The book to accompany
the podcast, featuring
lots of illustrations

Sven Rentschler

Misconceptions in ventilation technology and air pollution control

CONSULTING + PLANNING

ISBN: 978−3−922420−74−3

1st edition 2023

Author: Sven Rentschler, Rentschler REVEN GmbH, Ludwigstr. 16–18, 74372 Sersheim

Photographs, image credits: Rentschler REVEN GmbH

Layout, cover image, drawings, illustrations: Gabriele Wiedemann, digital-kunst.com

Editing: Eva Schwarz, technische-uebersetzungen-eva-schwarz.de

Printing: Esser bookSolutions GmbH, Göttingen

Publisher: cci Dialog GmbH, Poststr. 3, 76137 Karlsruhe

You can find the full range of our own titles and an exclusive selection of specialist books at cci-dialog.de.
cci Buch is a brand of cci Dialog GmbH.

Feedback on the podcast

The response to the podcast was so overwhelming that turning it into a book practically happened of its own accord. Feedback that speaks for itself:

"... the podcast on airflows really made me want to find out more ..."

"... I'd like to congratulate you on the interesting podcast 'Misconceptions in Ventilation Technology and Air Quality Control' and thank you for the information …"

"... thank you very much for the truly interesting podcast. I would be delighted if it were to continue. I've been a project manager in ventilation engineering for over 20 years and have learnt a great deal that I can apply in practice and to future projects. I'd be delighted if I could you on the next kitchen ventilation system ..."

"... I'd like to congratulate you on the podcast. The subject matter is very easy to understand, even for people like me who aren't that familiar with the subject..."

"... as a regular listener to your podcast, I'd 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 resource ..."

Acknowledgements

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

Ms Wiedemann’s graphics and Ms Schwarz’s copy-editing draw on our many years of shared experience and form the basis for our unparalleled understanding of the subject matter. Working together on this book was a pleasant and straightforward experience, resulting in a product of a quality I could never have achieved on my own.

I would also like to extend my special thanks to our shareholders in the ScHAKO Group, who supported the project to write this book from the very beginning and recognised the opportunity it presented to emphasise our group’s slogan, ‘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 quality management over the past few 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 covered in this book in greater depth. You can contact me via LinkedIn. I look forward to exchanging views with 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 took place throughout the country. There were passionate debates about how classrooms should be properly ventilated. It was often noted with surprise that a great many office spaces could not be supplied with fresh air via a building's ventilation system. A gold rush suddenly broke out amongst manufacturers of compact room air purifiers. Across the country, there were heated debates on how indoor air pollution could be measured and assessed. Campaigns were even launched promoting clean air as the most important 'foodstuff'.

Where does this sudden and intense commitment come from? Many of these arguments and questions have been with me throughout my entire professional life. In 1995, I joined our company, REVEN GMBH.

REVEN stands for REntschler VENtilation. Ventilation is precisely the field that REVEN GMBH has been specialising in for generations, and one with which I too have been involved 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, for example, production halls in the food industry, mechanical engineering facilities, and large kitchens and canteens. These production areas all have one thing in common: the air inside the rooms or halls is often heavily contaminated and polluted. Measuring and analysing the level of pollution in such areas, and filtering and purifying the air – these are the tasks we at REVEN GMBH have been tackling for decades.

Since the start of the coronavirus crisis in 2020, these air purification tasks have suddenly become relevant not only to the industrial sector, but have become an issue across the whole of

Germany. During the discussions – some of which were conducted with great passion – I noticed that the requirements in the commercial and domestic sectors were becoming increasingly similar. However, due to the sudden and rapid surge in demand, some manufacturers were no longer being entirely accurate with their claims regarding the performance of their air purifiers. Many claims were made, and even more promises were given. The ventilation performance, filter performance and efficiency of many solutions are – particularly for laypeople – difficult to grasp and led to misunderstandings in the debate. These misunderstandings, for example regarding clean air and adequate indoor air purification in classrooms, are similar in nature to the misunderstandings that have become entrenched as half-truths in the industry over many decades.

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

I will not explain the individual topics in an overly scientific manner, but rather on the basis of the experience I have gained since 1995 in my professional work and practice at REVEN GmbH. Even whilst studying mechanical engineering at the University of Stuttgart, I gained insights into the key tasks involved in successful technology and innovation management. This enabled me to gain valuable insights into innovative product development and the exchange of knowledge between research and practice.
I would like to use this book to further support this exchange and explore it in greater depth within the field of ventilation technology and air pollution control, thereby dispelling a number of misconceptions.

