

The book accompanying
the podcast, with
numerous illustrations



Sven Rentschler

Misconceptions in ventilation technology and air pollution control



+ E CONSULTING PLANNING

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Comments on the podcast

The response to the podcast was so great that it was almost inevitable that it would be turned into a book. Feedback that speaks for itself:



"... the podcast on air currents made me curious for more ..."

"... I would like to congratulate you on the interesting podcast 'Misconceptions in ventilation technology and air pollution control' and thank you for the information..."

interesting podcast. Via , a continuation would be greatly appreciated. I have been a project manager in ventilation technology for over 20 years and have been able to take away a lot for practical use and further projects. I would be delighted if I could build your next kitchen system ..."

"... I would like to congratulate you on the podcast. The topic is very easy to understand, even for people like me who are not so familiar with the subject matter ..."

"... As an avid listener to your podcast, I would like to take this opportunity to order the reference book announced for 2023. I look forward to further episodes on the topic of air – our most precious commodity ..."

Acknowledgement

I would like to express my special thanks to Gabriele Wiedemann and Eva Schwarz. I have been working successfully with both service providers for many years. Over a decade ago, this collaboration resulted in a product catalogue for our company, REVEN GmbH, which dealt with the same topics as this book. We have also realised other projects with this team, such as the successful implementation of our company website. The experience we gained during these projects has contributed significantly to this book.

Ms Wiedemann's graphics and Ms Schwarz's text corrections are based on many years of shared experience and form the backdrop for an unparalleled understanding of the subject matter. Working together on this book was a pleasant and straightforward experience, resulting in a product that I could not have achieved on my own.

I would also like to express my special thanks to our shareholders at the SCHAKO Group, who supported the project of writing a book from the very beginning and recognised the opportunity to reinforce our group claim, "Pure competence in air."

I would also like to thank my colleagues Holger Reul, Sascha Kess and Vitali Lai for all the stimulating discussions on the topics of ventilation technology and air pollution control over the past years, which provided me with a great deal of inspiration for this book.

I would be delighted if we could continue to discuss and explore the topics and ideas in this book in greater depth. You can contact me via LinkedIn. I look forward to hearing from you.

Foreword

With the onset of the pandemic in 2020, proper ventilation became one of the top issues in Germany. Discussions about healthy indoor air were held throughout the country. There were heated debates about how classrooms should be properly ventilated. It was often noted with dismay that a large number of offices could not be supplied with fresh air via a ventilation system in the building. Manufacturers of compact room air purifiers suddenly found themselves in a gold rush. Across the country, there were heated discussions about how indoor air pollution could be measured and evaluated. Campaigns were even launched promoting clean air as the most important foodstuff.

Where did this sudden and vehement commitment come from? Many of these arguments and questions have accompanied me throughout my professional life. I joined our company, REVEN GmbH, in 1995.

REVEN stands for REntschler VENTilation. Ventilation is precisely the process that REVEN GmbH has been involved in for generations and which I have also been involved in for decades, first as technical director and now as managing director. REVEN GmbH's air purifiers and ventilation products are used to ensure clean air in commercial premises. These include production halls in the food industry, mechanical engineering facilities, large kitchens and canteens. These production areas all have one thing in common: the air in the rooms or halls is often heavily polluted and contaminated. Measuring and analysing the degree of pollution in such areas and filtering and purifying the air are the tasks we have been working on at REVEN GmbH for decades.

Since the beginning of the coronavirus crisis in 2020, these air purification tasks have suddenly become relevant not only for the industrial sector, but also for the entire

Germany. During the sometimes highly passionate discussions, I noticed that the tasks in the commercial and private sectors were becoming increasingly similar. However, due to the sudden surge in demand, some manufacturers were no longer so precise with their specifications regarding the performance of room air cleaners. Many claims were made and even more promises were given. The ventilation effect, filter performance and efficiency of many solutions are difficult to understand, especially for laypeople, and led to misunderstandings in the debate. These misunderstandings, for example with regard to clean air and adequate indoor air purification in classrooms, are similar to the misconceptions that have become established as half-truths in the industry over many decades.

This book aims to provide an overview of the misconceptions and half-truths surrounding ventilation and where these misconceptions originate, both in the private and industrial sectors.

I will not explain the individual topics in a highly scientific manner, but rather based on the experience I have gained since 1995 in my professional work and practice at REVEN GmbH. During my mechanical engineering studies at the University of Stuttgart, I gained insights into the important tasks of successful technology and innovation management. This provided me with valuable knowledge about innovative product development and knowledge exchange between research and practice.

With this book, I would like to further support this exchange and deepen it in the field of ventilation technology and air pollution control in order to clear up some misunderstandings.

"In our polluted environment, the air is slowly becoming visible."

(Norman Kingsley Mailer (1923—2007), American writer)

Table of contents

Acknowledgements	3
Preface	4
1. How can something be extracted?	9
1.1. Misunderstandings regarding the measurement of air pollution	12
1.2. Blowing can help with detection and extraction!	22
2. How can something be filtered?	27
2.1. The misunderstanding about the difference between filtering and separation	29
2.2. Hurricanes can help clean the air!	35
3. How can vapours and odours be eliminated?	47
3.1. The misunderstanding about the difference between vapours and aerosols	50
3.2. FID measuring devices can help analyse air pollution!	57
4. How can viruses and odours be neutralised?	65
4.1. The misunderstanding about UV-C radiation	68
4.2. Can UV-C radiation eliminate aerosols?	77
5. How can air flows be made visible?	87

5.1. The misunderstanding caused by colourful pictures of air currents.....	90
5.2. CFD simulations make air flows visible!	95
 6. How can air pollution be measured?	105
6.1. The misunderstanding about indoor air quality.	114
6.2. Particle measurements make air pollution visible!	126
 Concluding remarks	132

1. How can something be extracted?

?



How can something simply be extracted? It's a simple question, and one that every ventilation engineer would be able to answer straight away! But is effective extraction really as simple and straightforward as it might seem at first glance?

Practical example: the vacuum cleaner

Here is a simple example that we are all familiar with: vacuuming – whether in our beloved car or at home in the living room. When we vacuum, we want to remove dirt, such as bread crumbs from the carpet. The closer we bring the vacuum cleaner nozzle to the crumbs on the carpet, the easier and faster they are sucked up. We achieve the best results when we hold the vacuum cleaner nozzle directly over the dirt. Before we know it, the crumbs have disappeared into the vacuum cleaner.

That is the answer to the question of how to vacuum something properly! You have to cover it one hundred percent. Only then can it be completely vacuumed up. In our example, we had to hold the vacuum cleaner nozzle directly over the bread crumbs on the carpet in order to vacuum them up properly and completely.

The correct suction position

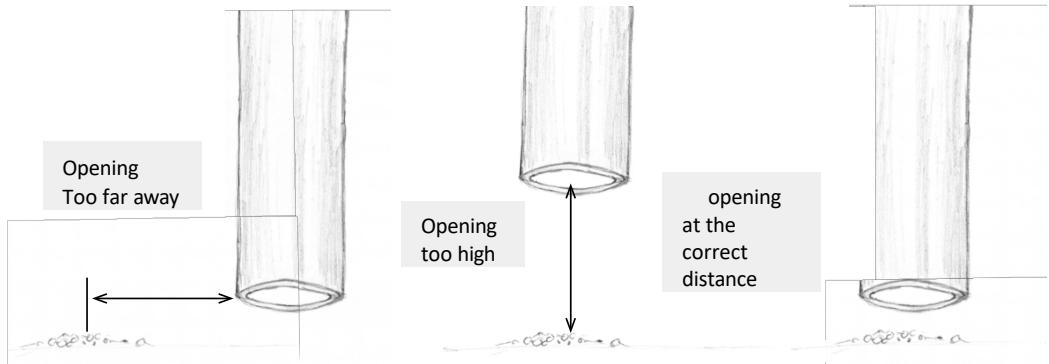


Figure 1

This basic principle must be applied in ventilation technology wherever stale and contaminated air is to be extracted completely – in classrooms where virus-laden air is to be removed, in welding halls where welding fumes must be captured, in kitchens where cooking fumes are to be extracted, and in mechanical engineering, where evaporated coolants and lubricants must be captured on modern machine tools. In all these examples, vapours, gases, virus-contaminated air and aerosols must be captured and extracted in various forms.

The focus here is primarily on the sequence:

First capture, then extract!

1.1. Misconceptions regarding the collection of air pollutants

As we learned in our example at the beginning, the breadcrumbs on our carpet can only be quickly and easily vacuumed up if we hold the nozzle directly over the crumbs! The same applies to ventilation technology in kitchens. It is important to maintain the correct distance when vacuuming. It does not matter whether we are talking about a large ventilation system in a factory canteen or looking at our kitchen at home. Our designer cooker hood at home is also subject to the same principle described below when capturing and extracting kitchen fumes.

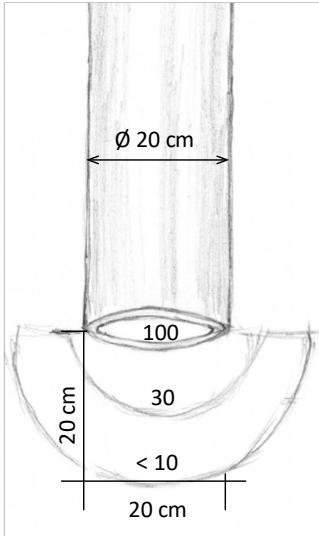
Misunderstanding

Relationship between extraction power and distance of the extraction pipe

The extraction power directly at the opening of an extraction device is one hundred percent. This also applies to the nozzle of our vacuum cleaner! Here, too, the highest extraction power is achieved directly at the nozzle opening. The further we move away from the nozzle opening, the lower the extraction power becomes.

What is often underestimated is the extent to which the suction power decreases. With a suction pipe with a diameter of twenty centimetres, only 10% of the original suction power is achieved at a distance of twenty centimetres from the opening.

Suction power in relation to distance



100% suction power directly at the pipe inlet

The suction power decreases significantly with increasing distance from the suction pipe inlet.

The suction power is only approx. 10% when the distance between the suction pipe and the pipe diameter (here 20 cm) is the same.

Figure 2

If the distance between a suction pipe and the contamination is the same as the diameter of the pipe, the suction power is only approx. 10%.

This rule applies to all types of suction devices, regardless of whether they are vacuum cleaners or kitchen hoods at home, ventilation systems in a commercial welding shop or large ventilation ceilings in a factory canteen. If the distance between the extraction device and the point at which the released pollutants must be captured is too great, the extraction capacity is zero. In the vast majority of cases, this is already the case at distances of thirty to fifty centimetres!

Misconception

Higher efficiency through flow-optimised nozzle plates

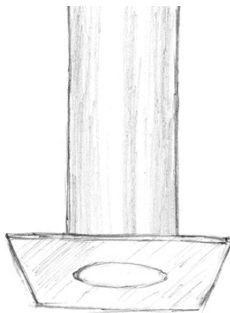
There are also frequent misunderstandings regarding efficiency. In many cases, there is a widespread belief that so-called flow-optimised nozzle plates contribute to more efficient use of the intake force. In this case, an additional plate is fitted around the intake pipe. The pipe sits centrally in an opening in the plate and the transition from the plate to the intake pipe is shaped as an inlet nozzle with a radius. This inlet nozzle is designed to optimise the air flow in the intake area and thus ensure more efficient extraction. However, when comparing a suction pipe with a flow-optimised nozzle plate to a conventional suction pipe with a plate without an inlet nozzle, only minor advantages can be observed.

Nozzle plates

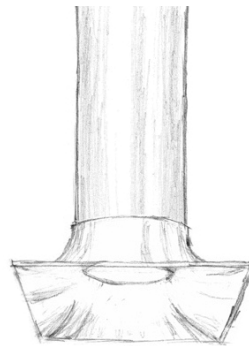
Nozzle plates are useful for "guiding" the air flow, but have only a minor effect on the suction performance.



Suction pipe
without nozzle
plate



Suction pipe with
flanged plate



Suction pipe
with nozzle
plate

Figure 3

Experiment – Extinguishing a candle flame by sucking

Let's use a candle to illustrate this. Have you ever tried to extinguish a candle by sucking air into it? I can only warn you: don't try it! I regularly perform this experiment in front of an audience during lectures on this topic and repeatedly burn my lips because I have to bring the suction point, i.e. my mouth, very close to the candle in order to have any effect on the flame. However, extinguishing the flame by sucking usually does not work!

This simple example clearly shows how limited the suction effect is and how important proximity to the suction point is when we want to grasp and suck something.

Misunderstanding

Distance from the air purifier's intake opening is not that important

This misconception often leads to mistakes in practice: in air cleaners in schools, ventilation units on welding equipment, kitchen hoods above cooking appliances and aerosol separators on machine tools, the intake openings are often much too far away from the emission point.

We can quickly solve this problem with a vacuum cleaner by moving the suction nozzle to the dirt. Unfortunately, this is not possible with permanently installed cooker hoods. Here, the cooking vapours must reach the suction area of the cooker hood, otherwise the kitchen fumes will simply not be captured and therefore cannot be extracted.

CFD simulation

The collection and extraction of air flows and the pollutants they contain can be simulated, visualised and analysed in detail using appropriate software solutions. Numerical flow simulation, also known as CFD simulation, is used for this purpose. CFD is an abbreviation for Computational Fluid Dynamics. This simulation method can be used to visualise a wide variety of air flows and evaluate the efficiency of the extraction system.

Our in-house experience

At our company, we have used this method to investigate the efficiency of the collection and extraction of conventional kitchen hoods, among other things. The first numerical flow simulations were carried out in-house back in 1996. The analysis of the simulations, which were still quite simple at the time, and the calculation of the results often took several days.

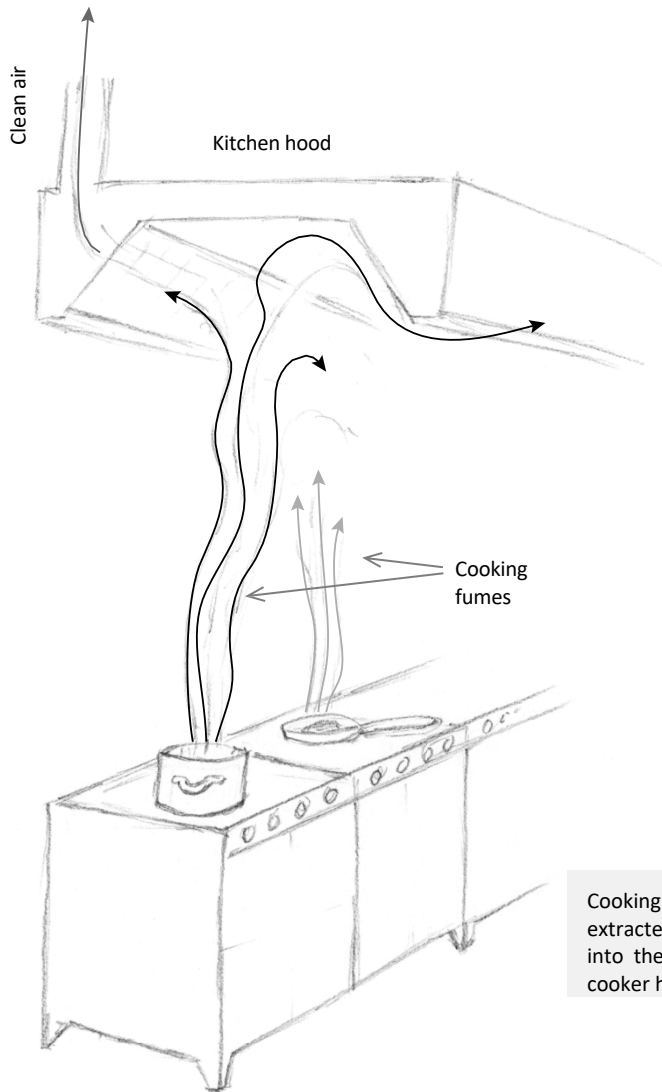
Since then, this technology has developed rapidly and the results are now available in a fraction of the time. Today, they are much more accurate and meaningful, even for very complex components such as fans.

Thanks to this development, it is now possible to analyse and visualise air flows not only for individual components, but for entire rooms!

Significance for kitchen ventilation

This analysis is particularly important for extraction systems that are located far away from the source of emissions, such as a cooker hood installed at a considerable distance from the hob. The cooker hood can only capture cooking vapours that enter its collection area directly. What does this mean in concrete terms? The vapours from the cooking pots must flow directly into the extraction and filter area of the cooker hood as they rise.

Kitchen ventilation



Cooking fumes are only extracted properly if they flow into the extraction area of the cooker hood.

Figure 4

Significance for air purification in classrooms

If the air in a classroom is to be continuously cleaned of viruses during lessons, it must flow unhindered towards the air purifiers installed in the room so that it can be captured and cleaned there. Often, a tilted window is enough to divert the air flow so that it is only inadequately captured and cleaned.

A poorly designed fresh air supply can have a similarly unfavourable effect on extraction as a tilted window through which the wind is blowing. With modern CFD systems, these interactions can be investigated, identified and prevented. This is the only way to achieve complete capture. CFD studies on our own air purifiers and kitchen hoods have also confirmed the principle explained above: the further away the intake points of the kitchen hoods are from the cooking pots, the less likely it is that the cooking vapours can be completely captured and extracted. Similar findings have been made with air cleaners in school classrooms: the further away they were positioned from the area where viruses were emitted, the less likely it was that the virus-contaminated air would be captured and extracted.

Ventilation in schools

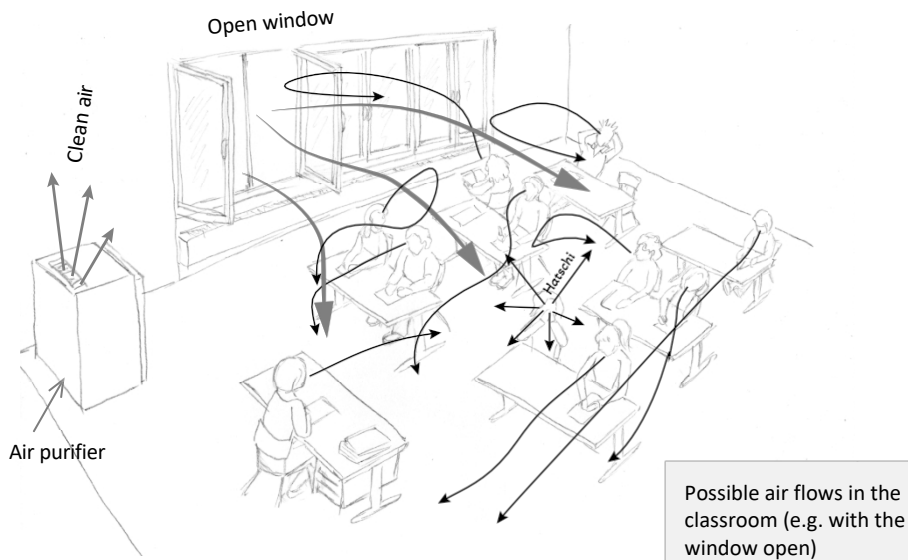
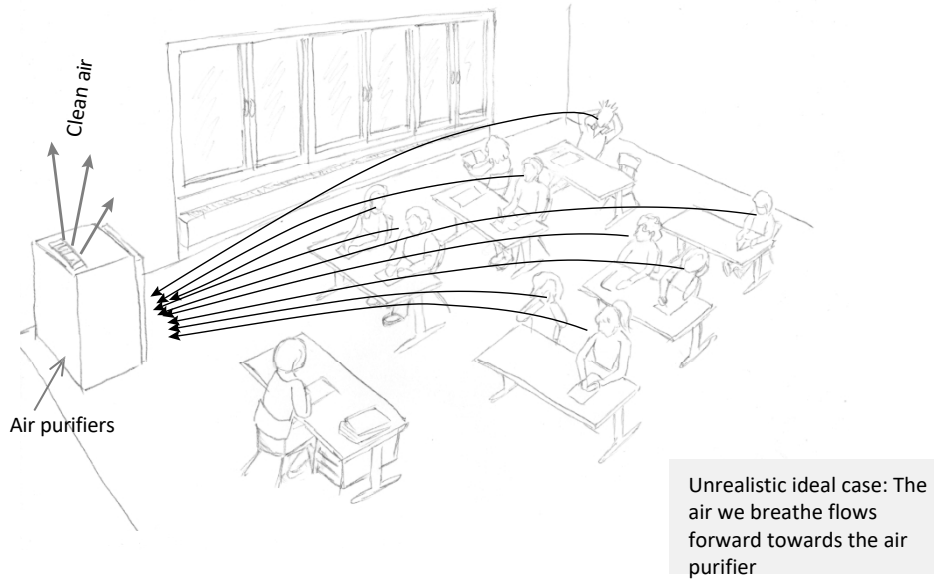


Figure 5

Significance for extraction in mechanical engineering

We made exactly the same observation when simulating complex flow conditions in extraction systems on modern machine tools. Here too, the extraction of air contaminated with cooling and lubricant aerosols is very often extremely inefficient, as the air cleaner's intake point is far too far away from the actual workpiece machining process where the aerosols are generated.

