can generate ozone and secondary impurities, including aldehydes, (3) plasma methods that can generate nitrogen oxides and ozone and (4) photocatalytic oxidation that can produce e.g. formaldehyde and acetaldehyde. The use of Ionizers, or air ionizers, is not considered suitable for virus control by the Finnish Institute for Health and Welfare, because they do not remove the virus from the air.

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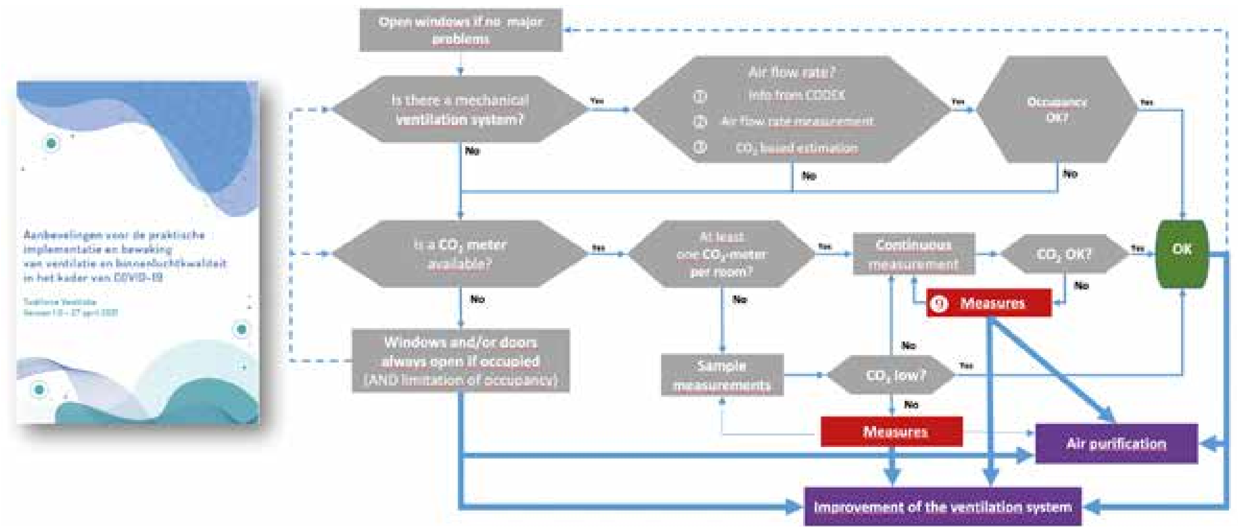
Mr. Hannu Salmela added that in his opinion the advantage of air purifiers is that they are a "fast track tool" in strategies towards more healthy indoor premises, offering (1) a readymade solution for poorly ventilated spaces or places where a permanent installation is not feasible or (2) a temporary solution before ventilation renovation. With regard to remaining hurdles, Mr. Salmela stressed that there is still a lot of uncertainty related to Covid-19, also with regard to air transmission. Important, but unclear for instance is the target level to reduce the exposure. Another part of the discussion that wasn't touched upon thus far is the monetarization aspect; how much we are ready to invest after Covid-19? Are people prepared to make a paradigm shift and effectively invest in clean air?

In the fight against tuberculosis (TBC) that paradigm shift has already been made a long time ago, explains Dr. Wouter Arrazola de Onate. The measures now promoted are very similar to measures that have been taken in the prevention of TBC for many years. Like SARS-CoV-2, tuberculosis is a respiratory disease caused by an airborne infection. About 120 years ago, Europe was hit by a tuberculosis pandemic, causing accumulatively 1 billion deaths. The VRGT, established in Belgium in 1947, has extensive experience in preventing TBC, relying strongly on 'light' and 'air', in other words making use of UV and ventilation. Modern medical wards dealing with infectious diseases are equipped with ventilation, filtration and UVC equipment to ensure safety, but a case by case approach is always necessary to determine what devices should be used and where they should be placed. In a new facility devised for patients suffering from multidrug resistant TBC, VRGT opted for a building with a lot of natural ventilation, a mechanical ventilation system ensuring 12 ventilation rates per hour and large windows to ensure natural light. From the very start, in March 2020, VRGT was pointing out to governments that they were convinced that Covid-19 was also transmitted by aerosols and droplets and insisted on the importance of ventilation and sunlight (UV) in the fight against Covid-19.

In relation to the risk of airborne transmission prof. dr. Buonanno proceeded to state that it is not possible in an indoor environment to obtain 0% risk. However, he went on to state that luckily it is now possible to better assess the risks; risks that can be mitigated with a multidisciplinary approach. In doing so, one should always start from the emission and focus on ventilation as a next step. The ventilation should be driven by the mitigation of the transmission of respiratory diseases, not only by energy of thermal comfort. The indoor environment should be managed to mitigate the risk through the multidisciplinary approach, in which ventilation is one of the key aspects. Mitigating the risk also means reducing exposure time or reduce the number of occupants in a room. It is possible to create the outdoor safety indoors, as we have the insights; capabilities and technologies that can help us create and manage safe indoor spaces.