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

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

Table of Contents

1. How can something be extracted ?

How can something be easily extracted? Essentially a simple question to which every colleague in the ventilation sector would have an immediate answer! But is effective extraction really as simple and straightforward as one might initially think?

Practical example: the vacuum cleaner

Here’s a simple example we’re 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 breadcrumbs, from the carpet. The closer we bring the vacuum cleaner nozzle to the crumbs on the carpet, the easier and quicker they are to remove. 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’s the answer to the question of how to vacuum something properly! You have to cover it one hundred per cent. Only then can it be completely vacuumed up. In our example, we had to hold the vacuum cleaner nozzle directly over the breadcrumbs on the carpet to vacuum them up properly and completely.

The correct vacuuming position

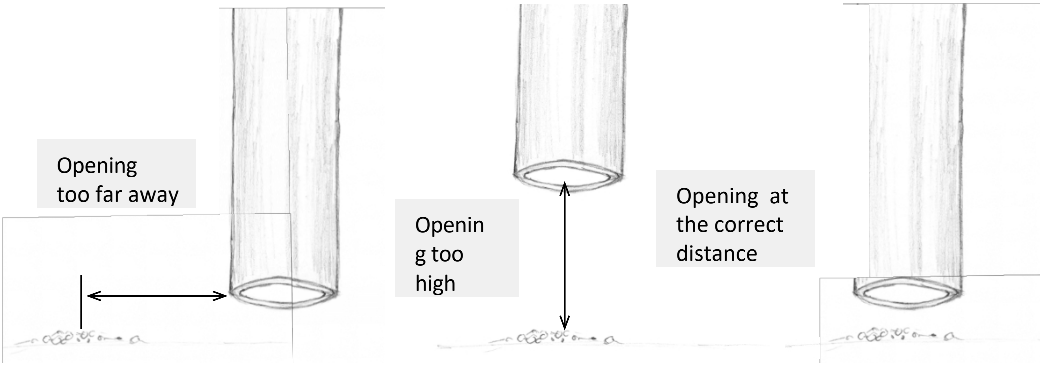


Figure 1

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

The main focus here must be on the sequence of operations:

First capture, then extract!

1.1. Misconceptions regarding the capture of airborne contaminants

As we learnt from our example at the start, the breadcrumbs on our carpet can only be vacuumed up quickly and easily if we hold the nozzle directly over the crumbs! The same applies to ventilation systems in kitchens. It is important to maintain the correct distance when extracting air. It makes no difference whether we are talking about a large ventilation system in a factory canteen or looking at our own kitchen at home. Even our designer cooker hood at home follows the same principle, described below, when capturing and extracting cooking fumes.

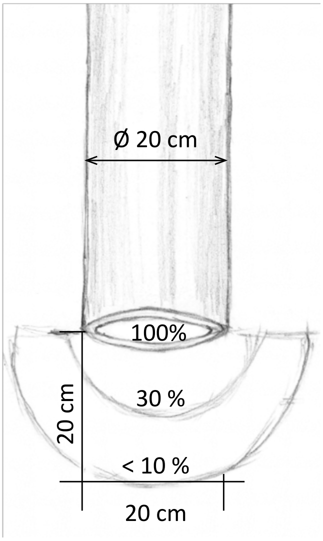
Misconception

> ***The relationship between extraction power and the distance of the extraction pipe***

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

What is very often underestimated is the extent to which suction power decreases. With a suction tube having a diameter of twenty centimetres, at a distance of twenty centimetres from the opening, the suction power is reduced to just 10 per cent of the original suction power.

Suction power in relation to distance



100% suction capacity directly at the pipe inlet

Suction power decreases significantly as the distance from the suction pipe inlet increases.

Suction capacity is only approx. 10% when the distance from the suction pipe corresponds to the pipe diameter (here 20 cm).

Figure 2

Thus, if the distance between a suction pipe and the source of contamination is exactly the same as the pipe's diameter, the suction capacity is reduced to only approx. 10 per cent.