Industrial air cleaners

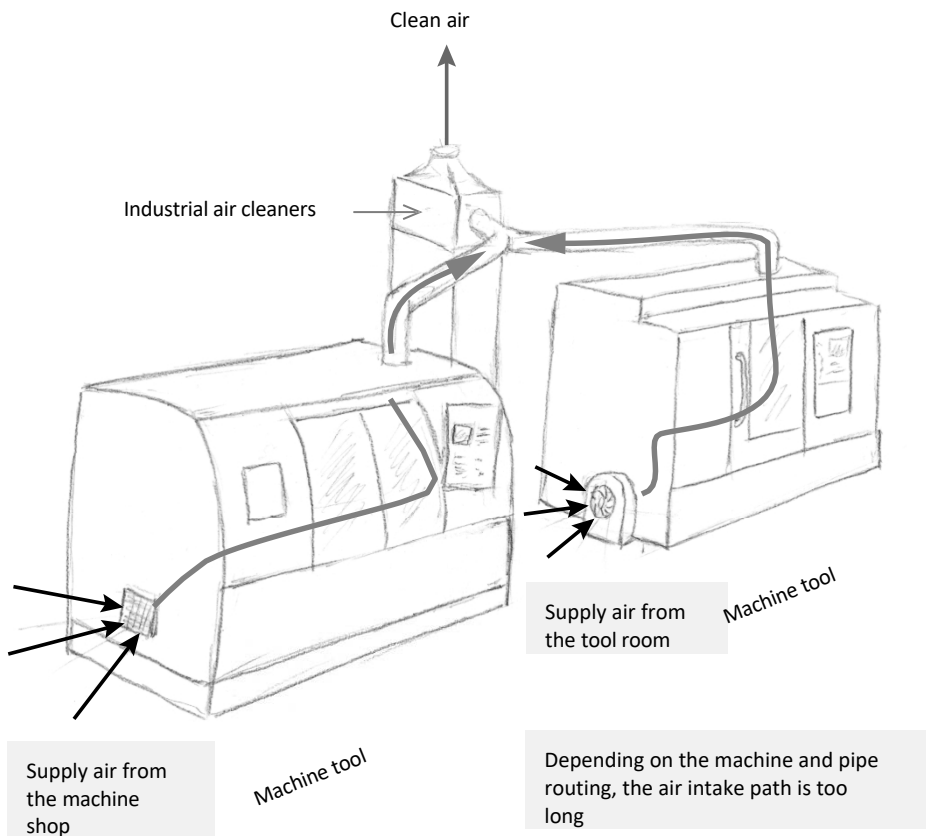


Figure 6

Misunderstanding

At some point, the pollutants flow to the extraction point.

In ventilation technology and air pollution control, we repeatedly encounter the incorrect assumption that air contaminated with pollutants, viruses or aerosols will sooner or later flow into the area where it can be collected and extracted. In many cases, however, this is not what happens. The aerosols and other pollutants that are not captured then cause considerable pollution of the air in the surrounding area.

1.2. Blowing can help with collection and extraction!

But what can be done if it is not possible to move the extraction area closer to the source of the pollutants? In this case, the same remedy can be used as for extinguishing a candle flame:

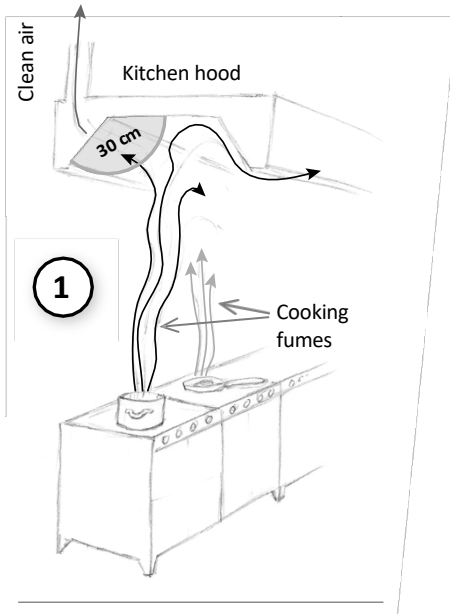
Blow instead of suck!

Applied to ventilation technology, this means that the air to be extracted, including any viruses, aerosols and other pollutants it contains, must be transported as quickly as possible by means of assisted blowing to where the suction power of the air cleaners, kitchen hoods or ventilation units is greatest, i.e. directly into the area of their intake openings (–).

Blow flow for commercial kitchens

To achieve this, REVEN GmbH has developed modern kitchen hoods with an integrated induction system. An induction current ensures that the cooking vapours rising from the cooking appliances flow directly and very quickly into the filter and intake area, where they can be captured and extracted.

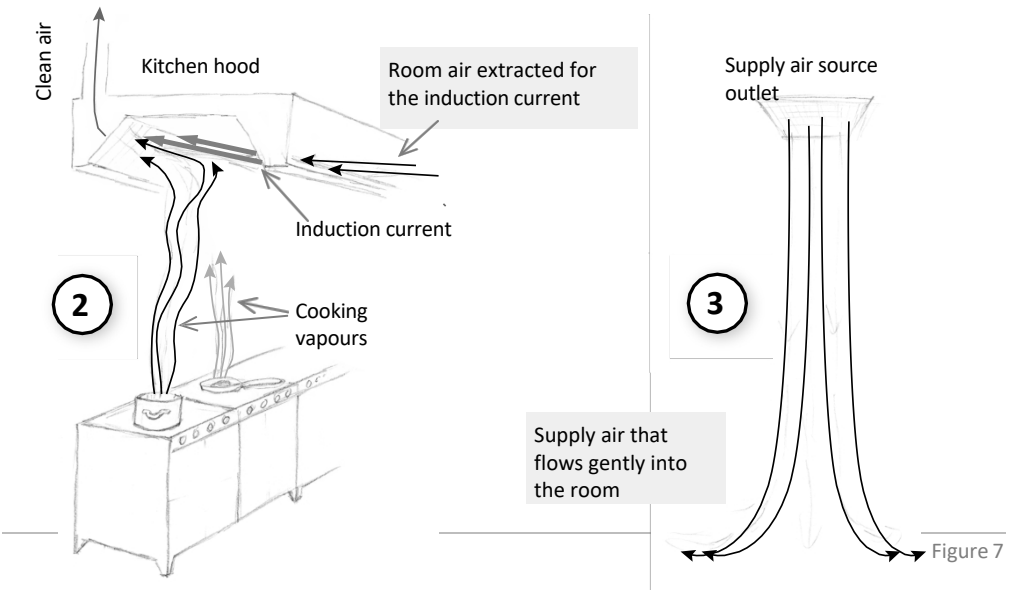
Kitchen ventilation



1. Cooking fumes can only be extracted (captured) within a radius of 30 cm in front of the separator. Outside this area, cooking fumes can enter the room air.

2. An induction current blows the cooking fumes towards the separator. **All** cooking fumes are captured in this way.

3. Supply air at the correct temperature is introduced without disruption and supports the capture of cooking fumes.



Additional fresh air

The capture by modern kitchen hoods of this type can also be supported by optimised fresh air supply.

The fresh air is fed into the room with minimal impulses using displacement air flow. This ensures that the air velocity of the fresh air is kept very low during injection and that other air flows in the room are not disturbed. This scenario can also be analysed and visualised using CFD systems.

Blow flow for machine tools

The same principle can also be applied to machine tools. Here, an air flow is generated in the machine cabin that flows towards the air cleaner and ensures that the cooling and lubricant aerosols can be effectively captured and extracted. Optimising extraction in machine cabins often starts with a simple question: If we extract one thousand cubic metres of air per hour from the top of a machine tool, where can this air flow into the cabin? If there is no way of ensuring that air flows in, we will have very high negative pressure in the cabin, but no targeted air flow towards the collection area of the air cleaner.

Practical example: Negative pressure

After installing air cleaners on very well-encapsulated grinding machines, the problem arose several times that the operating door of the machine tool could no longer be opened because the negative pressure in the cabin was much too high!

2. How can something be filtered?



How can something be filtered? This is basically a question that is just as simple as the one about effective extraction explained above. As you can probably imagine, the answer is not quite so straightforward.

The effectiveness of many processes in ventilation technology and air pollution control is based on efficient collection and extraction, including the removal of pollutants from the air. If, for example, virus-contaminated air in a classroom is not completely collected and extracted, it cannot be reliably cleaned of viruses. In principle, this also applies to a large welding shop in a mechanical engineering company. The welding fumes released contain pollutants and must be completely captured and extracted. This is the only way to effectively remove all pollutants from the room air.

Effective and complete air purification therefore comprises three very important processes:

Capture *Extraction* *Cleaning*

The third step – cleaning the air – is the topic we will focus on here. There are also a few misconceptions that I would like to clear up. Let's start with the question:

"How can pollutants be removed from the air?"

The pollutants must be filtered out of the air, that's logical! That is the obvious answer. However, separators are also becoming increasingly established in the air purification sector. Probably the best-known example of this are the cyclone vacuum cleaners from the global company Dyson, which work without filters.

This technology works on the principle of a mini tornado. The air is set in rotation and air vortices are formed, which eject particles from the air due to their high speed. This process is also suitable for separating airborne pollutants. However, there is often confusion here, as separation is often confused with filtering.

2.1. The misunderstanding about the difference between filters and separation

Textile fleece

We can also explain the principle of filtering using the example of a vacuum cleaner. Vacuum cleaner bags are used to clean the air collected and extracted by the vacuum cleaner. These are often made of non-woven fabric. The air can flow through this fine-mesh fabric, but dust particles are retained and thus separated from the air flow.

Fibre glass particulate filters

This is basically how all types of filtration work in ventilation technology– , even with very high-quality particulate filters. However, different filter materials are used here. Instead of textile fleece, glass fibre mats are used for these filters. These mats are also permeable to air, but the fabric is much finer than that of a vacuum cleaner bag. The fibres in HEPA filters have a diameter of approximately 1 to 10 micrometres, i.e. 0.001 to 0.01 millimetres. This allows them to filter much smaller particles from the air stream than textile fleece.

Metal mesh filters

This filter principle can also be found in many standard kitchen hoods for private use. Metal filters are often used in these extractor hoods. They usually consist of an aluminium or stainless steel mesh, similar in principle to textile fleece or fibreglass matting, but with a much coarser structure.

The relatively coarse metal filter is used here because it is much less sensitive. Whether in domestic or commercial kitchens, extractor hoods have the task of separating liquid aerosols from the air flow. In this case, it is not dry dust that needs to be filtered out, as with

vacuum cleaners, but liquid particles such as water and oil droplets must be filtered out of the air. This is a significant and very important difference that is often overlooked.

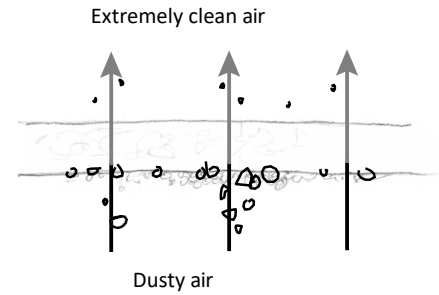
Every type of filter collects and stores what is separated from the air flow. The amount of filtered material in the filter therefore increases continuously. In vacuum cleaner bags, dry dust is collected and stored until the bag is completely full of dust and needs to be replaced.

If the material filtered out of the air flow is liquid droplets, collecting these substances is often much more complex.

Metal mesh filters store the small droplets filtered out of various liquids directly in the filter medium. This accumulation of different liquids can lead to serious problems!

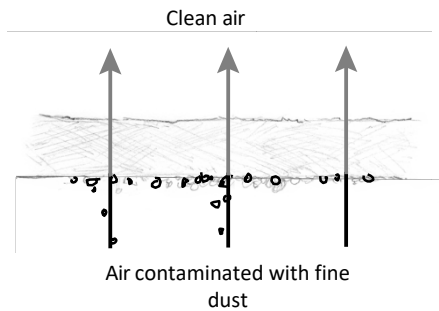
The storage capacity of metal mesh filters is often very low. This means that these filters can become clogged even with small amounts of stored liquid. For this reason, they are usually designed with a fairly coarse mesh. This prevents them from becoming clogged, but many smaller particles pass through the filter with the air flow and are not separated from the air stream.

Different filters



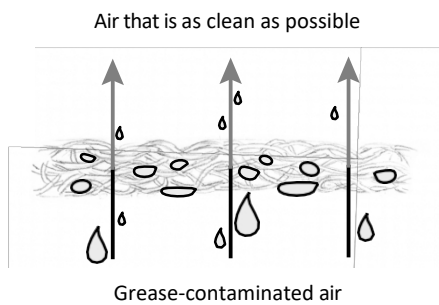
Fleece filters

Fleece (e.g. vacuum cleaner bags) keeps dust out of the air flowing through. However, the smallest dust particles can pass through the fleece.



Glass fibre filter

Glass fibre is finer than a fleece and can filter out even the smallest dust particles in the nano range, i.e. retain them.



Metal filter

In the kitchen, metal mesh is primarily used to filter grease particles. Depending on their size, the droplets remain in the mesh. However, the smallest droplets can pass through the mesh.

Figure 8

Risk of germ formation

In food processing plants and also in the manufacturing industry, the accumulation of liquids in filters can also lead to hygiene problems. At temperatures around 20 degrees Celsius, germs can multiply very quickly in the filters in combination with moisture. Therefore, storing and collecting liquids over a longer period of time is often not advisable, and regular cleaning or replacement of the filters is strongly recommended.

Fire hazard

If the filtered substances are oil or grease, the liquid stored in the filter increasingly poses a fire hazard! This is a fact that is often forgotten.

Example from company history

I still remember a large meeting at a global tool manufacturer. The employees showed me their production facility with hundreds of grinding machines. The air pollution control systems in the production area were equipped with large particulate filters that could store up to 100 litres of liquid. The problem was that the stored liquid was a very thin and highly flammable coolant and lubricant. With 50 filters in use, this could add up to 5,000 litres of stored liquid! When I asked the company employees during this tour about the fire protection measures for these 50 air pollution control systems and the relevant protection concepts, I was met with a series of shocked faces.

My questions and thoughts about the filters in air purification are by no means just theoretical musings, but relate to specific hazards, and unfortunately, tragic fire disasters have already occurred because the problem of fire load was not given sufficient attention.

Practical example: Fire in mechanical engineering

In 2006, a devastating fire broke out in a mechanical engineering company in southern Germany with an extraction system similar to the one described above. The fire damage amounted to a mid-range double-digit million figure. Production halls and facilities covering more than 3,000 square metres were completely destroyed. The probable cause of the fire was a defective machine tool. The rapid spread of the fire through the ventilation duct network did the rest.

Practical example: Fire in a hotel complex

A similar disaster occurred in 1980 in a large hotel with 2,000 rooms in Las Vegas. At the time of the accident, approximately 5,000 people were in the hotel complex. The fire started in one of the hotel's restaurants and spread at breakneck speed throughout the entire building complex. 85 people lost their lives. This tragic event is still considered one of the most catastrophic hotel fires in modern US history.

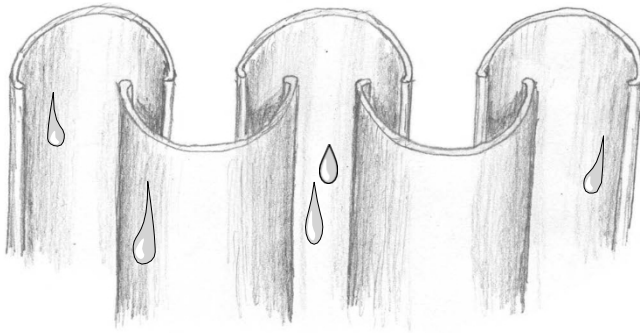
Such catastrophic fires ultimately led to the metal mesh filters described above being discontinued in many commercial applications. In commercial kitchen ventilation, they have even been banned in many countries for years. In North America and most European countries, for example, metal filters of this type are no longer permitted in new commercial kitchens due to the increased fire risk.

Invention of baffle plate separators

After the catastrophic hotel fire in Las Vegas, alternatives to metal mesh filters were developed in the USA – so-called baffle plate separators. This type of separator is constructed from stainless steel sheets. As the air flows through, it is deflected at least twice

. The difference to conventional metal mesh filters is that these separators made of stainless steel sheets do not store any liquid.

Baffle plate separators



Fluids such as oil and water are separated at the baffle plates and, ideally, run down the plates.

Figure 9

Misunderstanding

Different modes of operation of filters and separators

As we have seen, filters and separators work differently. But it is precisely these differences that cause misunderstandings. The properties, modes of operation and efficiency data are often lumped together. Sometimes, no effort is even made to clearly separate and distinguish between the terms!

In ventilation technology and air pollution control, there are therefore not only misunderstandings regarding the difference between filtering and separation, but also regarding the functioning and efficiency of separators made of sheet metal.

To clarify the differences, we must first take a look at some weather phenomena in nature and how they have been incorporated into air pollution control technologies.

2.2. Hurricanes can help clean the air!

You may be surprised, but it's true. Cyclones such as hurricanes, typhoons, tornadoes and tropical cyclones served as fluid dynamics models for the development of modern separators made of sheet metal.

The first separators developed after the great hotel fire in the USA were simple baffle plate separators. Two semi-circular stainless steel plates bent into a U-shape are arranged opposite each other. The air flow is deflected twice as it passes through the separator, the first time when it hits the first half-shell and the second time when it hits the second half-shell.

Principle of operation of baffle plate separators

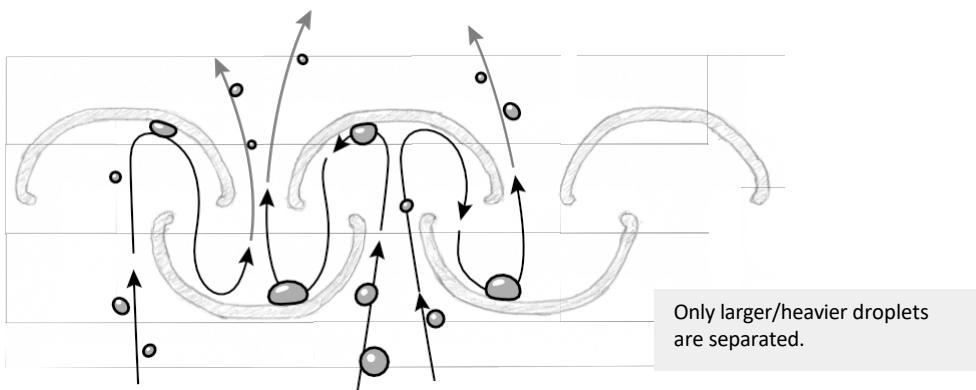


Figure 10

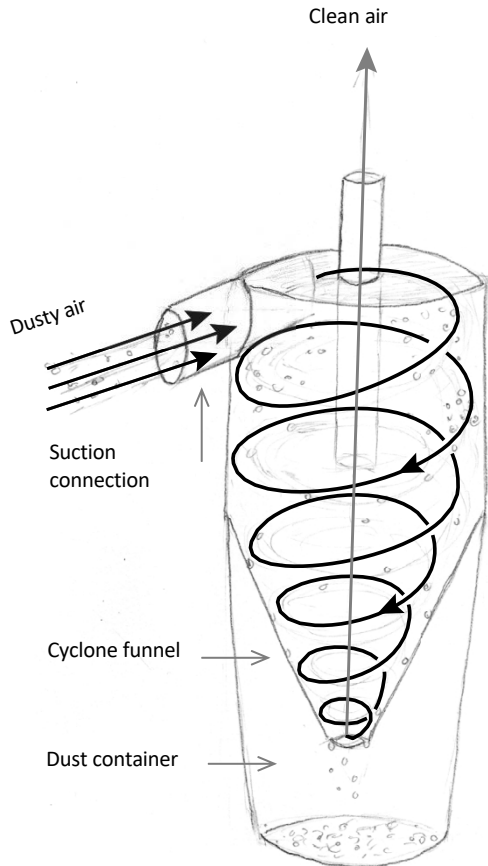
The U-shaped half-shells are formed over a radius or bent at a 90-degree angle. In both cases, however, the separation efficiency is very poor, as only large airborne droplets are separated from the air stream. The air flow

In a simple separator of this type, the flow is very turbulent and only very large droplets with a relatively high weight and high inertia can be separated from the air stream when they collide and are deflected. Smaller airborne droplets with a lower weight pass through these deflections with the air flow and are therefore not separated. The only advantage of these simple baffle plate separators was that they did not store any liquid, but their efficiency in separating particles from the air flow was very low.

Tropical cyclones as a model

It was only when manufacturers of separators took nature as their model and learned from tropical cyclones that they succeeded in eliminating this disadvantage. The best-known example of this is the aforementioned company Dyson with its cyclone vacuum cleaners. This technology works without filters and basically functions like a mini cyclone. As in a cyclone, the air is set in a rotating flow at very high speed. The higher the rotational speed, the smaller the particles that can be thrown out by the air flow and thus separated.

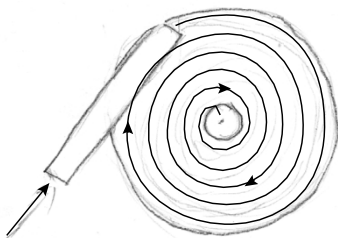
Principle of a cyclone vacuum cleaner



The conical shape of the cyclone funnel causes the sucked-in air to move in a spiral pattern.

Centrifugal force throws the dust particles against the wall.

The dust particles are collected in a dust container.



Cyclone spiral seen from above

Figure 11

A great deal of research and development work was naturally required to acquire the expertise needed to create such artificial whirlwinds on a small scale in vacuum cleaners, cooker hoods and air purifiers. This certainly cannot be achieved with simply bent baffle plates. Numerical flow simulation, or CFD simulation for short, is also used in the development and optimisation of cyclone technology. CFD stands for Computational Fluid Dynamics. This simulation can be used to visualise a wide variety of air flows. However, this is not sufficient to optimise the separation technologies. Here, too, misunderstandings often arise in ventilation technology and air pollution control!

Misunderstanding

Optimising the air flow is sufficient!

In many cases, ventilation technology is all about air flow. For example, how to bring fresh air into a large concert hall as comfortably as possible without concertgoers feeling an unpleasant draught or cold. The air should also be brought in completely silently.