The next panel member, dr. Peter Wouters of the Belgian Building Research Institute, is an important contributor



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to the Belgian national guidelines that were released with regard to ventilation in the fight against Covid-19. He is part of the Corona Commissariat that was created to assist various governments in terms of preparing and implementing Covid-related measures. Recently one of the task forces within the Commissariat released a rapport "Recommendations for the practical implementation and monitoring of ventilation and indoor air quality in the framework of Covid-19" (Taskforce Ventilatie, 27 april 2021) that included a practical schematic to help people determine what measures they should take to create a safe indoor air environment.

Two types of measures were included: ventilation and air purification. As a rule of thumb dr. Wouters stressed that with regard to ventilation what you do is basically add additional outdoor air that will dilute the virus concentration in the room. The parameter to monitor therefore, is the amount of outdoor air/m^3 that you can naturally or mechanically add to the room. With regard to purification the parameter to monitor is the CADR, for the device will filter/ capture or inactivate the virus. The CADR will allow you to evaluate the impact of an air purifying device. Interesting to know is that the American association AHAM has listed the CADR of several air purification devices. With regard to the effectiveness of the technology the government is setting up a database to be able to assess both safety and efficiency.

Prof. dr. Buonanno again stressed the importance of a multidisciplinary and nuanced approach. As an example he indicated that CO_2 in and of itself is a flawed parameter in order to understand the ventilation necessity, because a person breathing or speaking will roughly emit the same amount of CO_2 but the emission of the quanta of the viral load will be completely different. The choice for the right ventilation or correct air purifier has to take into account the characterization of the source and the dynamics of the environment. A simple parameter like CO_2 will be insufficient.

Prof. dr. Vlieghe agrees that a multidisciplinary approach is necessary. At the start of the pandemic the preference was given to drastic measures with a direct impact, followed by measures with regard to mask wearing and ventilation, the latter being not the easiest strategy to adopt in larger spaces with many people. It is necessary to share information, best practices and experiences between stakeholders such as physicians, engineers, governments and others. Implementing efficient ventilation strategies has not been easy in public transport, schools, hospitals and so on. Thanks to the multidisciplinary approach and the lobby work of stakeholders the importance of ventilation is now part of the debate. It is important to measure, to gather information and to learn how to better ventilate and take other measures.

The Flemish agency of Care and Health works on the edge where health meets environment. They promote and protect the health of the population. With regard to air quality over the past year the focus was mostly on outdoor air. And when looking at indoor air, most attention was devoted to chemical and physical contaminants. Until of course SARS-Cov-2 emerged. Legislation regarding indoor environments did not deal with viral pathogens either. The challenge is to integrate the new insights on biological contaminants into the existing legislation, but also focus on the bigger picture of which the codex of occupational health, the legislation on product safety and building materials (of which air purification is part) and legislation with regard to quality of housing and energy efficiency is all part. It is a big puzzle that has to be put together in a balanced way, keeping in mind the biological, chemical and physical environment. Also with regard to implementation it will be necessary to focus on practical aspects such as education, maintenance and so on. This will not be easy, as it is in part location specific. It will be necessary to educate industry, government but also the public. Doing things outside is a solution as well, but it requires a shift in mentality.

In conclusion, it is clear that good air quality, free from physical, chemical and biological pollutants, is a right for all people. Ventilation and air purification are part of the solution, but there will also be new technologies to guarantee clean air at an affordable price. Thanks to the Covid-19 pandemic, this right to clean air has become a higher priority for both society and politics.

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QUESTIONS AND ANSWERS

Why ventilation first, purification second? Ventilation is the strategy that allows for better monitoring. CO_2 gives a good indication to what extent ventilation contributes to the dilution of virus emission. This is more difficult with regard to air purifying or air cleaning – more difficult to measure efficiency. Yet by supplying fresh air, all indoor-related air pollutants are being diluted. But again CO_2 is just the one parameter. It is important to have an integral approach focusing on ventilation, purification, reducing numbers indoors, wearing masks and so on. It is possible to be energy efficient and create a healthy air climate. We can estimate risk in each scenario and find different solutions regarding the needs ; the situation can be managed and air purifiers are a key aspect. It is about balance.

Is there a comparative review of devices that takes into account life cycle cost, maintenance, acoustics, in short all aspects related to choosing a device? At this stage, there are no studies available. More research is necessary. From a buyers perspective this is not evident.

If we avoid contact with pathogens, will this not have an impact on the immune system. Will we weaken ourselves? On the one hand, we will never have zero contact with pathogens, viruses will have many opportunities to pass from one person to another, depending of course on one's lifestyle. But there are studies on microbiome indicating that rectal swaps in Vietnam included more bacteria, than comparative swaps in Sweden. So creating a purer indoor air climate will probably have an impact, but probably not to an extent that it would weaken immunology.

Should we not pay more attention to IAQ when constructing renovating? Should government not stimulate this more? Yes, absolutely. Researchers have been promoting ventilation for a long time. But other aspects such as energy efficiency have been higher on the agenda. Within IAQ respiratory viruses have not been included in many studies, because they are difficult to measure. In 2006 the obligation for ventilation systems came into force as part of the Energy Performance Building Directive (EPBD). In 2016 ventilation has been required to be measured in new dwellings. This year a proposal for a resolution was submitted in Flemish Parliament regarding ventilation. The European Commission is doing a feasibility study into the inspection of HVAC. So there is a growing recognition of the problem, but it takes time; both political and societal support are essential.

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