This principle applies to every type of extraction system, regardless of whether it is a domestic vacuum cleaner or cooker hood, the ventilation system in a commercial welding workshop, or the large ventilation ceiling in the factory canteen. If the distance between the extraction system and the point at which the released pollutants need to be captured is too great, the extraction efficiency is zero. In the vast majority of cases, this is already the case at distances of thirty to fifty centimetres!

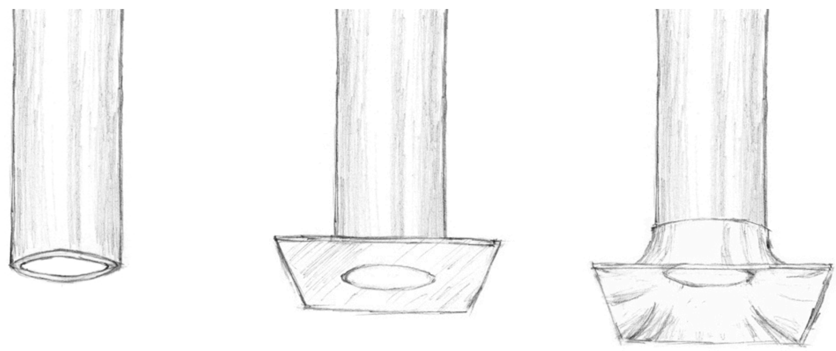
Misconception

Greater 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 a more efficient utilisation of the suction force. In this case, an additional plate is fitted around the suction pipe. The pipe is centred within an opening in the plate, and the transition from the plate to the intake pipe is shaped as an inlet nozzle over a radius. This inlet nozzle is intended to optimise the air flow in the intake area and thus ensure more efficient extraction. However, when comparing an intake pipe with a flow-optimised nozzle plate to a conventional intake pipe with a plate without an inlet nozzle, only minor advantages can be observed.

Nozzle plates

Nozzle plates are useful for 'guiding' the airflow, but have only a minor effect on suction performance.



Intake manifold without a nozzle plate

Intake manifold with flanged plate

Suction pipe with nozzle plate

Figure 3

Experiment – Extinguishing a candle flame by suction

To illustrate this, let's take the example of a candle. Have you ever tried to blow out a candle by sucking in air? I must warn you: you'd be better off not trying it! As part of my talks on this subject, I regularly demonstrate this experiment to an audience and, time and again, I almost burn my lips in the process, as I have to bring the suction point – that is, my mouth – very close to the candle in order to have any effect on the flame at all. Even so, extinguishing the flame by suction usually doesn't work!

This simple example clearly illustrates how limited the suction effect is and how important proximity to the suction point is when we want to capture and extract something.

Misconception

> ***Distance from the air purifier's intake opening isn't that important***

This misconception often leads to mistakes in practice: with air purifiers in schools, ventilation units on welding equipment, cooker hoods above hobs and aerosol separators on machine tools, the intake openings are often far too far away from the source of emissions.

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

CFD simulation

The capture and extraction of airflows 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. With the help of this simulation method, a wide variety of airflows can be visualised and the efficiency of the extraction system assessed.