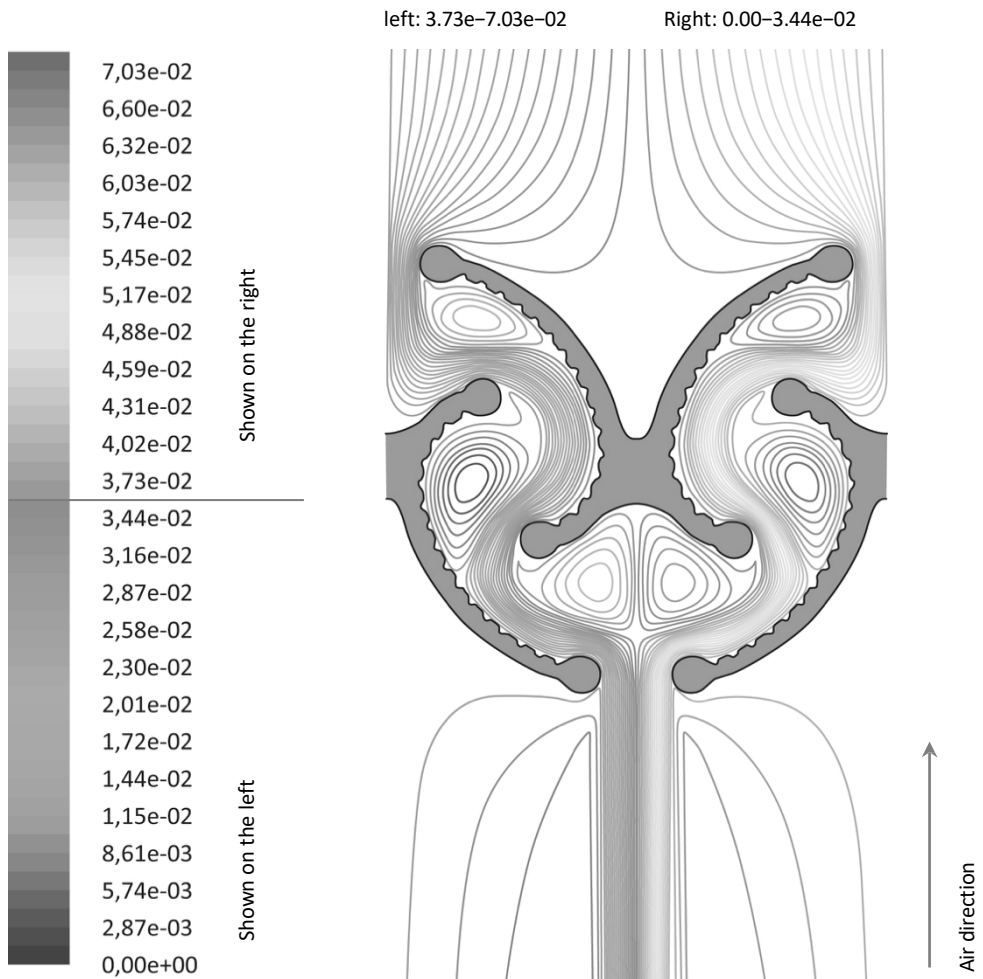
However, optimising filters and separators in air pollution control is not just about air flow and analysing its path and speed. The actual task of air purification is to separate the particles carried along from the air flow by filtering or separating them. In simple terms, filters work like a sieve and separators like whirlwinds. If you want to optimise the functioning of separators, you have to create small whirlwinds in the separators. Only then will the particles be ejected from the air flow and separated.

Analysis of particle trajectories

Today, CFD systems can also be used to analyse and visualise the flow of particles. This means that it is no longer necessary to look only at the air flows, but also at the behaviour of the particles or aerosols they carry.

Do the smaller and therefore lighter aerosols follow the same path as the air flow? A very interesting CFD investigation is the visualisation of the different aerosol trajectories. The course of these paths depends on the particle size. With very good CFD analyses, it is now even possible to see at which point in a separator an aerosol is separated from the air flow! During the further development of our separators, we were amazed and astonished more than once by the results of such analyses.

CFD analysis of an X-CYCLONE® separator



Flow behaviour of particles of different sizes (kg/s)
The different particle sizes are indicated by different shades of grey.

Figure 12

Example from the company's history

When developing our separators, we too often believed that we knew in advance what the air flow would do and what would happen to all the airborne particles– , i.e. where they would be ejected. To validate our assumption, we carried out CFD analyses. The results presented were often completely different from what we had expected.

I still remember a test in which we were all 100% convinced that small whirlwinds with strong rotation would form very quickly in a separator we had newly developed and that these would eject the airborne particles with very high efficiency. We proudly named this newly developed prototype X-CYCLONE®.

The X stands for the geometry of the separator. We no longer constructed it from two simply bent sheets of metal in a U-shape, but gave the separator profiles a much more complex geometry. Initially, we were only able to produce these using extruded aluminium profiles. The surfaces resembled miniature versions of aircraft wings, which we arranged in an X-shape. As you may have guessed, the second part of the name of our new development stands for tropical cyclones (–) in the English spelling CYCLONE.

The CFD analysis of the new separator prototype was intended less as an analysis and more as a confirmation that we wanted to carry out for safety reasons, regardless of the high cost. We knew what the result would be anyway. At least, that's what we thought...

CFD analysis is indeed very complex. As explained above, the investigation examines not only the behaviour of the air flow, but also the particles in the air. In order to carry out this investigation, a three-dimensional model of the separator is required.

No problem, I thought years ago, we have everything we need, otherwise we wouldn't be able to produce it. But I too had fallen prey to a misunderstanding!

Misunderstanding

A three-dimensional model of the separators is sufficient for a CFD simulation.

The three-dimensional spatial model

For the investigation, we needed not only a three-dimensional model of our separator, i.e. the aluminium profiles, but also a model of the room through which the air flows. That makes sense! When analysing the air flow in a round ventilation duct, you look at the cylindrical space inside the ventilation duct and not at the sheet metal of the air duct. However, this did not make our task any easier. Since the geometry of our new X-CYCLONE® aluminium profile was already very complex, the space through which the air flows became even more complex. But for the CFD analysis, this is exactly what needs to be modelled.

The mesh (calculation grid)

This already complex procedure is further complicated by the fact that the air-permeable space must also be covered with a calculation grid. The English term "mesh" is often used for this. How such a calculation grid is arranged in this air-permeable space has a significant influence on the quality of the CFD analysis. However, if this approach is taken with great care, very detailed flow analyses of both the air flow and the particles can be obtained, even if the results can be extremely frustrating!

CFD analysis of an X-CYCLONE® separator

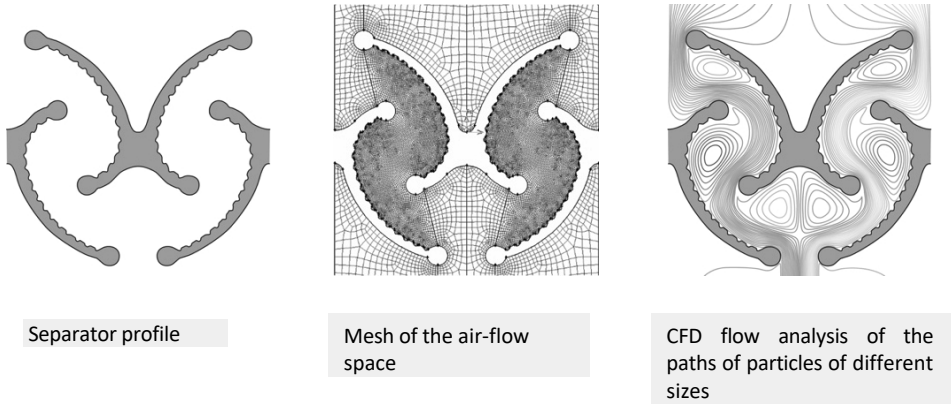


Figure 13

A sobering result

– , the air flows differently than expected!

The CFD analysis delivered very sobering results for our first X-CYCLONE® prototypes. In the area through which the air flows, where we were absolutely convinced that small cyclones would form and then eject particles at a rotational speed of over 10 metres per second, nothing of the sort happened! I can still see it as if it were yesterday. The CFD analysis clearly showed an empty area that resembled a drop about one centimetre in size.

The cause

Because the X geometry of our profile had far too much curvature, the air flow could not follow this geometry and an area formed that was not penetrated by air, let alone cyclones forming there and ensuring separation! Even ventilation professionals cannot always correctly assess the behaviour of air flow in advance.

The optimisation

For our development project at the time to optimise the X-CYCLONE® separation, this meant going back to square one and reworking the geometry of our separators. Basically, it was a never-ending process of continuous development and improvement. Ultimately, we succeeded in developing products with similar technology to that used by Dyson and in applying them to ventilation and air purification in accordance with industrial standards.

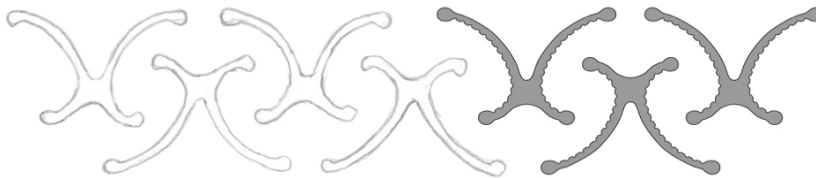
Development of separator geometry



Baffle plate separators with U-shaped profiles



Prototype of the X-CYCLONE® separator with X-profiles in the shape of aircraft wings



X-CYCLONE® separator with profiles in optimised X geometry for optimum air flow control (see Fig. 15)

Figure 14

The triumph of our separators

The X-CYCLONE® separators we have developed have now established themselves in a wide range of industries.

On drilling platforms, in textile finishing plants, in milk powder production facilities, in paint shops in the automotive industry, in the food industry, in commercial kitchens, in mechanical engineering, and even in plants for the production of silicon wafers for microelectronics, "cyclone whirlwinds" in our X-profile separators now ensure highly efficient air purification.

Principle of an X-CYCLONE® separator

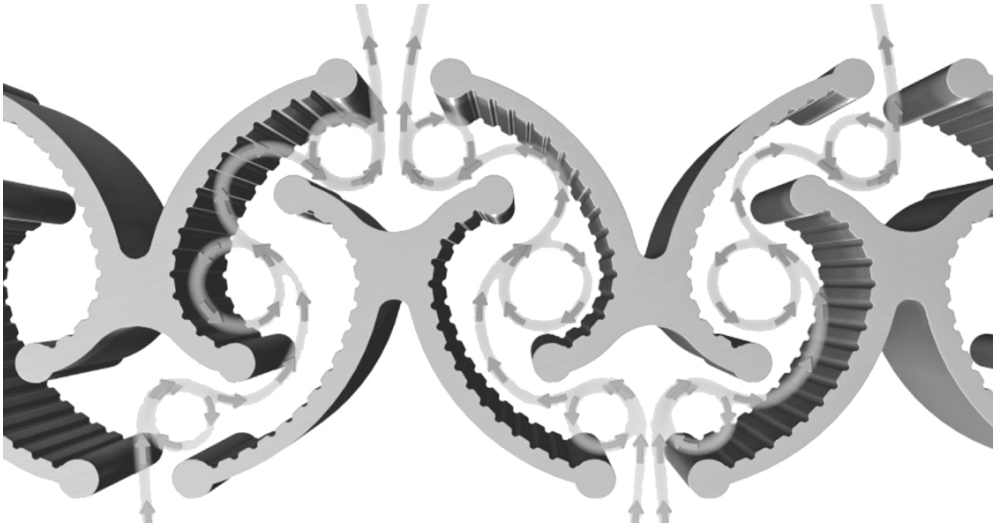


Figure 15

3. How can vapours and odours be eliminated?



The removal of vapours and odours is a very complex task in ventilation technology and air pollution control. One might think that after collection, separation and cleaning, the air should actually be clean and therefore no odour should be noticeable. All particles, aerosols and pollutants have been removed – so what else could cause odour pollution?

Misunderstanding

There is no odour pollution in air that is free of aerosols, particles and pollutants.

Unfortunately, this is another misconception in ventilation technology and air pollution control, which will be discussed in this chapter. Let me explain with a simple example from practice.

Practical example: Refuelling

Many of us have been to a petrol station to fill up our cars with fuel. Most of us will have noticed the smell of petrol or diesel.

The smell of petrol when refuelling



Figure 16

But why do we actually smell petrol when refuelling, even though there are usually no fuel splashes or aerosols flying through the air? This becomes very clear when you want to fill your tank to the brim and have to be careful not to spill anything. When checking to see when the fuel level becomes visible in the filler neck, your nose is close to the filler neck and you can smell the fuel intensely – even without anything leaking.

If you were to measure the particles in the immediate vicinity of the filler neck, you would not be able to detect any fuel aerosols or particles in the air around the filler neck. But why does it still smell like fuel when you fill up? The answer is below.

3.1. The misunderstanding about the difference between vapours and aerosols

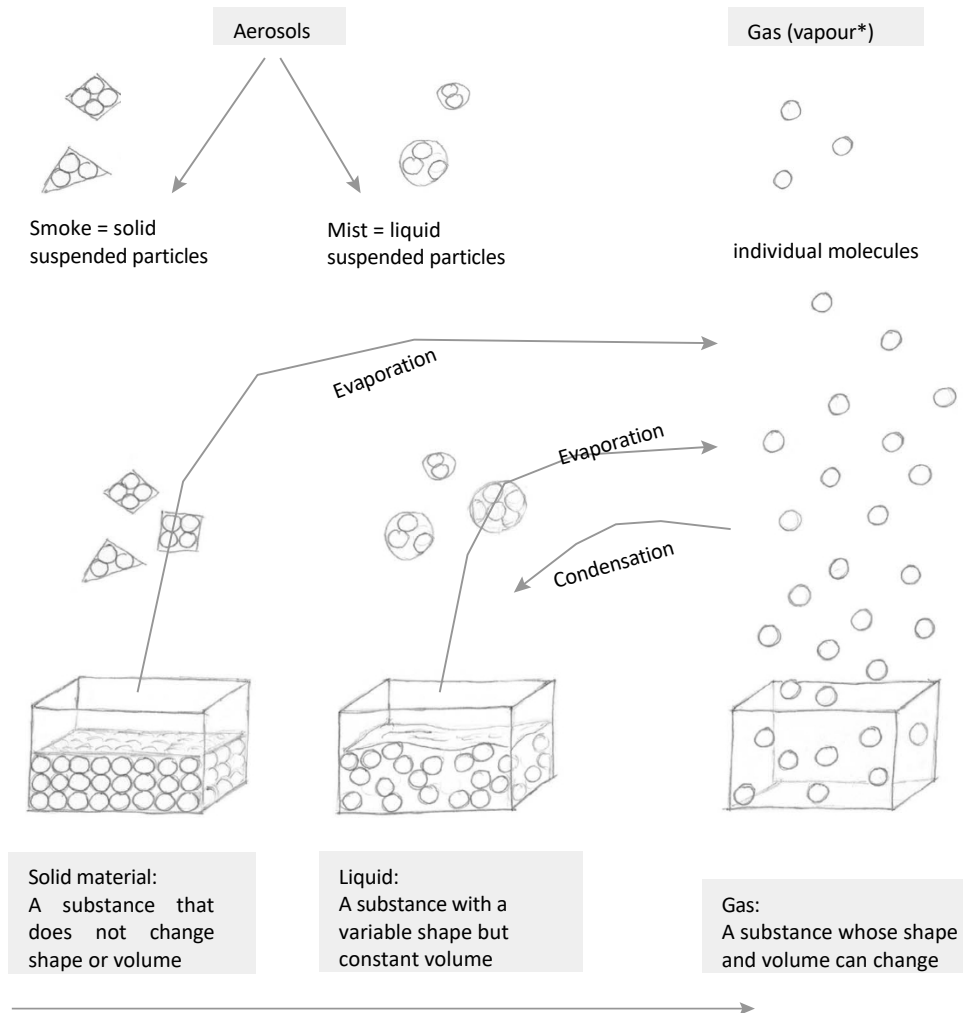
Why does it smell like fuel when you fill up, even though you can't see anything in the air? What you smell is evaporated fuel. Super Plus in particular is very volatile. This means that it evaporates even at relatively low temperatures. This vapour, or gas to be precise, escapes from the fuel filler neck and causes the smell.

Misconception

Aerosol-free air is clean.

This simple example clearly illustrates that air that is free of aerosols is not necessarily clean and can still be harmful to the environment. Air pollution caused by evaporated liquids is a problem that is also causing professional associations a great deal of concern.

Difference between aerosols and gas



Rising temperature →

* Steam is generally understood to be droplets in the air, such as steam rising from cooking. From a scientific point of view, however, steam is the gaseous state of a substance (created by evaporation, boiling or sublimation).

Figure 17

Practical example from mechanical engineering

I remember well when I visited the professional association responsible for mechanical engineering in Bavaria with our sales partner from Bavaria. There we were shown studies with measurement results that had investigated the air pollution caused by coolants and lubricants on machine tools. The results showed exactly the same phenomenon as in the above example of the petrol station. Analysis of the air around the machine tool showed that there was virtually no air pollution from aerosols and that all air quality limits were complied with. At least, that was the assumption.

When the specialists from the employers' liability insurance association then looked at the proportion of evaporated coolants and lubricants from various machine tools, they found significant amounts of these in the air – , concentrations of up to 100 milligrams of coolant and lubricant vapours in one cubic metre of room air were found in some cases. This exceeded the applicable limit values by a factor of ten! How could this happen?

The initial evaporation effects are caused by very high pressure inside the machines, where coolants and lubricants are atomised very finely via nozzles. Furthermore, a great deal of liquid evaporates due to the high temperatures on the tools that machine the metal. What is often underestimated in this context is the constant air flow through the air cleaners in the machine tools.

Coolant vapours in a machine tool

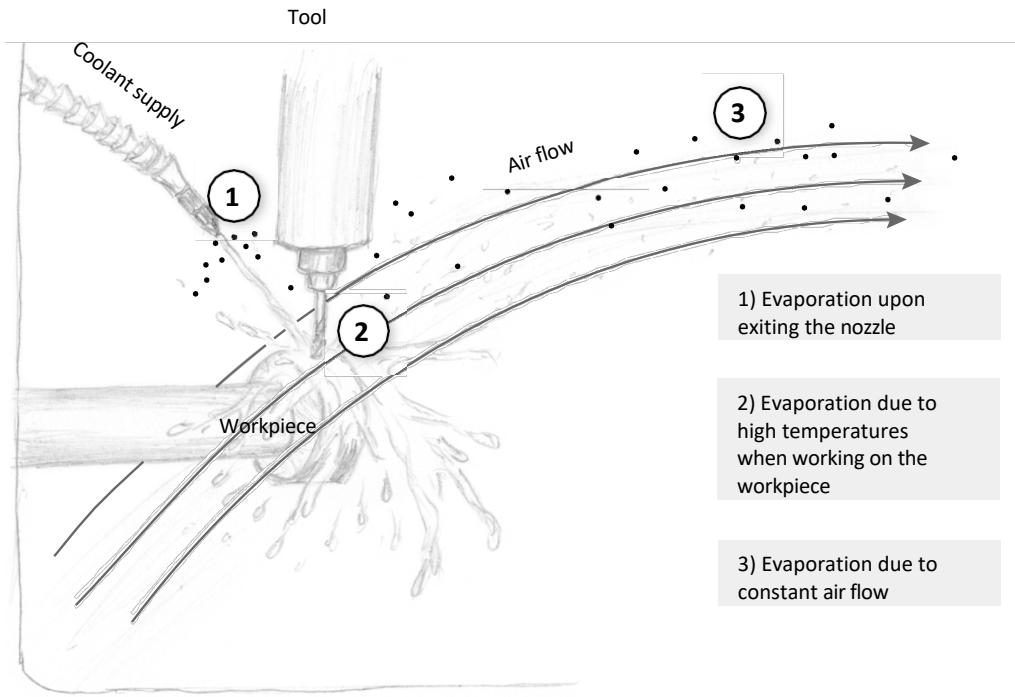


Figure 18

Remember what we established in Chapter 1: To capture and extract, we need a high volume of exhaust air and air flow in the direction of the capture point. This air flow can be compared to wind blowing across the surface of a large lake. This air flow alone causes water to evaporate, which is absorbed as humidity and carried away with the air flow. We see similar effects in a machine tool or when refuelling a car. This transports immense quantities of liquid in vapour form with the air. These vapours can cause considerable health problems and odour nuisance.

Example: Food industry

The same phenomenon can also be observed in the food industry and commercial kitchens. Liquids evaporate on all equipment and cooking appliances that operate at high temperatures. Typical processes include baking, frying and deep-frying. Temperatures of around 140 to 190 degrees Celsius are common here. Oils and fats partially evaporate and are captured and extracted by ventilation systems.

Practical example: deep-frying equipment

In the food industry, we have already seen potato chip frying machines that are the size of a large bathtub. Every day, hundreds of thousands of potato chips are fried in this tub, releasing immense amounts of steam. This consists largely of vaporised oil from the frying fat and vaporised water that was still bound in the potato chips before frying. Here, too, we observed the phenomenon described above: when analysing the process exhaust air by means of particle measurement, no air pollution was detected; the air appeared clean and hardly polluted. Nevertheless, it was already visually apparent that the exhaust air from this processing process could not be clean, as it looked like the steam cloud from an old steam locomotive. Similar to the petrol station, there was also an intense odour. Although this was more pleasant than when refuelling, it still clearly indicated air pollution.

Example: private kitchen

You can observe something similar at home in your kitchen when you fry a steak at a high temperature, for example. There may well be the odd splash of oil that can be classified as an aerosol, but what rises above your hob and is captured and extracted by your cooker hood is mainly air with evaporated oils and water. Only a few drops, aerosols and splashes are present.

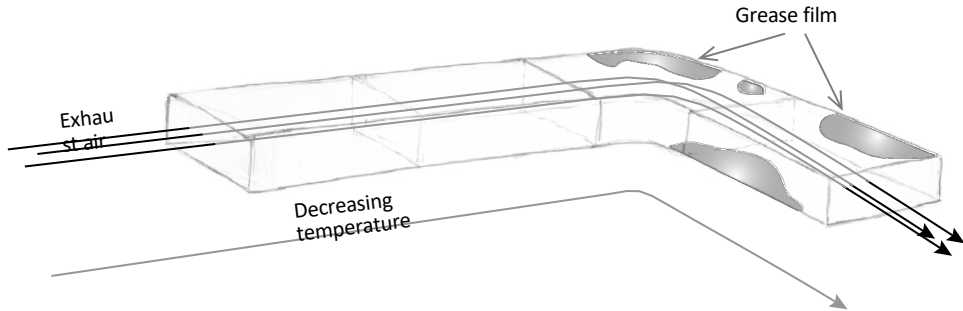
Condensation of vaporised liquids

In industry and commercial kitchens, these evaporated liquids cause major problems in process exhaust air. This is because these vapours not only cause unpleasant odours, but can also condense again when the exhaust air cools down. The evaporated liquid then changes back from a gaseous to a liquid state. This can be observed particularly in large industrial plants and large hotels. Why? Because in large buildings, the exhaust air ducts often have to cover long distances.

Hygiene problems and fire hazards caused by long exhaust air ducts

Whether it is a cooking process in a large hotel kitchen or a processing process in an industrial plant, the air that is collected and extracted directly at the process must then be transported a very long way through the exhaust air duct until it finally leaves the building and is blown out with the aid of large ventilation units. During its long journey through the ventilation duct, which is often made of rectangular sheet metal segments, the air cools down. This causes the evaporated liquid to condense and settle in the exhaust air ducts and the ventilation unit. These deposits not only pose a hygiene problem, but also create a fire hazard.

Long exhaust air ducts and their dangers



On its way outside, the air continues to cool. This causes vapours to condense and form water and grease films inside the exhaust air duct– These films are a breeding ground for microorganisms and a potential source of fire.

Figure 19

European standards require consideration of vapours and their condensation

Air that is free of aerosols and particles is therefore not necessarily clean. What is often perceived as an unpleasant odour is usually vapour. For this reason, European standards such as DIN EN 16282 require that, in addition to air purification in commercial kitchens using filters and separators, attention must also be paid to evaporated liquids and their condensation! To this end, these sometimes very high concentrations must be measured and analysed.

3.2. FID measuring devices can help analyse air pollution!

FID measuring devices can provide an indication of how much vaporised liquid is in the air. FID is the abbreviation for flame ionisation detector. A FID measuring device helps to determine the amount of evaporated volatile organic compounds. Colloquially, this is often referred to as total C in the exhaust air, which refers to the vapour-phase hydrocarbons in the air. If, for example, we want to find out how much vaporised fuel enters our nose when refuelling, such a measuring device would be the ideal equipment. FID measuring devices are also useful for analysing vaporised coolants and lubricants in the manufacturing industry or in food production facilities.

Measuring particle and vapour quantities

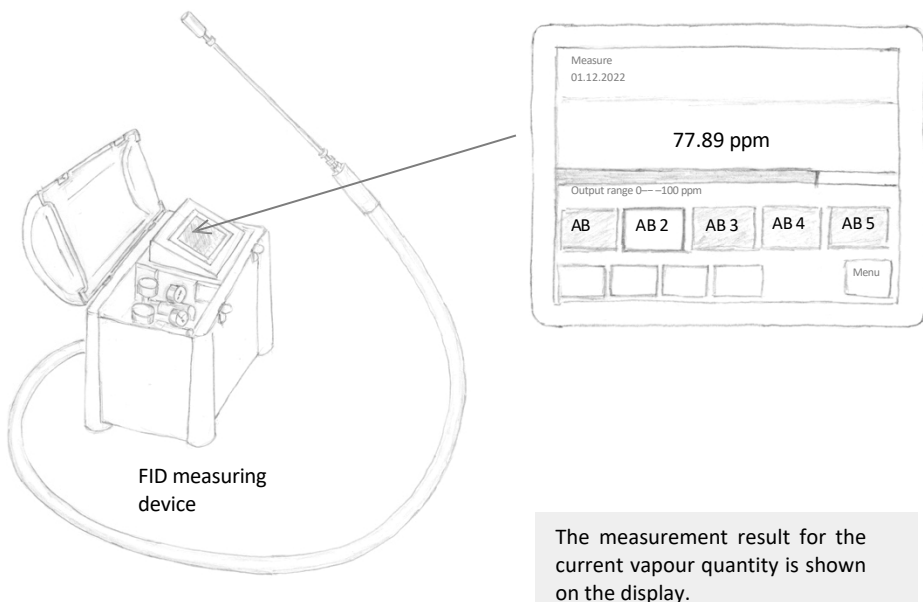


Figure 20

Analysis of air pollution

If the exhaust air from the above-mentioned processes is analysed, the actual pollution is usually determined by the sum of the airborne aerosols and vapours. The result of such an overall assessment often shows that 80 milligrams of vapour and only 20 milligrams of aerosols are present in one cubic metre of room air. Applied to this example, this would mean that we would have a total of 100 milligrams of pollutants in one cubic metre of room air. Whether this pollution comes from a coolant and lubricant in a mechanical engineering company or from frying oil in food production or a hotel kitchen is irrelevant at this point, because the problem and the task at hand are initially the same: we have to deal with both.

Misunderstanding

Evaporated liquids do not need to be measured.

We need to consider both the evaporated liquids and the airborne aerosols from these liquids. A common mistake in ventilation technology and air pollution control is not to measure and analyse these air pollutants at all. If anything is measured at all, it is at best the particle concentration of the aerosols. Virtually never are both vapours and aerosols analysed. This was also confirmed in discussions with colleagues from the professional association in Bavaria.

In commercial kitchens, for example, white clouds rise from deep fryers or large collection containers for hot metal chips in manufacturing plants or similar facilities during operation. Visually, these look very similar to the steam that rises when you heat water in a saucepan at home. The difference, however, is that the steam rising from commercial containers contains oils and coolants or lubricants.

These substances are often the source of strong odours and are not given nearly enough attention or investigation.

Perform particle and FID measurements

It is essential to investigate such emissions using both particle and FID measurements. This is because the next step can be derived from these measurements: cleaning the air by removing these vapours.

Solution 1: Activated carbon

One solution to this problem is the use of activated carbon filters. In simple terms, activated carbon acts as a kind of molecular filter. It is highly porous and has numerous tiny pores that can absorb vapours through adsorption. The vapours are then bound to the surface of the activated carbon. However, this only works as long as the activated carbon is not overly contaminated by aerosols produced during condensation.

Disadvantages of using activated carbon

Activated carbon filters are often only used in ventilation units at the end of a long exhaust air duct. By the time the exhaust air reaches this point, it has already cooled down by several degrees and the vapours begin to condense. This clogs the many small pores of the activated carbon far too quickly, rendering it ineffective. If the condensing vapours are oils, they combine with the activated carbon to form a literally fire-hazardous mixture!

Use of activated carbon

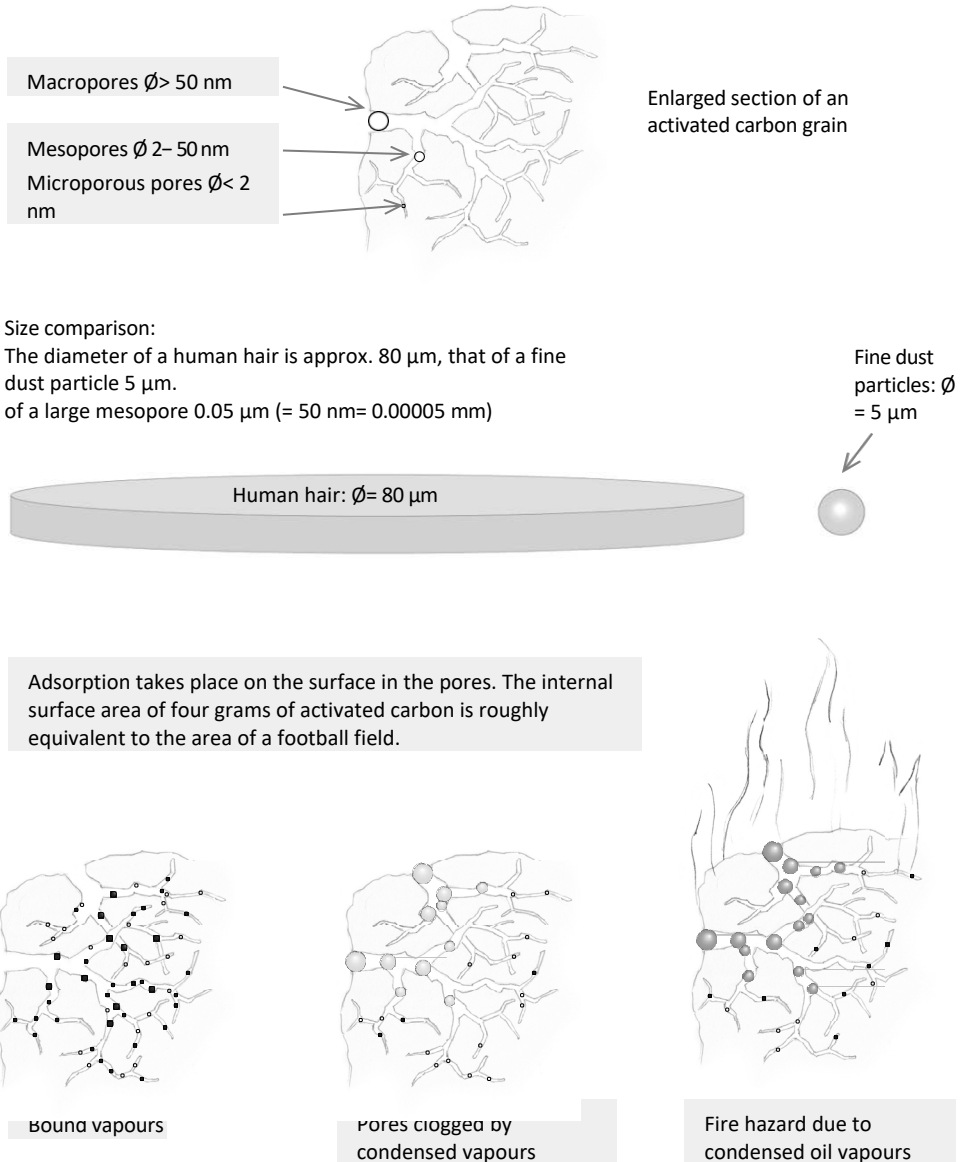


Figure 21

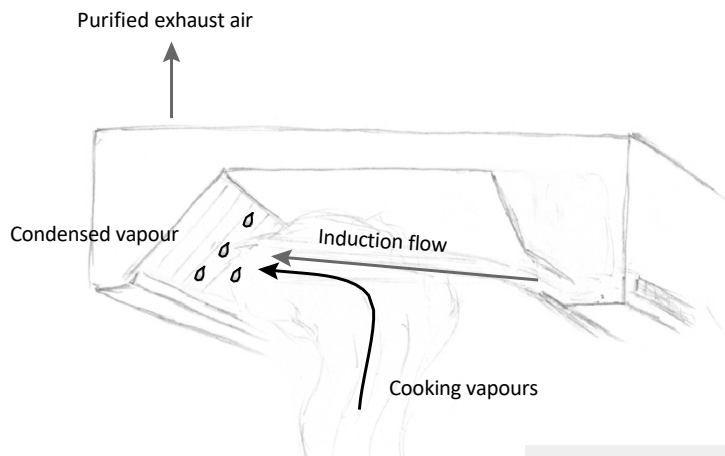
Solution 2: forced condensation

Another way to control the evaporated liquids and reduce their quantity is forced condensation directly during collection and extraction.

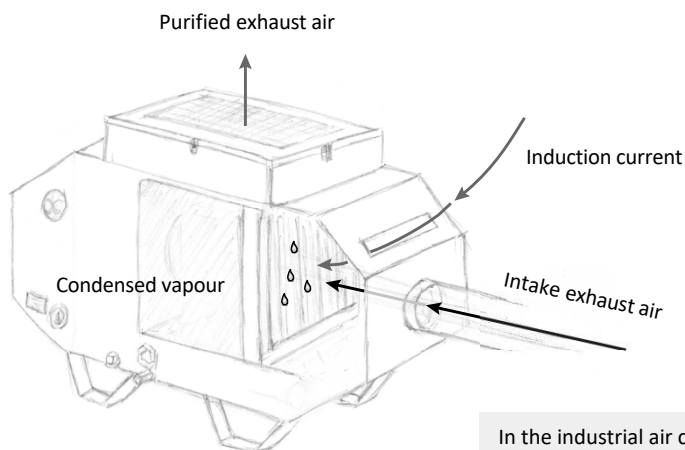
As described in Chapter 1, we at REVEN GmbH have developed collection devices that not only suck but also blow. The air to be captured, together with the aerosols, viruses and pollutants, is transported as quickly as possible by means of supporting blowing into the area where the extraction capacity of the air cleaners, kitchen hoods and ventilation units is greatest – i.e. directly into the area of their intake openings.

To this end, we have developed both modern kitchen hoods and industrial air cleaners equipped with an additional support blowing device. In the case of kitchen hoods, this ensures that rising cooking vapours flow quickly and directly from the cooking appliance into the filter and extraction area, where they are captured and extracted. We have also succeeded in forcing the condensation of evaporated liquids. The air in the induction flow, i.e. the blown-in air flow, is always a few degrees colder than the air to be captured. This temperature difference helps us to trigger the condensation of the evaporated liquids directly during capture and extraction, both in our advanced extraction hoods and in our air cleaners for machine tools.

Forced condensation



In the kitchen extractor hood: The cooler induction flow causes vapours to condense and be separated on their way to the exhaust air duct.



In the industrial air cleaner: The cooler induction flow causes vapours to condense before reaching the X-CYCLONE® separator, where they are separated.

Figure 22

Advantages of forced condensation

When the process exhaust air is freed from evaporated liquids and airborne aerosols, it is truly purified and clean. This also reduces odour emissions to a minimum and can be completely neutralised by downstream odour filters. The technologies used for odour neutralisation can be UV, ozone, activated carbon or chemical oxidation systems. They all have one thing in common: they only work and deliver their full performance if the exhaust air has been efficiently cleaned of aerosols and vapours beforehand. Only then does it make sense to install additional downstream technologies for complete odour removal. More on this in the next chapter.

4. How can viruses and odours Neutralised?



Neutralising odours and completely removing viruses and bacteria from the air is a task that requires several steps. The first step is efficient collection and extraction, followed by highly effective aerosol filters or separators. In this context, condensation of the vapours is also necessary, as discussed in the previous chapter. Only when all these steps are followed can odours be reliably and completely removed using UV-C or ozone systems.

Misunderstanding

UV radiation solves all problems relating to viruses, bacteria and odours.

A widespread misconception in ventilation technology and air pollution control that persists is the belief that there is no need to worry about all these steps, from detection and extraction to separation and condensation. Just put some lamps that emit ultraviolet light into the air cleaners and exhaust air systems and everything will be fine. This or something similar is suggested by the promises of many market competitors that I hear time and time again.

There is a great deal of misunderstanding and misinformation regarding the functioning and effectiveness of air purification technologies that use ultraviolet radiation. This begins with the fact that many manufacturers do not inform users about the actual area of application for ultraviolet radiation. An important aspect that must be considered is the question: "What is the intended purpose of using UV-C systems?" Do we want to rid the air of viruses and bacteria, or do we want to remove fats and oils from the exhaust air? I think you will agree that these are different tasks and that removing viruses from the exhaust air cannot be the same as removing oils and fats.

That is why we should first discuss why we actually want to use ultraviolet radiation in our ventilation system. The UV-C system used depends on the task at hand. Such systems can have the following different tasks:

- *Disinfection of objects*
- *Neutralising odours in the air*
- *Killing viruses and bacteria in the air*

These three tasks alone cover three completely different areas, each of which requires the use of very different UV-C systems. There is no single system that can perform all three tasks.

Added to this is the myth-shrouded task of so-called fat burning. We will clarify what this is all about later.

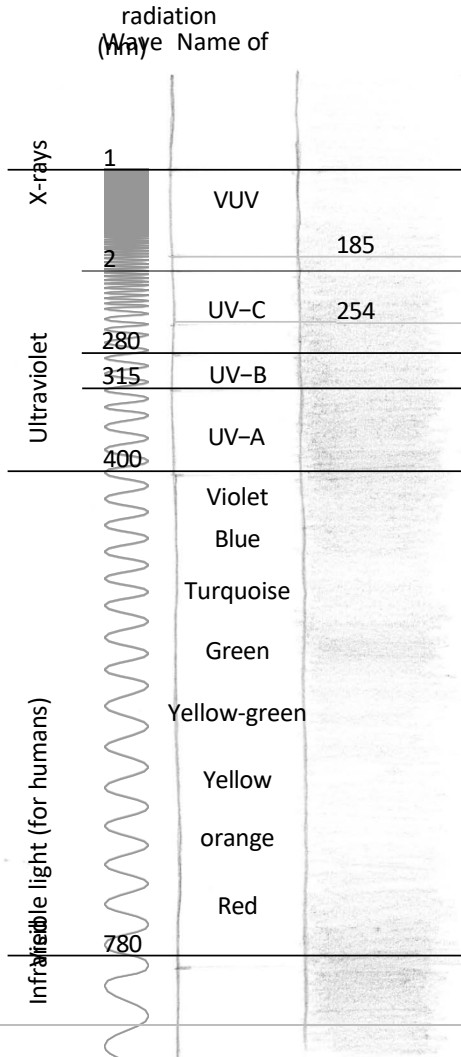
So we need a UV-C system that is specifically designed for one of these tasks. But even then, it is still questionable whether the task in question can really be solved satisfactorily.

4.1. The misunderstanding about UV-C radiation

UV-C systems are often integrated into air purifiers for residential use. In the wake of the global pandemic, the market was literally flooded with such air purifiers from 2020 onwards. Users were promised that the ultraviolet radiation emitted by these devices could kill dangerous viruses. But how is this supposed to work?

Visually, these UV-C systems resemble conventional fluorescent tubes, such as those used in lighting systems in large offices. They are available in different sizes. When a UV-C tube is switched on, it does not emit white light like office lighting, but shimmers blue, as is familiar from solariums. This blue light is artificially generated short-wave UV-C radiation with a wavelength of approximately 250 to 280 nanometres.

Electromagnetic spectrum



UV-A and UV-B

These UV rays are the only ones that reach the Earth. Humans depend on them to produce vitamin D in the body. They cause the skin to tan. However, in excessive doses, the radiation is harmful, both in the short term (risk of sunburn) and in the long term (risk of skin cancer).

UV-C

For sterilisation, artificially generated UV-C light with a wavelength of 250 to 280 nm. 254 nm is particularly ideal for damaging the genetic material of microorganisms. UV-C is also harmful to humans.

V(vacuum)UV

Artificially generated light with a wavelength of 185 nm is used from the ultraviolet spectrum to form ozone. This only works with special quartz tubes.

Figure 23

Wavelength factor

The wavelength range of the radiation is important for UV-C systems, as this is the only way to kill bacteria and viruses or prevent them from multiplying by damaging their genetic material. This knowledge has long been used in medical technology, for example to disinfect surgical instruments and medical tools. These disinfection devices are often rectangular boxes that look similar to standard microwave ovens. These boxes contain integrated UV-C tubes that can be used to irradiate the interior in a wavelength range of 250 to 280 nanometres. Objects placed in such an ultraviolet steriliser are disinfected by the UV-C radiation.

The time factor

The data sheets for these UV-C sterilizers repeatedly point out that complete sterility, i.e. sterilization, can be achieved after an irradiation time of only about 30 seconds.

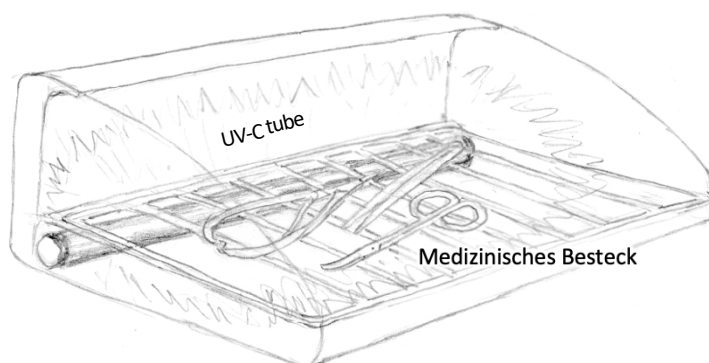
Most UV-C sterilizers allow you to set a disinfection time of 30 seconds to 60 minutes, similar to the time setting on a domestic microwave.

Wavelength+ Time= Desired result

This gives us an initial area of application for which there are many technical solutions, products and experiences: if we want to completely neutralise viruses and bacteria on objects such as scissors, knives, pliers, needles, etc., we need artificially generated ultraviolet radiation in a wavelength range of approximately 250 to 280 nanometres. It is also very important that these objects are exposed to this radiation for at least 30 seconds to ensure that they are truly sterile. Thus

At least, that is the recommendation of manufacturers of UV-C sterilizers, which have been used in medical technology for many years.

Disinfection in a UV-C steriliser



This modern steriliser works in two steps:

- UV-C radiation (254 nm) for at least 30 seconds to destroy the genetic material of microorganisms.
- VUV radiation (185 nm) to completely kill the microorganisms with ozone.

Figure 24

What conclusions should or must we draw from this for ventilation technology and air pollution control?