Our in-house experience

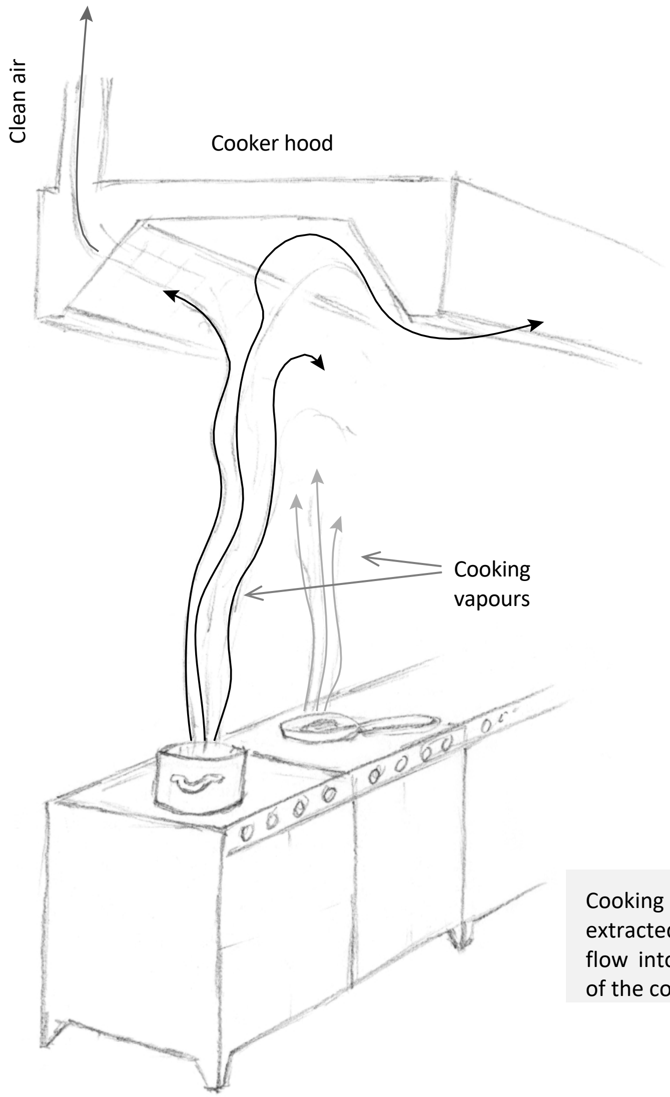
Within our company, we have used this method to investigate, amongst other things, the efficiency of the capture and extraction systems in conventional kitchen hoods. The first numerical flow simulations were carried out in-house as early as 199d. Analysing these simulations – which were still relatively simple at the time – and calculating 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 significantly more accurate and informative, even for highly complex components such as fans.
Thanks to this development, it is now possible to analyse and visualise not only the airflows 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 the cooking vapours that enter its capture zone directly. What does this mean in practical 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 vapours are only extracted properly if they flow into the extraction area of the cooker hood.

Figure 4

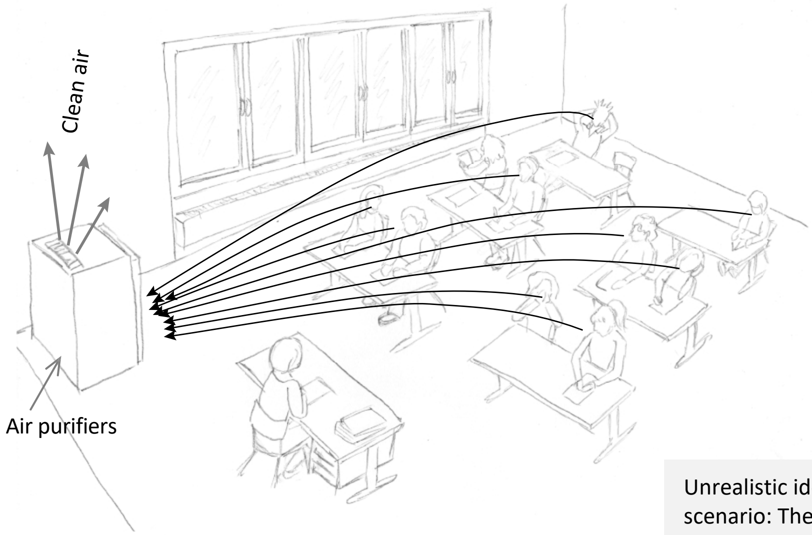
Implications for air purification in classrooms

If the air in a classroom is to be continuously purified of viruses during lessons, it must flow unhindered towards the air purifiers installed in the room so that it can be captured and purified there. Often, even a slightly open window is enough to divert the airflow in such a way that it is no longer adequately captured and purified.

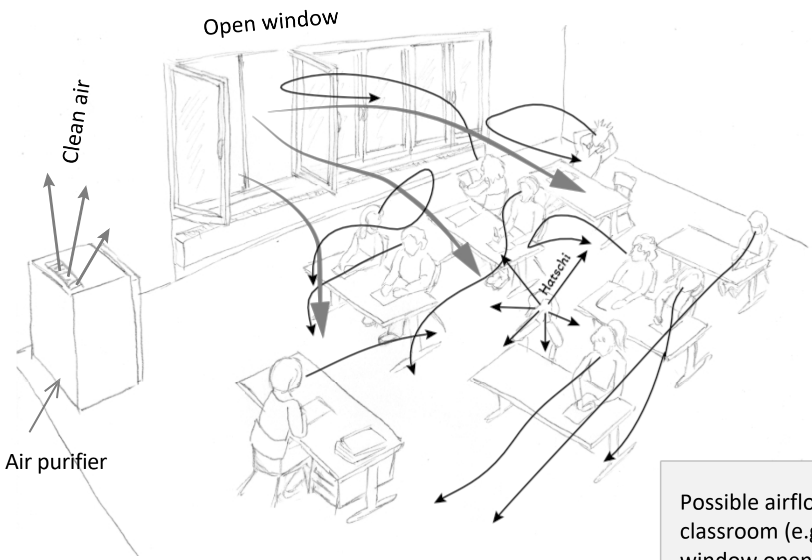
A poorly designed fresh air intake can have a similarly adverse effect on extraction as a tilted window through which the wind blows. With modern CFD systems, these interactions can be investigated, identified and prevented. Only in this way can complete capture truly be achieved.