The answer is actually quite simple and obvious: if we want to kill bacteria and viruses in an air stream, we need the same ultraviolet radiation, and it must be exposed to the viruses and bacteria for a certain amount of time.

Misconception

Air sterilisation works in exactly the same way as for objects.

As simple and obvious as this sounds, this is where the problems in ventilation technology begin. In ventilation units and air purifiers, we are dealing with flowing air and not with objects that remain stationary for half a minute during sterilisation. Air moves through ventilation units and air purifiers at a speed of at least one metre per second. Everything in this air stream, including bacteria and viruses, travels at least one metre in one second. In many systems, the distances are even greater, ranging from two to five metres per second.

Distance travelled by air in one second

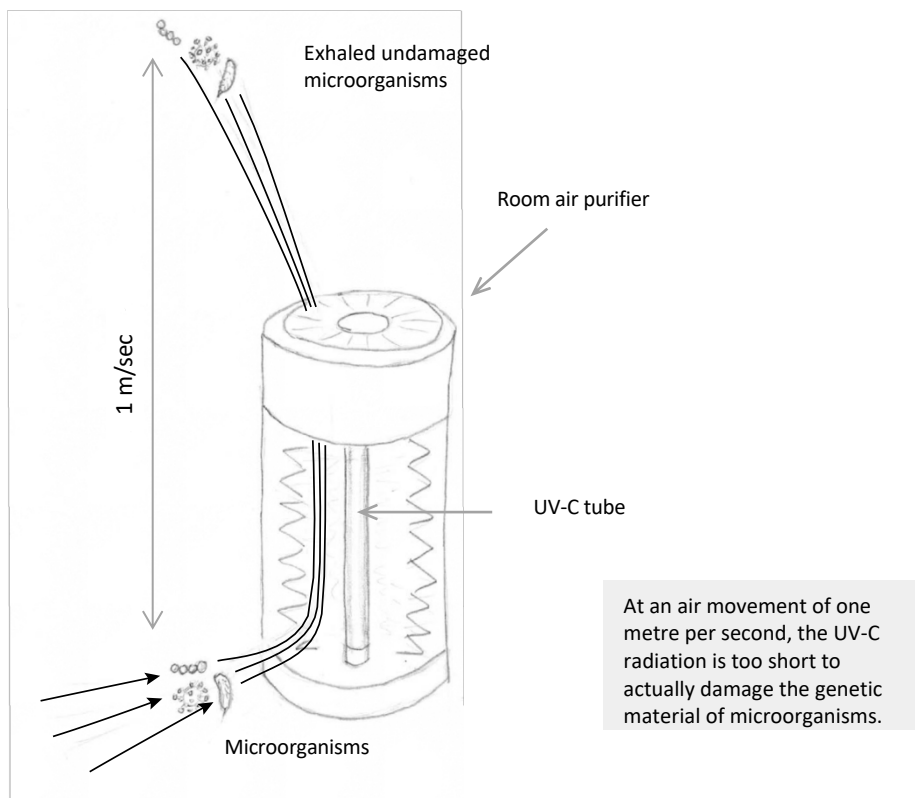


Figure 25

This circumstance already presents the first problem and a major challenge. As we have learned from the description of sterilizers in medical technology, it would be advisable to expose bacteria and viruses to ultraviolet radiation for at least thirty seconds. How can we achieve this in a ventilation system?

An exhaust air system with an air velocity of one metre per second would require a thirty-metre-long exhaust air duct with UV-C tubes. However, you will not find such a system. Ventilation units and air purifiers with UV-C tubes are rarely much longer than one metre. It is therefore very easy to calculate how long the bacteria and viruses transported with the air are exposed to UV-C radiation in these devices: in such systems, the radiation only has one second to act on viruses and bacteria. This is far too short a time for sterilisation.

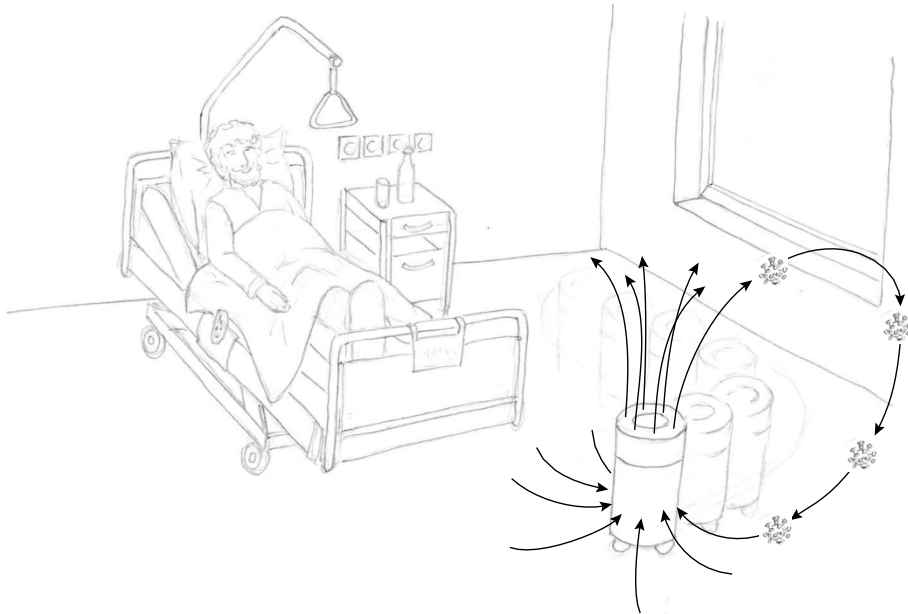
It is therefore not sufficient to simply install UV-C tubes in a ventilation unit or air purifier, and in most cases it is not advisable either. So what should be done?

One option would be to repeatedly bring the air into the area of the UV-C tubes for at least half a minute in order to achieve a sufficiently long exposure time.

Practical example: disinfection robots

This is essentially what the newly developed disinfection robots in hospitals do. These devices were developed during the pandemic and can be used in hospital rooms. They drive into a room automatically and clean the air there. To do this, they suck in the air and blow it out again. The air is exposed to ultraviolet radiation. This process is repeated continuously in the room for a certain period of time. As you can imagine, this allows an exposure time of at least thirty seconds to be achieved.

Disinfection robots in hospital rooms



Only when the same air is passed through the disinfection robot (simplified illustration) in a "continuous loop" can the hospital germs it contains be rendered harmless by the UV-C radiation.

Figure 26

However, this process can only take place if we have a closed room in which the robot can repeatedly draw in, irradiate and expel the same air for a certain period of time. If, on the other hand, we have a ventilated room into which fresh air is blown and from which the stale, contaminated air is extracted, the situation is completely different.

There is not enough time

Even with simple and small room air purifiers, it takes barely more than a second to suck in, clean and blow out the air. It is therefore clear that we cannot sterilise the air in such compact

air purifiers. There is simply not enough time.

Use of HEPA filters

The performance of compact room air purifiers can be improved by installing particulate filters. These are high-performance filters that can filter even very small particles, viruses and bacteria from the air. In combination with UV-C radiation, which irradiates this high-performance filter for long enough, the viruses and bacteria on the filter can be killed.

Auxiliary equipment: particulate filters

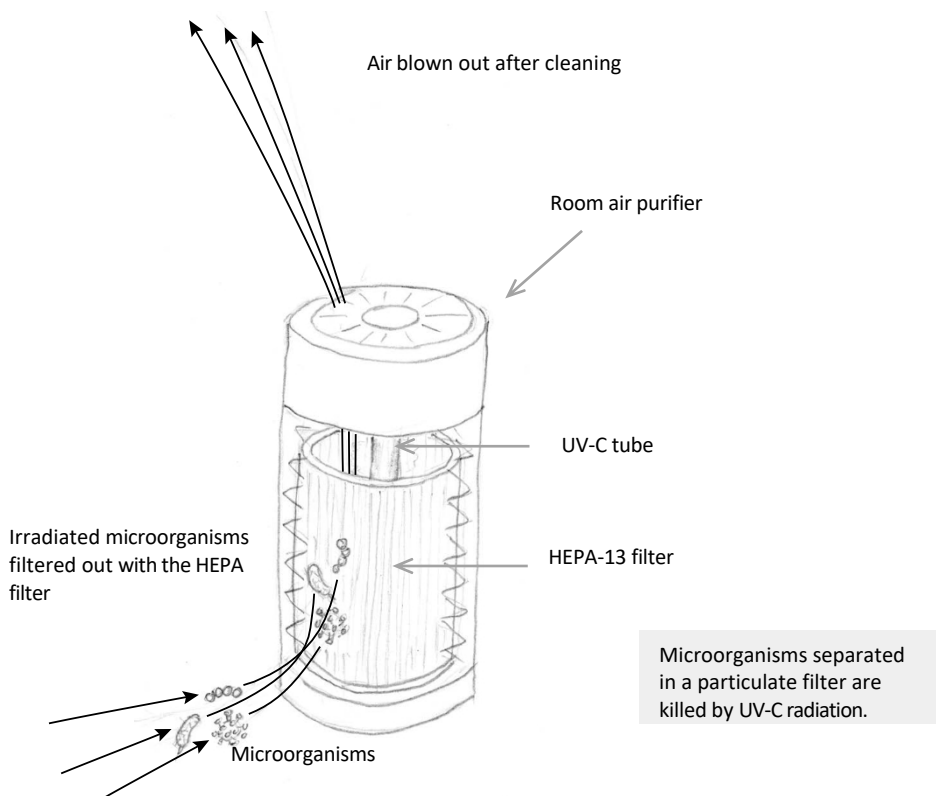


Figure 27

There are numerous comparable examples. Ultimately, it is always a matter of exposing viruses and bacteria to the appropriate ultraviolet radiation for long enough to sufficiently damage their genetic material and prevent them from multiplying. Only complete destruction can achieve true sterilisation. In more scientific terms, this fact can be summarised as follows:

The radiation has a lethal effect on viruses and bacteria if it is intense enough and acts for long enough.

Radiation intensity factor

The radiation intensity depends on the tubes, or more precisely, on their output per square metre of irradiated surface. The more power we use in watts, the shorter the exposure time required. If we use low-power UV-C LEDs that only deliver a few watts of power per LED lamp, we need a correspondingly long exposure time. The interaction is relatively simple: the higher the radiation output and the longer the irradiation time, the greater the disinfecting effect – and vice versa.

Let us now turn to the removal of oils and fats from exhaust air and how UV-C radiation can help in this process. Upon closer examination of this question, we encounter one of the greatest misconceptions in the field of ventilation technology and air pollution control. However, this is more of a mystery than a misconception and can be described with the following question.

4.2. Can UV-C radiation remove aerosols?

If we are to believe the claims of many manufacturers in the ventilation technology sector, then the answer is yes. It is often claimed that ultraviolet radiation from UV-C tubes is capable of removing oils and fats from the exhaust air stream. This mystery is particularly widespread in commercial kitchen ventilation. According to some manufacturers, it is not so much the aerosol separators I presented in chapter two as UV-C systems that supposedly keep kitchen ventilation free of grease and oil.

As explained above, such oils and fats can be present in the air either as aerosols or in vaporised form.

Misunderstanding

UV-C radiation cleans the air of fats and oils.

Many manufacturers claim that a suitable UV-C system in the kitchen exhaust air system can remove all these forms of grease and oil from the air stream and keep the kitchen ventilation system completely free of oil and grease.

Sounds great, doesn't it? Unfortunately, these groundbreaking air purification properties have not been proven once on a reasonably scientific level.

We now know how complex it is to reliably eliminate bacteria and viruses using UV-C radiation. Purifying the air of aerosols and droplets of oils and fats using ultraviolet radiation is something completely different!

This starts with the size and properties of these air pollutants: a virus is many times smaller than an oil aerosol. In addition, viruses and bacteria do not simply evaporate or decompose in other ways. Ultraviolet radiation damages their genetic material so severely that they can no longer reproduce and die.

When cleaning exhaust air of oils and fats, it is claimed that these are completely dissolved and disappear – at least according to the grandiose promises! How is this supposed to work?

Misunderstanding

Fat decomposes completely through photolysis.

Manufacturers make the most outlandish claims on this subject. For example, special UV lamps are said to be able to break down grease in the air through photolysis. This would reduce grease pollution by 95% and convert the grease into the end products oxygen, carbon dioxide, water and dust-like residues.

When asked how such claims have been measured and validated, the response is always the same: "We have observed this!" or "We have been installing such systems for many years and have observed this time and again; we cannot be mistaken!"

In most cases, there is no measurement technology, no measurement protocols and no studies whatsoever to even begin to support these statements and observations. The promises and assurances are based on decades of experience and personal observations, which cannot be wrong over such a long period of time.

Practical example: exhaust emissions

The VW Group also has decades of experience in the development of diesel engines and was certain that it could not be mistaken about the exhaust emissions of its engines.

Where does this excessive enthusiasm come from? Why do so many manufacturers use this technology in commercial kitchen ventilation?

Because it is an extremely lucrative business. The tubes are easy to purchase, and any reasonably experienced electrician can integrate them into an exhaust air system, meaning that you can upgrade your kitchen ventilation system by several thousand pounds with very little effort!

Misunderstanding

A kitchen ventilation system is always enhanced by the use of UV light.

However, this raises the question: has the system really been upgraded? Are 95% of grease and oil reliably removed? Does this additional investment actually provide the user with lasting added value?

To answer this question seriously, we need to look at the facts. Only then can we attempt to answer the questions posed above. To this end, we have listed all the well-founded facts relating to these myths:

1. A UV system must produce ozone

UV-C systems only have an effect on grease and oil in commercial kitchen exhaust air if the correct UV-C tubes are used. These must be capable of emitting ultraviolet radiation with a wavelength of less than 200 nanometres. This is only possible with tubes

made of synthetic quartz glass. The trick here is that ultraviolet radiation in a wavelength range of 185 nanometres is not filtered out by this glass and can therefore be emitted. This is the basic requirement for producing ozone.

2. The ozone is intended to oxidise fats and oils.

When the right tubes and radiation with the right wavelength are used, ozone is generated in the ventilation system. Ozone is important for achieving any effect on oils, fats and many other substances. However, it is a very strong oxidising agent. For this reason, it is also harmful to health and is even suspected of being carcinogenic. However, it can be attempted to oxidise oils and fats in kitchen exhaust air. But I deliberately say here: it can be ATTEMPTED!

Research report from the USA

Recent studies from the USA show that this oxidising effect on oils and fats does exist, but is not very efficient. Oils and fats are only partially oxidised, and these studies do not confirm the claim that oils and fats can be completely eliminated. On the contrary! Given the high risk potential of ozone, the question arises as to whether the production of ozone in such systems does more harm than good to the environment! The relevant research report was published in 2020 by ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) and is entitled "Research Project 1614 Determining the Effectiveness of UVC Systems on Commercial Cooking Effluent".

3. Effective grease removal in advance

Due to the low impact of ozone on oils and fats, the main focus in kitchen exhaust air systems must therefore be on capturing, extracting and cleaning the exhaust air using filters and separators, so that the exhaust air is already largely free of oils and fats. If the exhaust air also has a strong odour, this is due to evaporated

oils and fats. For this purpose – and only for this purpose – a UV-C system that produces ozone can be used to a limited extent. However, the potential hazards of such systems must not be ignored.

Sensible use of UV radiation in kitchen hoods

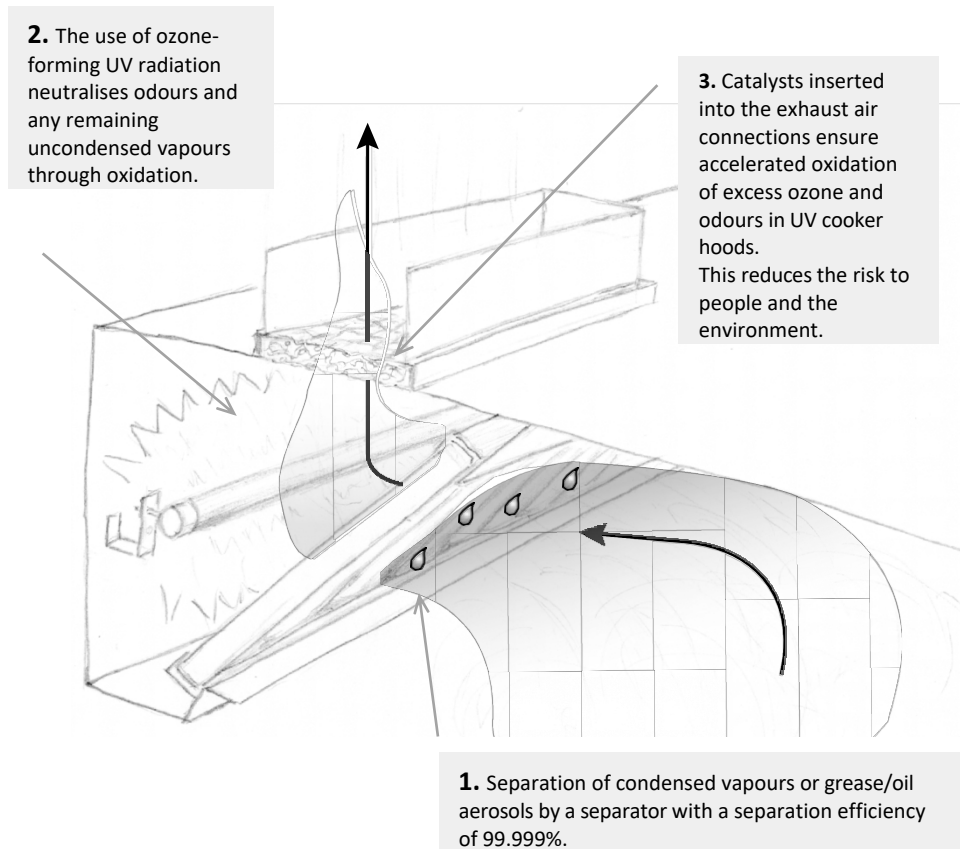


Figure 28

4. Ozone is potentially carcinogenic.

UV-C systems that generate ozone through their radiation pose a high risk potential, which users in commercial kitchens are far too rarely made aware of, let alone given detailed instructions on how to avoid health risks. As mentioned above, this radiation can damage the genetic material of viruses and bacteria. However, the damaging effect on genetic material is not limited to viruses and bacteria. It also affects people who are exposed to this radiation. The ozone produced is a harmful gas and is suspected of being carcinogenic.

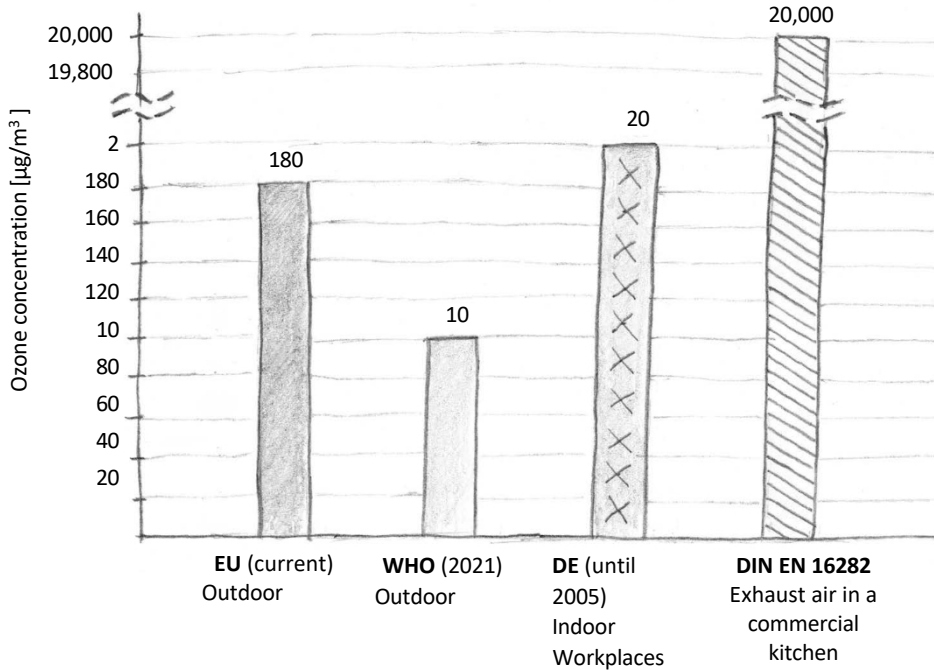
For this reason, all limit values for ozone in indoor spaces have now been abolished in Germany. In cities, ozone alarms are even triggered regularly when outdoor ozone levels are too high. When levels are high, the population is advised not to exercise outdoors and to stay at home if possible. However, many technical solutions in ventilation and air pollution control use precisely the type of radiation that produces such dangerous gases.

Practical example: kitchen ventilation

I have personally encountered several instances where chefs informed me about fluorescent tubes behind the filters in their kitchen hoods and were uncertain whether they were still operational. When I informed them and their kitchen staff that these were not fluorescent tubes but UV-C systems that generated dangerous radiation and released gases that were hazardous to health, I saw more than a few shocked faces.

This is a list of facts, which is by no means exhaustive and could certainly be expanded to include a number of other points.

Ozone limits



EU: maximum exposure level in one hour per day (1-hour average); if this value is exceeded, the population is informed



WHO: maximum exposure level in eight hours per day (8-hour average)



DE (valid until 2005): daily MAK (maximum workplace concentration). Since then, there have been no ozone limits for indoor workplaces in Germany, as ozone is suspected of being carcinogenic to humans. In Switzerland, the MAK of 200 µg still applies.



According to **DIN EN 16282**, 20,000 µg is the maximum ozone limit for exhaust air in a kitchen extractor hood. This is 100 times the workplace value in Germany (valid until 2005)! Or 200 times the WHO 8-hour average value for outdoor areas!

Figure 29

Measurement technology, for example, would be another point. You cannot imagine how many manufacturers sell ozone-generating systems but do not have suitable measurement technology to determine the concentration of the dangerous ozone gas.

Misunderstanding

Oils and fats have dissolved because they could not be measured (using certain techniques).

There are also manufacturers who use suitable particle measurement technology to provide allegedly verifiable proof that all oils and fats have been removed. In these cases, a simple temperature measurement would often be advisable. Why? Some systems have dozens of UV-C tubes installed in the exhaust air duct or kitchen hood. These become very hot during operation and heat up the entire surrounding room. This causes many oils and fats to evaporate.

5. How can air flows be made visible?



At the beginning of the pandemic in 2020, we observed an "exciting" trend in Germany. Not only did the range of compact room air purifiers suddenly explode, but there were also hundreds of ventilation experts and aerodynamicists in Germany. Thousands of graphical representations of air flow in open-plan offices or classrooms were created and displayed everywhere. What did all these illustrations have in common? They were colourful and featured lots of arrows. These usually pointed to an air purifier positioned in a corner of the room to remove viruses and pollutants from the air.

– , we know that sucking something in is extremely complicated. For this reason alone, it should now be clear that an air purifier in the corner is not capable of sucking in all the air in a classroom or open-plan office. No matter how many colourful arrows point to the room air purifier, the air will not flow there (see Fig. 5)!

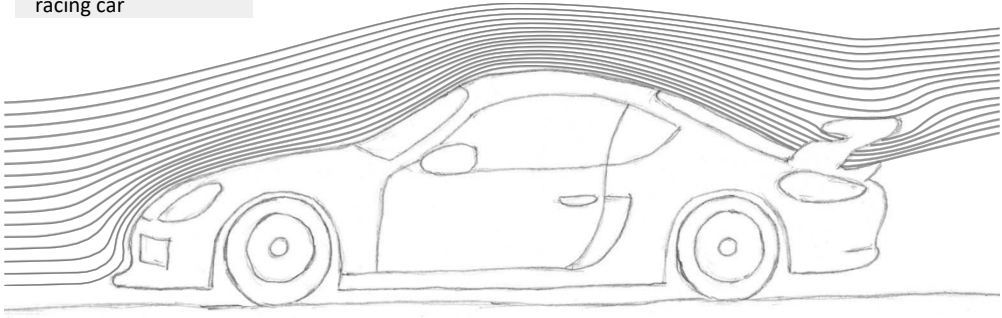
Most of these colourful graphics simply show fictitious air flows that have nothing to do with reality. But how can the actual course of these air flows be determined and made visible?

Basic research on the analysis of air flows

The Hermann Rietschel Institute at the Technical University of Berlin conducts extensive fundamental research on this topic. Representatives of the institute say the following about the analysis of air flows and the effectiveness of ventilation measures: "To evaluate how well air renewal and pollutant removal work in the room and in detail at each point in the room, we use what is known as ventilation effectiveness. This can be determined using numerical flow simulations and/or measurement techniques. We use these methods in all our projects to evaluate indoor air flows and develop new, effective forms of ventilation."

Visualisation of air flows

Visualisation of the aerodynamics of a racing car



Flow simulation has long been used in aircraft and racing car construction. Now, the calculation and visualisation of air flows is also used for optimisation in room air conditioning technology.

Figure 30

What does this mean for us? We need flow simulation and appropriate measurement technology. We have already mentioned this in previous chapters, for example in connection with aerosol filtration or UV-C technology. How is this process implemented for air flow?

5.1. The misunderstanding caused by the colourful pictures of air flows

The colourful images with lots of arrows are neither a numerical flow simulation nor are they based on measurements from a complex series of tests. In most cases, they are freely invented representations of air flow that have nothing to do with the actual conditions. They are literally plucked out of thin air and do not even begin to represent reality!

Misunderstanding

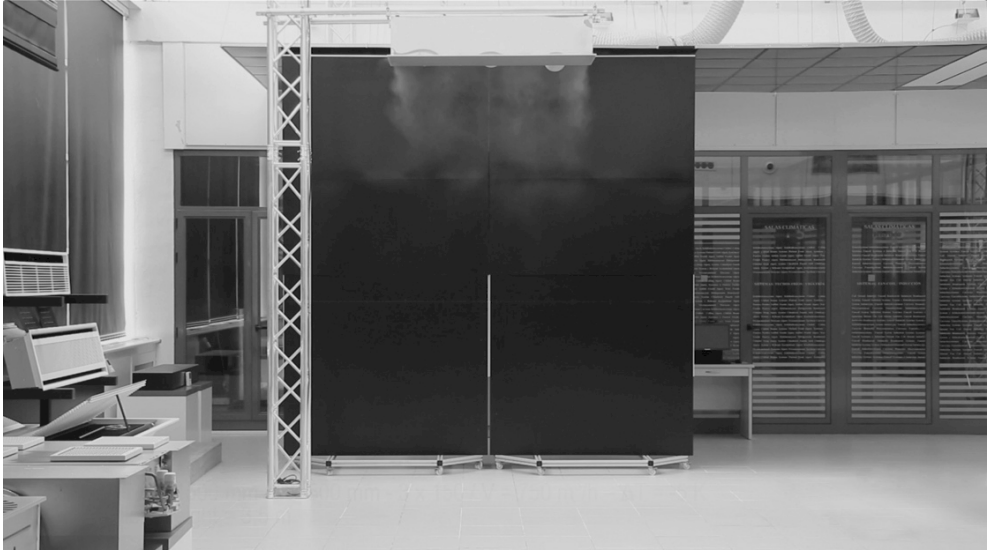
The path of the air flow is predictable.

A widespread misconception in ventilation technology is the hasty assumption that it is possible to know in advance how air will behave. In Chapter 2, we showed how this can lead to erroneous interpretations and false conclusions in product development. Even we in our team made this mistake back then, when we were developing our X-CYCLONE® technology. –

The SCHAKO CFD competence centre

Our SCHAKO Group even has its own team for flow simulations and measurement technology. At SCHAKO IBERIA in Spain, we have set up a CFD competence centre. This team is primarily concerned with the task so aptly summarised by the Hermann Rietschel Institute at the Technical University of Berlin! In our CFD competence centre, we use numerical flow simulations and suitable measurement equipment to visualise air flows.

The SCHAKO laboratory in action



Insight into the test setup for visualising supply air flows

Figure 31

Misunderstanding

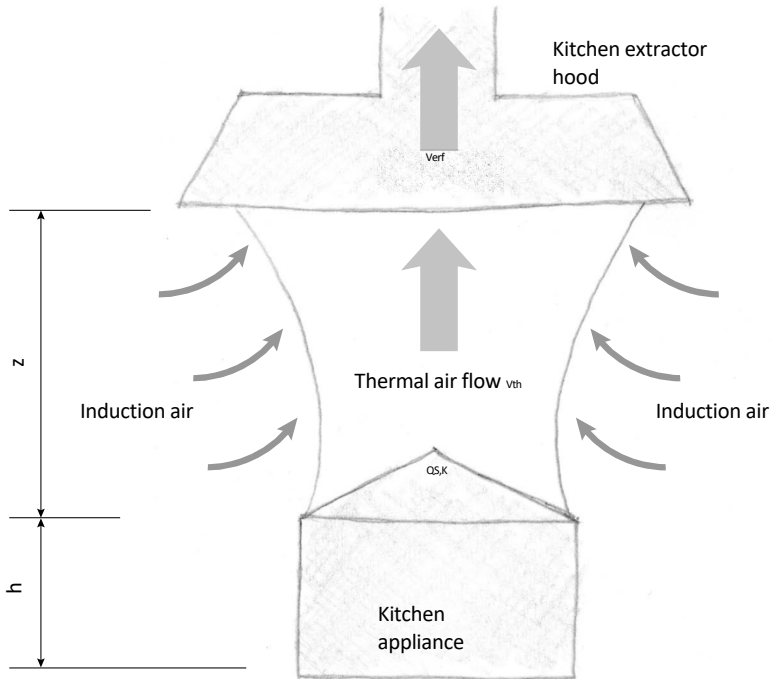
Visualisation models correspond to reality.

Standards and guidelines are also often based on the same misconception as the representations in the "colourful pictures". Guidelines for commercial kitchen ventilation such as VDI 2052 and international standards such as DIN EN 16282, which are valid throughout Europe, also contain representations with colourful arrows. The pictures show the cooking equipment in a kitchen and the air flows from this cooking equipment to the kitchen hood. Additional arrows pointing into the room are intended to represent the flow of fresh air into the kitchen. These are usually drawn as straight vertical or horizontal arrows, suggesting a sharply defined flow.

An arrow pointing vertically upwards from the cooking appliance and extending into the cooker hood is supposed to represent the air that is extracted directly and immediately at that point – but what does this have to do with reality? Certainly very little to do with the actual air flow. This is a model designed to represent the thermals above a cooking appliance. This thermal effect creates an upward air flow. This is captured by the kitchen hood above the cooking appliance and extracted. This is the model used in the VDI guideline VDI 2052. There is no question that this is a model from which a lot can be deduced. For example, design and calculation methods for determining the required exhaust air volumes are based on this model. These models are used to calculate the minimum exhaust air volume required by a cooker hood depending on the cooking appliances used.

So far, so good. However, what often leads to misinterpretations and misunderstandings is the assumption that such a flow model corresponds to reality. Unfortunately, this is usually not the case.

Simple flow model of a kitchen ventilation system



Simulated representation of the flow model according to VDI Guideline 2052:

The representation and direction of the arrows do not indicate the actual behaviour or real course of the individual air flows.

Figure 32

The actual course of air currents and their significance

As we have already seen, conventional kitchen and extraction hoods can only extract cooking vapours flowing upwards to a very limited extent. Very often, these vapours accumulate in conventional extraction hoods without being extracted immediately. This means that vapours that have been extracted can actually escape from the kitchen hood again.

The flow model in the aforementioned directive therefore only reflects the actual behaviour of air flows to a very limited extent. This also applies to models in other directives and standards. As with all scientific models, it is important to define the scope of the model precisely, i.e. to specify its area of validity. If the model is regarded as universally valid and understood as a representation of actual conditions, this will lead to fundamental misunderstandings! These will become apparent at the latest during a professional and appropriate CFD simulation.

5.2. CFD simulations make air flows visible!

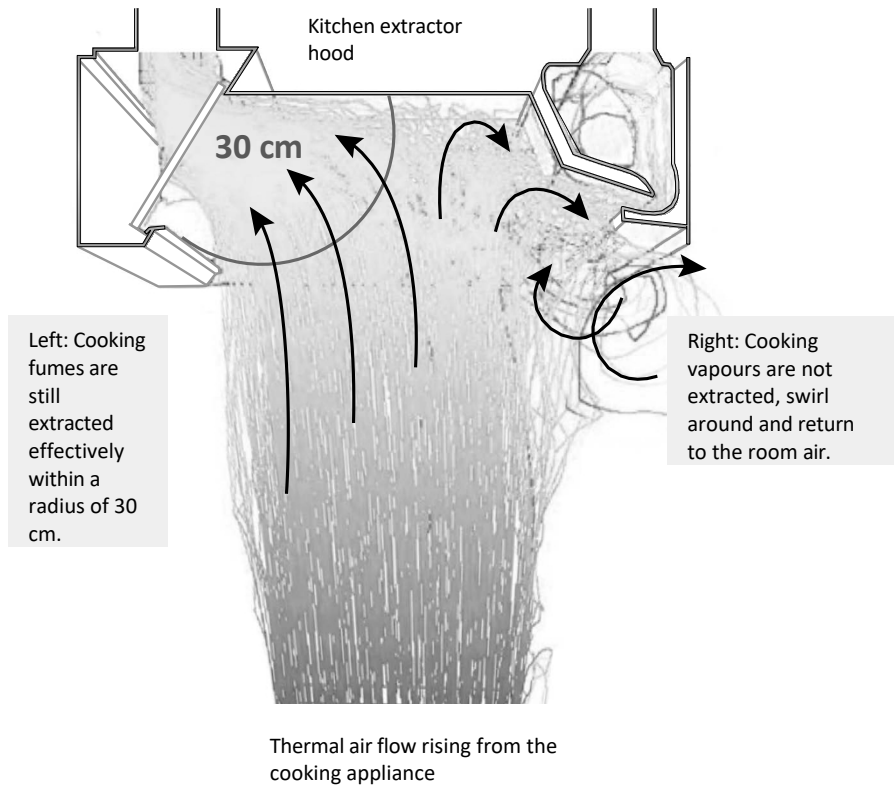
Well-designed CFD simulations show all physical variables of an air flow across the entire area. This allows the function and efficiency of a ventilation system to be demonstrated and verified. In Chapter 1, we have already shown in detail that conventional extraction hoods can only extract vapours flowing upwards directly in a narrow area around the intake point. At a distance of just 50 centimetres from the filters and the intake point, we can no longer detect any extraction. This is very easy to see in a CFD simulation, where the air flows show that vapours are also escaping from the kitchen hood. Vapours and air flows initially captured in the kitchen hood therefore escape again and are not extracted!

Misunderstanding

All rising vapours are extracted in a kitchen hood.

This observation refutes the model's assumption that all air flowing upwards from the cooking area into the hood is extracted immediately. We already know from previous chapters how to respond to this problem and what product developments are necessary based on these findings.

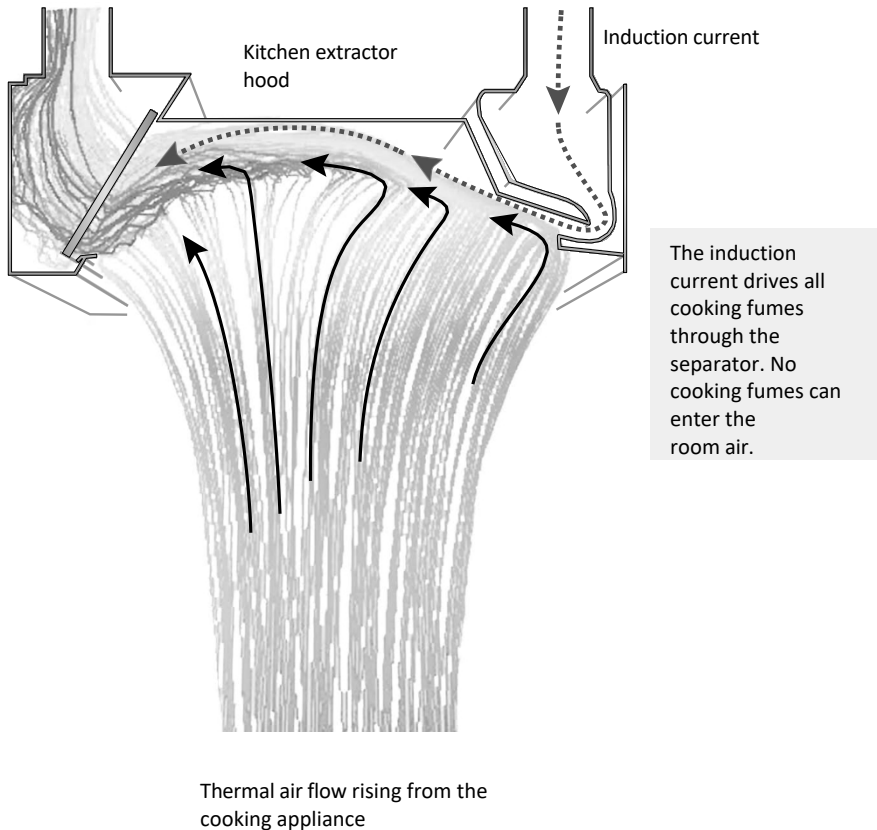
CFD flow diagram of a kitchen extractor hood without induction flow



This CFD simulation of the air flow in one of our kitchen hoods clearly shows how cooking fumes swirl outside the extraction radius and return to the room air when cooking is intense.

Figure 33

CFD flow diagram of a kitchen extractor hood with induction current



The CFD simulation shows the efficiency of an induction current.

Figure 34

This chapter also demonstrates how many misconceptions currently exist in ventilation technology and air pollution control. I have already explained that such misconceptions also existed at REVEN GmbH in the past. To conclude this series, here is another example:

In industry, it is not uncommon to use a so-called displacement ventilation system to supply fresh air to rooms. This involves supplying fresh air at low intensity. This means that the fresh air usually flows into the room at low velocity through fine perforated plates. Such displacement air systems are ideal where maximum comfort is required, as the low air velocity ensures quiet and draught-free fresh air supply. Ideally, a so-called layer flow is formed. The fresh air does not mix intensively with the air in the room; instead, thanks to this clever introduction, layers form in the room air, consisting of both fresh, uncontaminated air and stale or polluted air. In the ideal case, these different layers of air influence and disturb each other as little as possible. How can this be implemented in practice? Many manufacturers solve the problem with attractive "colourful pictures" with lots of arrows, similar to the model in the VDI guideline.

We at REVEN also succumbed to the fallacies of this model around 20 years ago. We designed new supply air products in which metal sheets were integrated in several layers. These were perforated sheets, i.e. sheets with thousands upon thousands of small holes. These serve to straighten the air flow.

In our opinion, the fresh air flow should be nicely fanned out so that it "trickles" evenly and slowly into the room. You can imagine this as being similar to a shower head. There, a strong, concentrated jet of water from the water pipe is evenly distributed and emerges from the shower head without much pressure.

Practical example: Source air systems – our assumption

Based on this principle, we developed the REVEN® displacement air systems around 20 years ago, because our team was 100% certain that such systems would only allow very finely distributed fresh air to "trickle" into the room form a clearly defined layer flow there to separate it from the stale air, and that these two air flows would not influence each other in any way. Just as in the many aforementioned

Models outline: Attractive blue arrows indicate how the supply air flows straight into the room and forms a layer of fresh supply air without disturbing the exhaust air shown by the red arrows, allowing it to flow unimpeded into the collection hood, where it is directly captured and extracted.

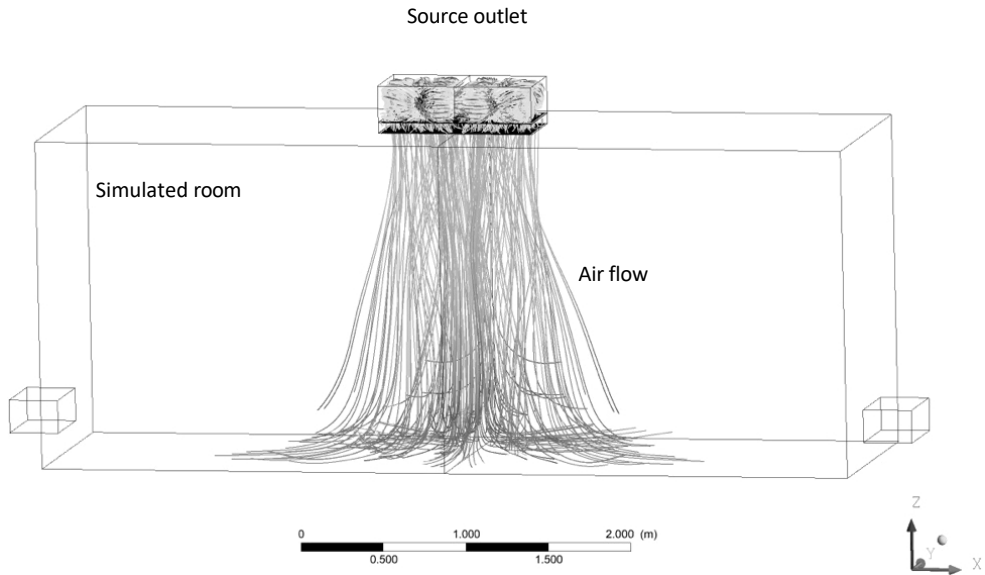
Practical example: Source air systems – doubts

I still remember when I presented our displacement air products to an expert from the Spanish SCHAKO CFD team in 2017. Using lots of great colourful pictures with arrows, I explained to him everything our supply air products can do. When he took a closer look at our design and analysed the relevant construction plans, he had doubts that quickly dampened my optimism. "Sven, we need to simulate this and record the measurements. I have my doubts that everything is as you have just explained to me." And what can I say? He was right!

Practical example: Supply air systems – the reality

When the technician showed me his initial CFD analyses, I was almost knocked off my feet. Shortly after the air flowed through the last perforated plate, the incoming fresh air fanned out and formed exactly the opposite of a sharply defined layer flowing directly from the ceiling towards the floor. I could hardly believe what I was seeing in the CFD analysis. The technician then examined our old supply air source outlet in the flow laboratory using measuring equipment and made the air flows visible with the aid of fog machines. This investigation showed the same result as the CFD analysis. By then, it was clear to me that we at REVEN had made a huge mistake!

CFD analysis of our source outlet



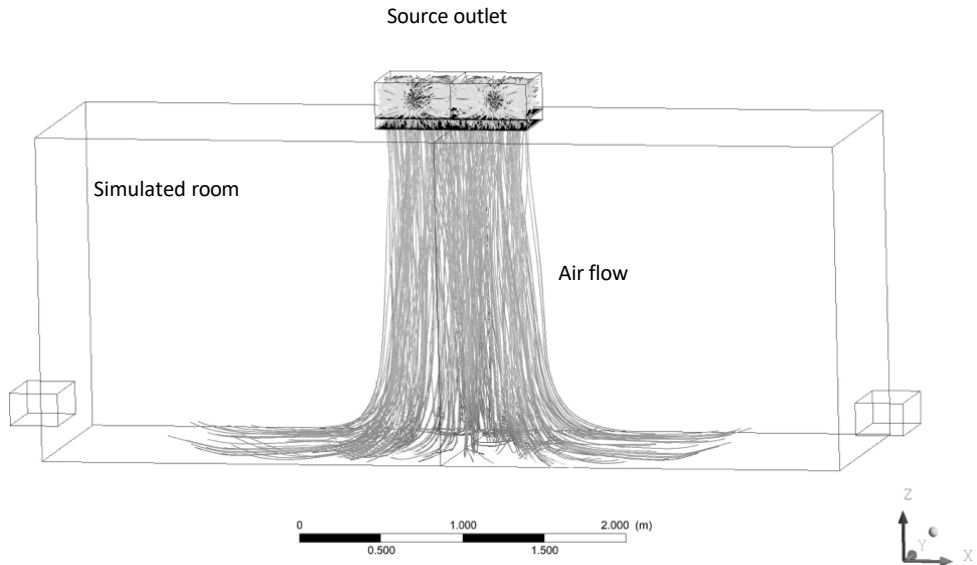
The CFD simulation shows the fan-shaped distribution of the supply air flowing in from the ceiling.

Figure 35

Practical example: Source air systems – optimisation thanks to CFD

True to the motto "better safe than sorry", we started doing exactly what we should have done from the beginning in 2017. We optimised the efficiency of our supply air products using CFD simulations and measurement technology, achieving an efficiency that really comes very close to the colourful picture with the blue arrow pointing downwards from the ceiling towards the floor.

Optimisation of the source outlet



The CFD simulation shows how the supply air flows in a straight line from the ceiling to the floor.

Figure 36

However, achieving this flow pattern required around 12 months of work involving numerous CFD analyses and flow simulations. The result was a truly efficient supply air system with no misunderstandings. Many thanks to the SCHAKO CFD team!

Visualisation of the air flow of an efficient supply air system



In the SCHAKO laboratory, the supply air is made visible using a fog machine. You can see how the supplied air flows gently downwards. Optimising the source outlet using CFD analysis has paid off.

Figure 37

6. How can air pollution be measured? be measured?



For many years, there has been consensus that polluted air is unhealthy. During the pandemic, we have learned how dangerous virus-contaminated air can be to our health. That is why I would like to list here what can contaminate or pollute the air. Air pollutants include, among other things:

- 1. Viruses and bacteria*
- 2. Fine dust, fungal spores and pollen*
- 3. Gases and vapours*

Particles and aerosols

According to information from the World Health Organisation (WHO), air pollution has the greatest negative impact on human health worldwide. That is why the PM standard was defined in the USA in 1987. PM stands for particulate matter and is the proportion of solid or liquid particles in the air. These solid or liquid particles are often components of aerosols. Aerosols are therefore a mixture of air and particles. Here, too, there are often misunderstandings and the terms are confused.

Misunderstanding

Aerosol is another word for particle.

The particles floating in the air alone do not constitute an aerosol; this only occurs in combination with the surrounding air. The term PM10 therefore defines the presence of tiny particles in the air with a diameter of 10 micrometres (0.01 millimetres) or less. By comparison, a human hair has a diameter of approximately 50 to 80 micrometres (0.05 to 0.08 mm). It should be noted that these suspended PM10 particles can consist of both solid dust particles and small liquid oil droplets. In simple terms, an aerosol always consists of gas, usually air, and a solid or liquid particle suspended in the air.

Size and composition of an aerosol

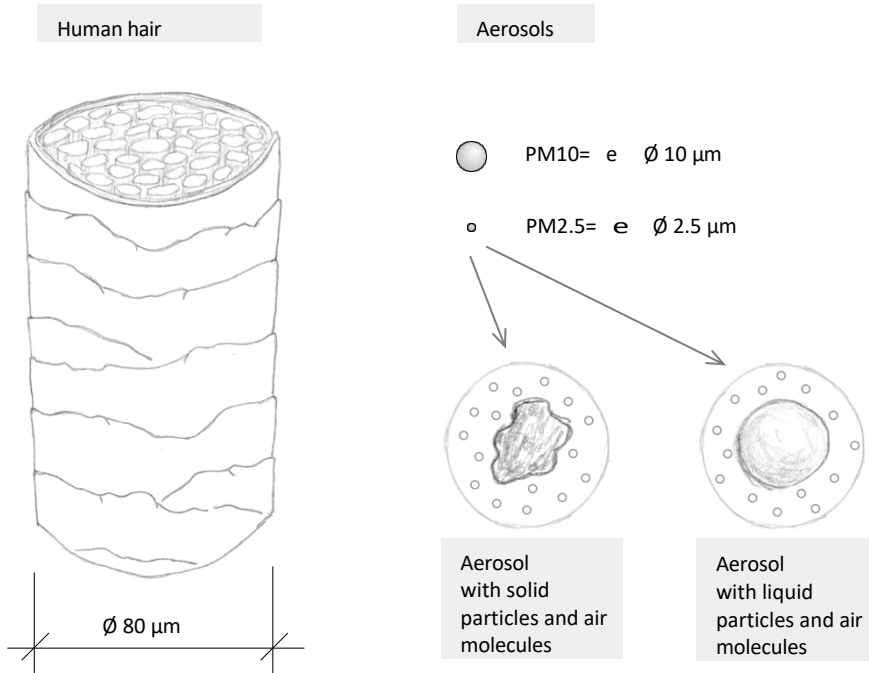


Figure 38

The designation PM10 or PM2.5 refers to the size of the particle. The number indicates the diameter in micrometres. Here, too, care must be taken to avoid misunderstandings!

Misunderstanding

The PM values can be used to determine the actual shape and size of a particle.

The specification of a diameter actually presupposes the geometry of a sphere. But how can that be? Do dust particles, grains of sand, viruses and all other air pollutants always have the geometry of a sphere? Of course not! These particles often have a completely different shape!

Assigning PM values to individual particles

But how can all these particles be defined by a diameter of PM₁₀, PM_{2.5} or PM₁? This can be done using a trick: simply compare the actual particles, which have any geometry, with particles that have a spherical geometry and behave in the air in the same way as the actual particles. This takes into account, for example, the flow behaviour, but also the diffusion behaviour and density of the particles. The aim is to identify which geometrically spherical particles exhibit the same behaviour as the actual particles in relation to these points. Spherical particles with the same flow and diffusion behaviour can thus be defined as PM₁₀, PM_{2.5} or PM₁. The diameter determined in this way is also referred to in science as the aerodynamic diameter.

Types, shapes and sizes of particles

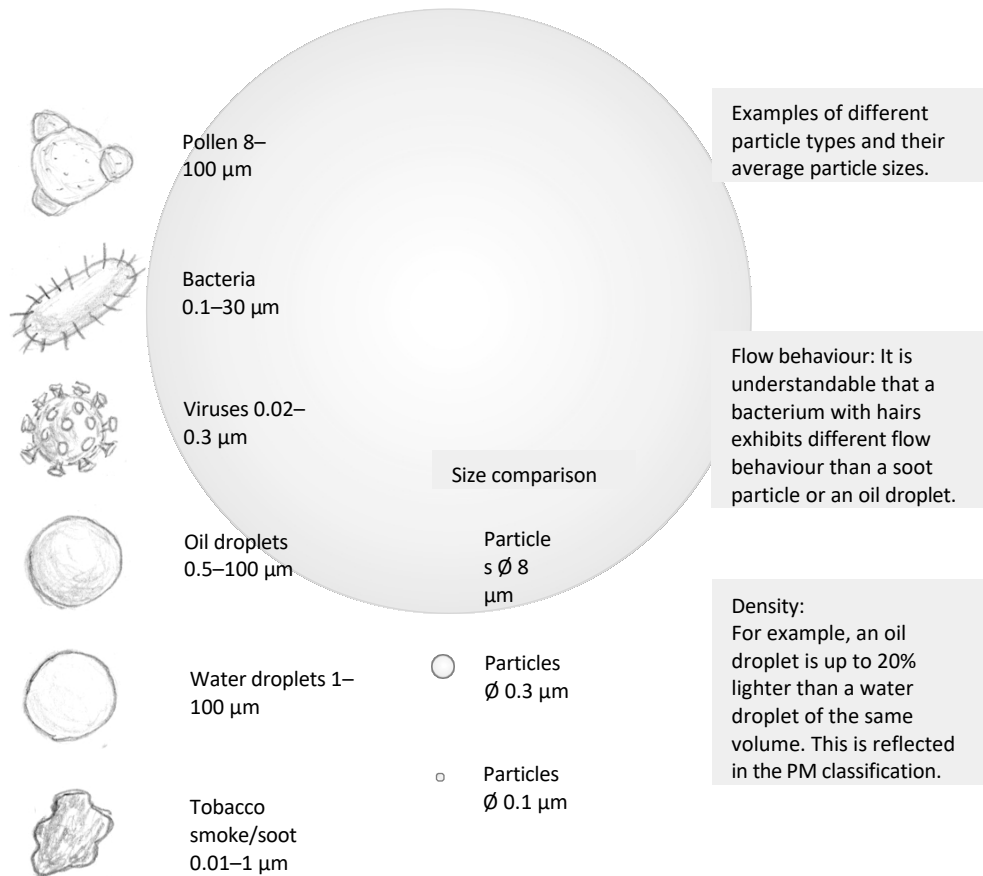


Figure 39

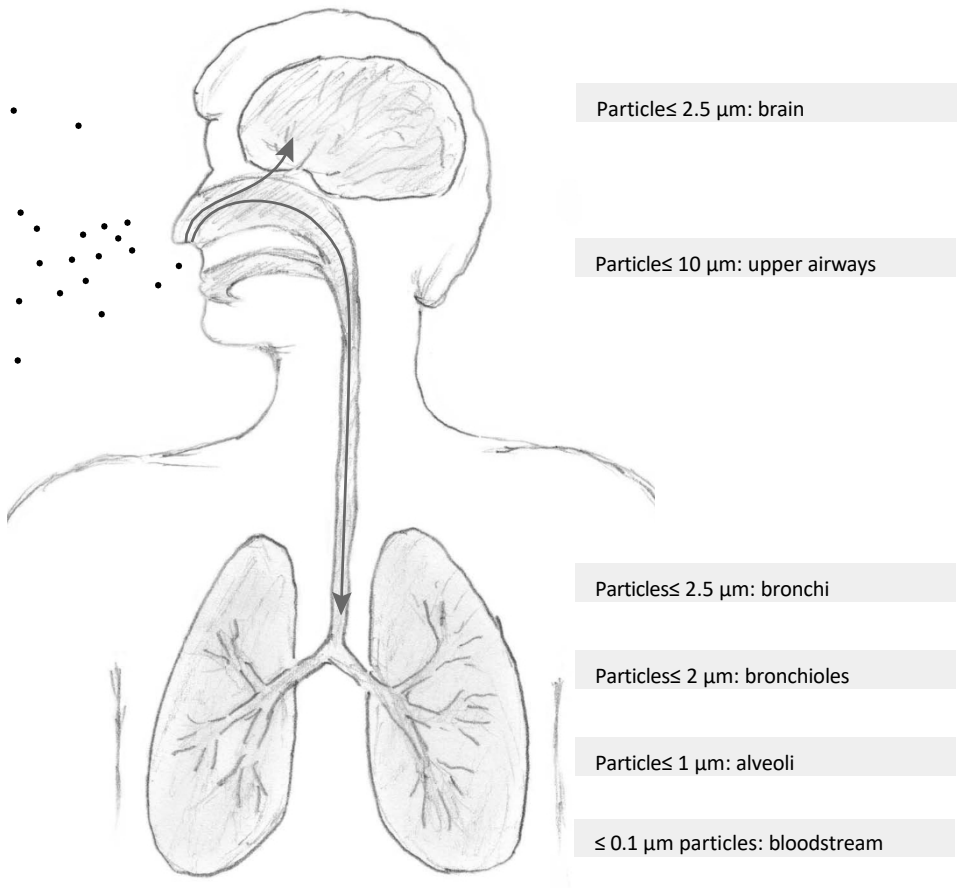
PM10 particles can be inhaled

When air pollution standards were defined in the USA in 1987, the first step was to investigate air pollution in the PM10 range, i.e. particles with a diameter of 10 micrometres and smaller. Why this size range? Because particles of this size are no longer filtered out and separated when inhaled through the mouth and nose. They reach the lungs.

PM2.5 particles reach the alveoli

This range has since been narrowed down to PM2.5. Here, too, health protection played a decisive role: particles smaller than 2.5 micrometres can penetrate our alveoli. If air pollution can penetrate into the innermost parts of our bodies, one can imagine the negative effects it can have on our health.

Particle absorption through inhalation



It is now well established that PM₁₀ particles in the upper respiratory tract and PM_{2.5} particles in the lower respiratory tract can cause damage. According to the latest studies, particles smaller than $2.5 \mu\text{m}$ can enter the brain directly via the olfactory nerve or the bloodstream, where they impair performance.

Figure 40

One of my interviewees recently summed it up in my new podcast "Luftpost" (Airmail):

"What we breathe indoors in a production facility are often substances that do not belong in our bodies and should not be allowed to enter our bodies!"

But here, too, there are major misunderstandings in ventilation technology and air purification!

6.1. The misunderstanding about indoor air quality

After more than two decades working in our industry, it still baffles me why there are such serious misconceptions about indoor air quality. For some inexplicable reason, people always assume that the air they breathe indoors is of acceptable quality and free from significant pollution.

Misconception

Indoor air quality is usually safe.

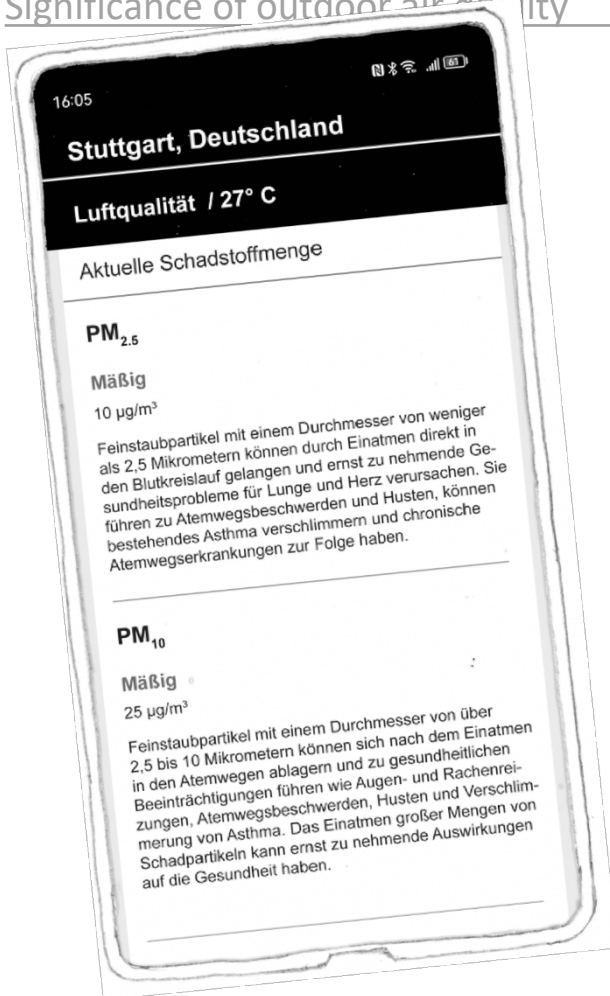
We have been committed to educating people about this topic for over a decade, but we are hardly being heard. We are often met with puzzled faces that reveal that people find it hard to believe what we are saying! Why is that? What are we trying to explain? It is actually quite simple: it is about how air pollution is dealt with in large German cities compared to how indoor air pollution is dealt with.

Fine dust measurement in large cities

In our cities, we talk about air pollution and consider driving bans when the limit value of 50 for PM10 fine dust particles is exceeded over a longer period of time. To determine the values, a measuring point in the city is used to measure how many PM10 fine dust particles are contained in one cubic metre of air.

To explain it again in simple terms: you have one cubic metre of city air and, using suitable measuring technology, you can measure how many particles of fine dust with a diameter of 10 micrometres or less are contained in this cubic metre of city air. The diameter of the particle can be used to calculate its volume, its density can be used to determine its weight, and the measured number can be used to calculate the total weight of pollutants in one cubic metre of city air. This total weight is expressed in micrograms.

Significance of outdoor air quality



The increasing importance of air quality can be seen in the detailed breakdown of pollutants in today's weather apps. The current values for the city entered are displayed, along with an explanation of what the pollutants can do.

Example:
Stuttgart on 14
July 2023
at 4:05 p.m.

PM10: 25 µg/m³

PM2.5: 10 µg/m³

Figure 41

Current outdoor air pollution limits

If, for example, the total weight is 20 micrograms, this is considered low air pollution according to WHO standards and therefore acceptable air quality. For example, the EU's particulate matter directive stipulates that the daily average value of PM10 particulate matter must not exceed 50 micrograms per cubic metre of city air and may not be exceeded on more than 35 days per year.

Global efforts to lower the limits

Discussions and efforts are currently underway worldwide to further reduce these limits, for example to 40 micrograms of particulate matter per cubic metre. The stricter consideration of PM2.5 particles instead of PM10 particles is also becoming increasingly important worldwide. So much for the situation in large cities.

Indoor air pollution

How does this compare to indoor air quality? In rooms where people cook, for example, or where modern machine tools process metal workpieces.

Practical example: indoor measurements

At REVEN GmbH, we regularly measure indoor air pollution. How do we do this? We use exactly the same measurement technology and procedure as described above for measurements in inner cities. We measure the number of pollutant particles in one cubic metre of indoor air, for example in a manufacturing plant or a large hotel kitchen.

The result obtained in this way gives an air quality index of, for example, 10,000, 50,000 or 100,000. These are completely different orders of magnitude than in cities! We have even had to present a measurement result of 500,000 to our customers! This means that up to 500,000 micrograms of pollutant particles are contained in one cubic metre of indoor air! And this is really not uncommon in production rooms!

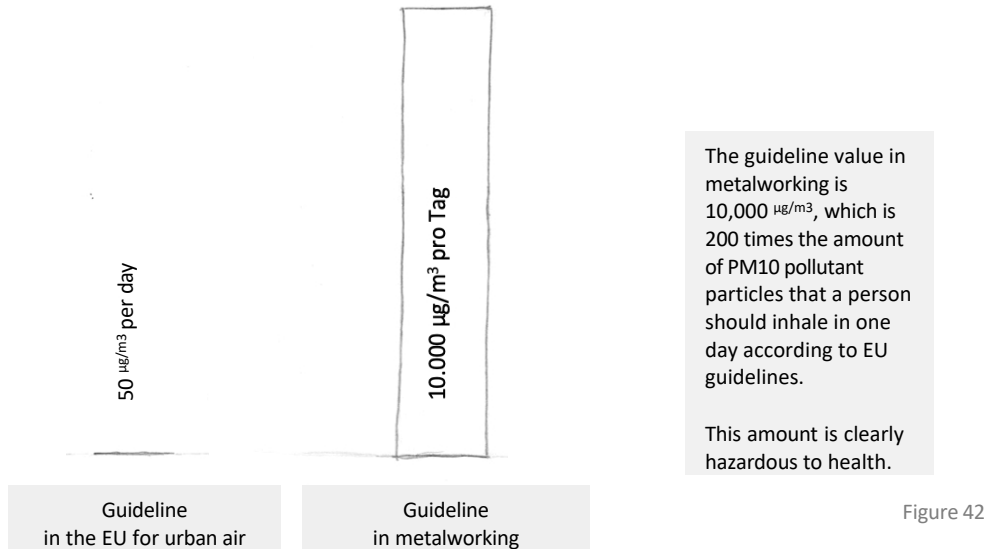
Official limit value recommendations for mechanical engineering

A review of the relevant guidelines and standards also makes it clear that such high levels of pollution are not uncommon. The following recommendation applies to mechanical engineering in official guidelines:

For water-miscible cooling lubricants used in metalworking and glass and ceramics processing, a limit value of 10 milligrams of these substances per cubic metre of room air is specified, as is the case for non-water-miscible cooling lubricants with a flash point below 100 degrees Celsius.

These 10 milligrams correspond to an air quality index of 10,000 in large cities! If such a value were measured in Stuttgart city centre for a week, no cars would be allowed to drive there during the day and all the media would report on it throughout the country.

Comparison of limit values for pollutant particles (PM10)



However, if such air pollution is measured in a machine shop or a hotel kitchen, hardly anyone is interested. Not even the representatives of these industries pay much attention to the issue. On the contrary– , against their better judgement, these conditions are hushed up because eliminating them would cost money.

Significance of the measurement results for employees

As a reminder, the EU's fine dust directive stipulates that the daily average value of PM10 fine dust must not exceed 50 micrograms per cubic metre of urban air on more than 35 days per year.

If the above-mentioned 10 milligrams are measured in a mechanical engineering company, this means that the employees in this company have to work at a maximum of 10,000 micrograms of pollutant exposure on around 200 working days per year.

Conclusion from practice

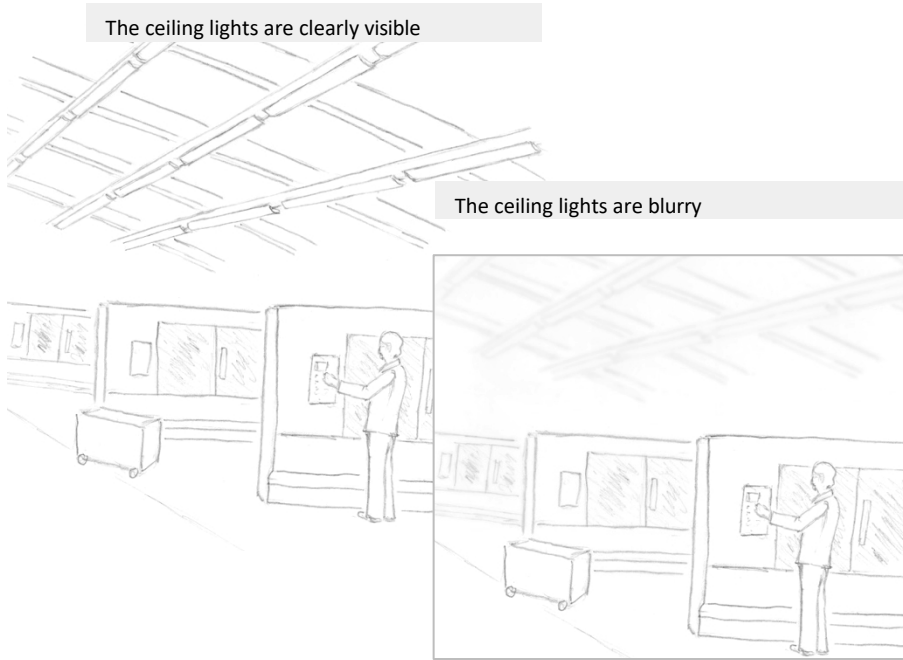
Over the past 20 years, we have taken thousands upon thousands of indoor air pollution measurements around the world. We have visited all kinds of production facilities where a wide variety of products are manufactured using a wide variety of materials. However, all of our measurements have repeatedly shown the following:

Whenever the air was visible, we measured air pollutants of over 10,000 micrograms in one cubic metre of indoor air.

A simple method for assessing air quality

In future, you may be able to assess air quality yourself! If you are in a production room– , whether in a hotel kitchen, a production facility in the food industry or in mechanical engineering, and you notice that the air no longer appears clear but rather resembles morning mist in autumn, then there is air pollution of at least 10,000 micrograms per cubic metre. The easiest way to determine this is to look towards the room lighting! If you can see the light clearly and the air around it is invisible, then everything is fine. However, as soon as you can no longer see the light clearly because a diffuse haze has formed around it, you can be sure that the air quality index in this room is around 10,000!

Simple assessment of air quality



If the ceiling lights in a room are not clearly visible, the level of air pollution is very high, at around $10,000 \mu\text{g}/\text{m}^3$.

Figure 43

Discrepancy between the assessment of outdoor and indoor air quality

This comparison with the intensively discussed air pollution in German city centres highlights the discrepancy that causes astonishment and incomprehension when it comes to indoor spaces. We are often asked how such differences can be explained.

In our opinion, they are simply indefensible. All attempts by those responsible to explain their actions are flimsy excuses to avoid urgently needed investments.

No one seems to be aware of the risks this poses for everyone involved. Concentrations of tiny particles that are considered seriously harmful to health outdoors are considered acceptable indoors at 200 times the outdoor level? Who will be responsible for this hazard in the future?

Ventilation system manufacturers need to rethink

We, the manufacturers of ventilation systems and air purifiers, must also face up to this problem! Why? Because there are hundreds of manufacturers of ventilation systems for commercial kitchens or mechanical engineering companies in our industry who do not even have the simplest measurement technology to measure and analyse such air pollution to any degree.

At the same time, however, they offer air purification products that are designed to ventilate rooms and remove pollutants from the indoor air.

The kitchen ventilation standard DIN EN 16282

There is now a "kitchen ventilation standard" for commercial kitchen ventilation systems, DIN EN 16282, which applies almost everywhere in Europe. This standard requires that all pollutants in commercial kitchens must be captured, extracted and then separated from the exhaust air stream, as we learned in the previous chapters.

If both of these things are achieved, i.e. the collection and extraction of pollutants and their separation from the exhaust air stream, you have

- a) a really good, modern and efficient ventilation system and
- b) good air quality with very low pollutant levels in the rooms.

Lack of implementation checks

Now my question to you: How many newly installed commercial kitchens do you think are checked for compliance with the standard when they are commissioned? About as often as the fuel consumption of new cars? Or as often as the power consumption of new heat pumps? In 1,000 newly installed commercial kitchen ventilation systems, this is checked in less than ten!

Practical example

I have seen several instances where competitors have approached us when a client insisted on this test and asked us to carry out the measurements for them because they did not have the necessary measuring equipment!

Ozone – an example of air pollution caused by gases

We have a very similar situation with air pollution caused by gases, where we observe the same phenomenon. I would like to illustrate this using the example of ozone. We already reported on the potential dangers of ozone in Chapter 4. The limit value for ozone in indoor air is still set at a maximum of 200 micrograms per cubic metre of indoor air in many European countries. This was also the previous limit in Germany, but it has since been abolished. However, this limit still applies in Switzerland. According to the classification criteria for carcinogenic substances of the German Research Foundation (DFG), ozone is classified as a substance that has not yet been sufficiently investigated but is suspected of causing cancer in humans.



for ozone levels

The weather app lists the highest pollutant values first. Ozone tops the list here with a value of 104 µg/m³. This concentration exceeds the WHO's recommended 8-hour average (see Fig. 29).

Example:
Hoyerswerda on 20
August 2023
at 9:55

o₃: 104 µg/m³

Figure

Ozone – outdoor limit values

The Federal Environment Agency provides information on outdoor limit values and health risks. It warns that ozone in the air can lead to reduced lung function, inflammatory reactions in the respiratory tract and respiratory complaints. The following applies

Limit value of 180 micrograms of ozone per cubic metre of city air. This value is referred to as the information threshold. If the concentration exceeds this value, recommendations for action and warnings are issued to the population via the media. At a concentration of 240 micrograms of ozone per cubic metre of city air, the alarm threshold is exceeded and an alarm is triggered. In addition, it should be noted that outdoor ozone levels may not exceed an average of 120 micrograms per cubic metre of city air over eight hours on more than 25 days of the calendar year.

Ozone – limit values in kitchen ventilation

However, experts in the field of kitchen ventilation currently still specify a permissible limit value of 20,000 micrograms of ozone per cubic metre of air. This information also originates from the European standard DIN EN 16282, a set of regulations that many national industry associations were involved in drafting. Who would think ill of it?

This standard stipulates that the concentration of ozone in the exhaust air of a commercial kitchen must not exceed 10 ppm. At an air pressure of 1013 hectopascals and a temperature of 20 degrees Celsius, the 10 ppm of ozone specified there corresponds almost exactly to a limit value of 20,000 micrograms of ozone per cubic metre of air (see Fig. 29).

Ozone – discrepancies that speak for themselves

I think that the differences in the assessment of indoor and outdoor air quality highlighted in this example speak for themselves and do not require further explanation. In this case, too, it should be clear to everyone what needs to be done, namely to completely avoid the formation of ozone, regardless of whether indoors or outdoors!

However, in order to achieve this goal, air pollution must be measured and analysed. We will explain how this can be done in more detail shortly.

6.2. Particle measurements make air pollution visible!

What measurement technology can be used to measure pollutants in the air? What measurement technology can be used to prove the efficiency of a ventilation system? Basically, this is not complicated and has already been described in Chapter 3. For precise determination of the pollutant load in the air, we recommend

- a) particle and aerosol measurement technology and
- b) a flame ionisation detector (FID)

We have already described FID measuring devices in detail in Chapter 3. Particle and aerosol measuring devices have long been state of the art for clean rooms. For decades now, there has not been a single operating theatre in a hospital or production facility for microprocessors where particle counters are not used to verify the function of the ventilation system when it is commissioned. Basically, this simply and conclusively proves that the air in such a clean room is really clean and free of even the smallest particles. This is what the particle counter is used for.

How particles are measured

Particle counters use complex optics and laser beams to analyse whether tiny particles are present in the air. They count the number of particles and simultaneously examine their size, i.e. determine their aerodynamic diameter.

Mobile particle counter

Mobile, battery-powered particle counter with scattered light measurement and data logging for real-time measurement of aerosol masses

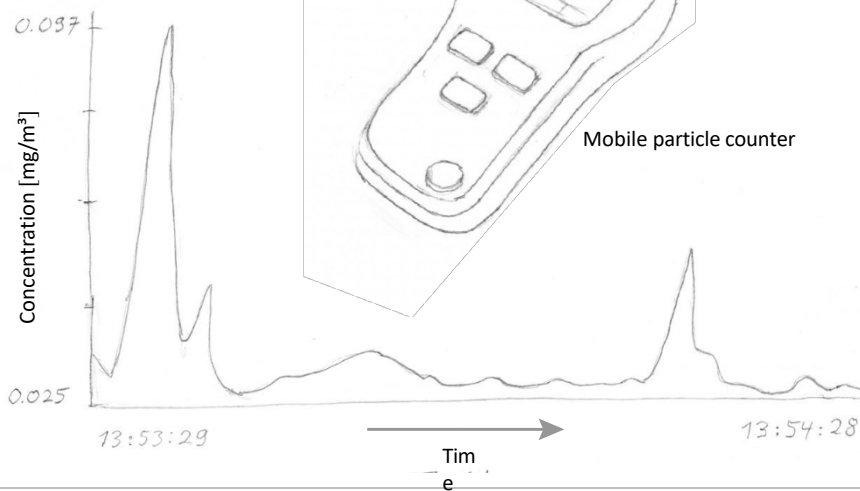


Figure 45

The particle measurement technology must be adapted to the situation.

Just like in clean rooms, you can also analyse the air in production facilities, commercial kitchens or machine shops and figure out how many particles are floating around. It's basically the same process, but with one big difference:

the number of particles differs enormously compared to clean rooms! While clean rooms are used to test whether PM₁₀ particles are present in the room air at all, the number of particles present in one cubic metre of room air is measured in the room air of a kitchen or production facility. This is often referred to as the

Ten thousand times more than in a clean room, or even more! The particle counters must be adapted to these conditions, or the correct measurement technology must be selected.

Practical example: Particle measurement by air dilution

When we carried out the first particle measurements in such highly contaminated rooms 25 years ago, we tried to use conventional particle meters, as there was hardly any more suitable measurement technology available at the time. As you can imagine, these initial measurements were often impossible to validate or reproduce and were of very poor quality, as the particle counters were completely overwhelmed by the high particle concentrations. A first approach to improvement was to dilute the air to be analysed in a defined manner. This meant that the air to be analysed was diluted 1,000 times with clean, particle-free air using suitable dilution stages. This diluted air was then measured with conventional particle counters and the result was extrapolated by a factor of 1,000. Simultaneous further development of the particle counters ensured that the devices were later less sensitive to very high particle concentrations and that the measurement results became increasingly accurate.

Modern devices ensure accurate measurements

Today's particle counters can even analyse heavily polluted indoor air with the same accuracy that has been standard in clean rooms for decades. The industry simply needs to want this accurate measurement and be prepared to invest in modern measurement technology.

Too few measurements are being taken

As things stand today, there are hardly a handful of manufacturers in the German-speaking kitchen ventilation market who use such measurement technology when commissioning new ventilation systems.

Unfortunately, this is not a misunderstanding!

The optimal functionality of ventilation systems is simply assumed, without measurement evidence.

The proper functioning of a ventilation system, the efficiency of detection and extraction, and the separation and filtering of pollutants from the air flow are all taken for granted and assumed to be a given. The motto is: it will work somehow and be fine. Most people don't really want to know if this is actually the case, and they certainly don't want transparency through analysis and documentation.

Measurement technology is essential for achieving optimum air quality

In the previous chapters, we have explained in detail how complex the tasks in ventilation technology, such as detection and extraction, filtering and separation, and ventilation with fresh air, actually are. For these reasons, measurement technology is essential to prove that the indoor air is really free of pollutants. There is no excuse for not using this measurement technology regularly.

Lack of measurement evidence for ozone air purifiers

Suitable measuring equipment can also be used to measure hazardous gases such as ozone. But even in this case, the same attitude prevails as with the particle measurement technology described above: among the thousands of suppliers of ozone air purifiers, you will hardly find one who can provide you with proof, using suitable measurement technology, that their products do not cause more harm than good through the ozone they generate.

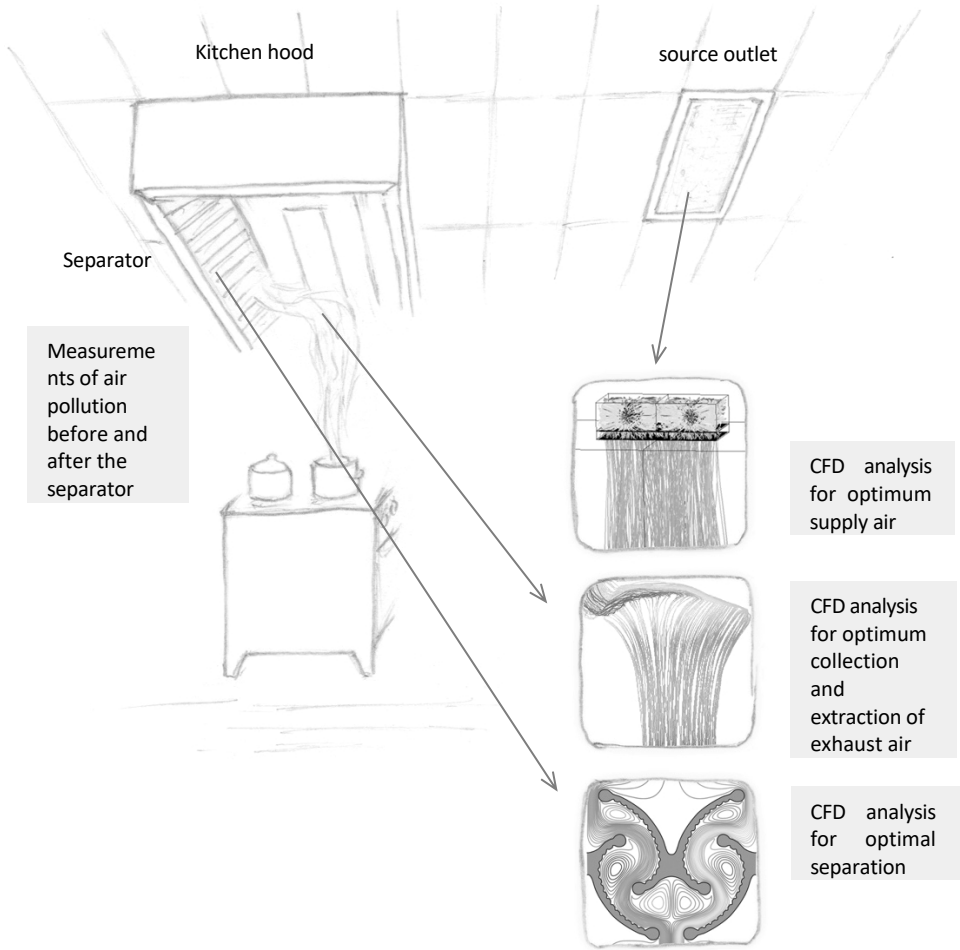
Reputable ventilation technology is scientifically sound

As demonstrated in the previous chapters, serious product development in ventilation technology and air pollution control requires a scientifically sound approach. Bold promises in attractively designed advertising brochures may all too often suggest otherwise in our industry. It is essential to remain vigilant and question such promises.

Conclusion

I hope that my comments have raised your awareness of this issue and provided you with some interesting information. We have now come full circle– , from efficient collection and extraction in Chapter 1 to suitable measurement technology for determining the efficiency of ventilation technology and air pollution control in Chapter 6, we have covered everything.

Scientifically sound ventilation technology



The functionality of kitchen ventilation technology is tested and optimised at Rentschler REVEN using scientifically proven methods.

Figure 46

Concluding remarks

You have now read all the chapters of this book, which were originally published in our podcast. "Misunderstandings in ventilation technology and air pollution control." I hope I have been able to give you some food for thought. A competitor recently criticised the content of the podcast. They said it was too superficial and that they had expected more from me. As I mentioned elsewhere, my aim was to make topics related to ventilation technology and air pollution control easily accessible and as entertaining as possible. I didn't want to write a scientific essay. The topics in our ventilation industry are rather niche topics that do not interest the general public. That is why it was important to me to explain the misunderstandings in a simple and understandable way, even to people outside the industry. I hope I have succeeded in doing so. We have written this book based on the podcast. It contains many interesting illustrations to visually reinforce the individual pieces of information.

It is important to me to make our industry attractive to young people, because air pollution control is an important issue and will continue to be so in the future. That is why we should approach this topic with care and a sense of responsibility.

My colleagues in sales will carry this book with them in future and will be happy to give you a copy to illustrate the various topics when you discuss new projects, new processes and new plans with them. Because we want our technologies and our products to be understood!

As a thank you to our podcast listeners, we are offering the newly published book free of charge.

Parallel to our book project, we now also have a new podcast. It is entitled "Luftpost" (Airmail).



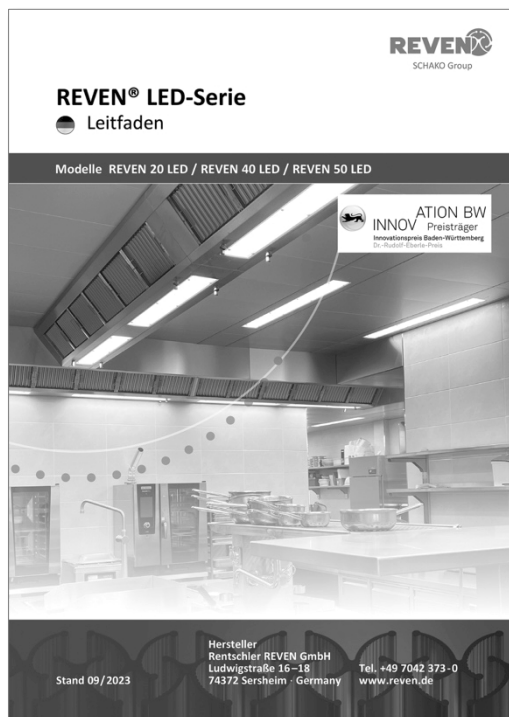
This new podcast series is all about healthy air. I introduce people and companies who are involved in air pollution control and ventilation technology. I interview players from a wide range of industries and discuss technologies. I chose this title because of the association the term evokes. In the past, news and announcements were often sent by airmail. I want to share the latest news on clean air and a healthy environment in my podcast "Luftpost" (Airmail).

You can find it at reven.news/luftpost, where the first episodes are already online.

If you are involved in the ventilation or air pollution control industry, we would be happy to create an episode of the podcast together. I would also be happy to visit you. Simply contact me atmarketing@reven.de .

Interesting facts made by REVEN

The guide to LED lights



The importance of good lighting for the use of a room is often underestimated.

Proper lighting is particularly important in commercial kitchens. Aspects such as brightness, contrast and colour should therefore be considered and taken into account during the planning stage. Our lighting management offers significant advantages in this regard.

In this LED guide, we explain which factors are important for good lighting and how REVEN® LED luminaires meet these requirements.

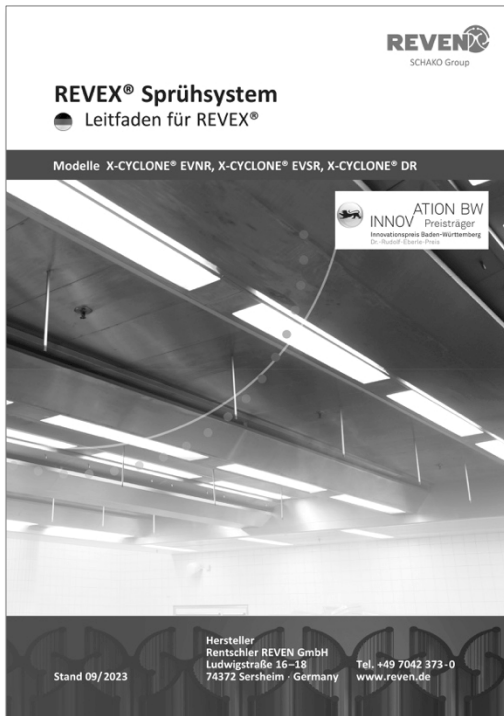
The RSC control brochure



To improve the efficiency of ventilation systems in commercial kitchens, Rentschler REVEN offers the intelligent RSC automatic control system. The system continuously adjusts the supply and exhaust air volume to the cooking activities, in line with the innovative Industry 4.0 standard.

Our brochure provides technical details on what needs to be considered when installing an RSC control system.

The guide to the REVEX® spray system



In the past, the topic of "cleaning kitchen ventilation systems" was often not given sufficient attention.

Regular, professional and proper cleaning of ventilation systems in commercial kitchens ensures that the system functions properly, reduces the risk of fire and prevents the growth of microorganisms inside the system. It also protects the health of kitchen staff.

Misconceptions in ventilation technology and air pollution control

The book

The response to the podcast was so great that it was almost inevitable that it would be turned into a book. Feedback that speaks for itself:

"... the podcast on air currents made me curious for more ..."

"... I would like to congratulate you on the interesting podcast

'Misconceptions in ventilation technology and air pollution control' and thank you for the information..."

"... Thank you very much for the really interesting podcast. I would be delighted to hear more. I have been a project manager in ventilation technology for over 20 years and have been able to take away a lot for practical use and further projects. I would be delighted if I could build the next kitchen system with you ..."

"... I would like to congratulate you on the podcast. The topic is very easy to understand, even for people like me who are not so familiar with the subject matter ..."

"... As an avid listener to your podcast, I would like to take this opportunity to order the reference book announced for 2023. I look forward to further episodes on the topic of air – our most precious commodity ..."

The author

Dipl. Ing. Sven Rentschler is the managing director of Rentschler Reven GmbH, a medium-sized manufacturer of air purification systems. As an entrepreneur, he has set himself the goal of raising awareness of air purification in industry and commerce worldwide. Two international patents and the Innovation Award of the State of Baden-Württemberg are the results of his commitment. Sven Rentschler is also a blogger and speaker on the subject of air pollution control.

The target

Anyone interested in what needs to be considered for optimal ventilation and air purification.

Beginners, refresher course participants and professionals in the air conditioning and ventilation industry, as well as cross-sector entrants from related trades, in particular ventilation designers in mechanical engineering and the food industry, contractors, experts, operators and planners of commercial kitchens.

● AIR ● CLIMATE ● COOLING

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