CFD analyses of our own air purifiers and cooker hoods have also confirmed the principle explained above: the further away the extraction points of the cooker hoods are from the cooking pots, the less likely it is that cooking fumes can be fully captured and extracted. A similar finding has also been observed with air purifiers in school classrooms: the further away these were positioned from the area where viruses were being released, the less likely it was that the virus-contaminated air would be captured and extracted.

Ventilation in schools



Unrealistic ideal scenario: The air we breathe flows forwards towards the air purifier



Possible airflows in the classroom (e.g. with the window open)

Figure 5

Significance for extraction systems in mechanical engineering

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

Industrial air purifiers

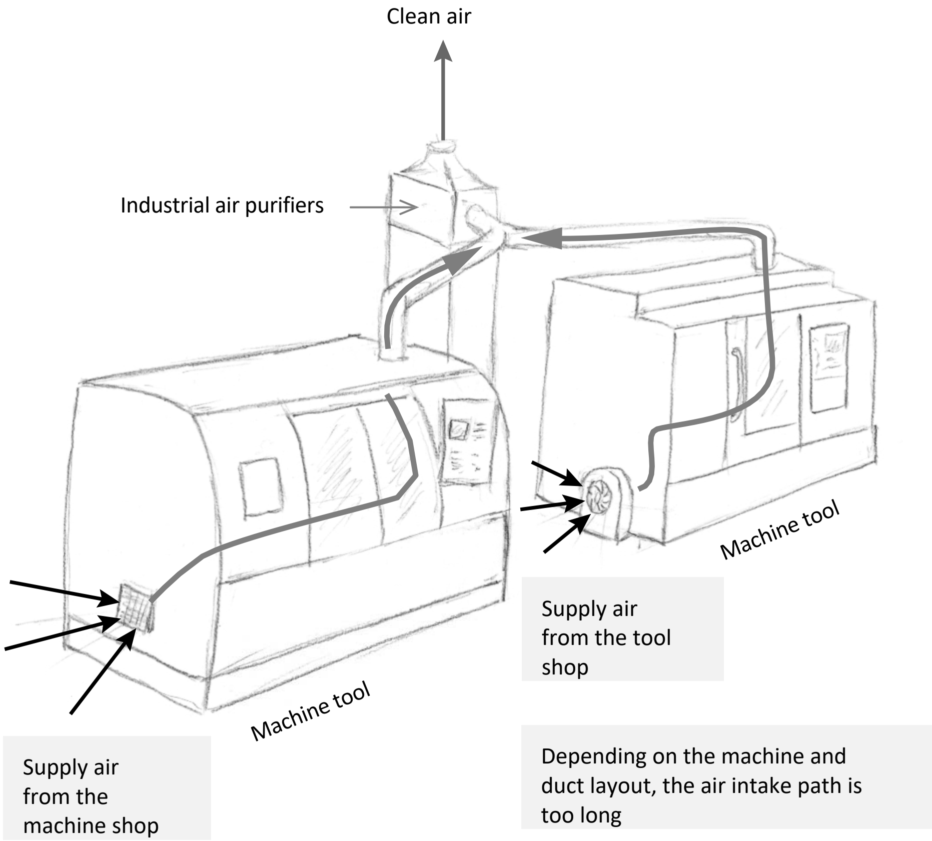


Figure 6

Misconception

Eventually, the pollutants will flow to the extraction point.

Time and again, in the fields of ventilation technology and air pollution control, we encounter the mistaken assumption that air contaminated with pollutants, viruses or aerosols will, sooner or later, flow into the area where it can then be captured and extracted. In many cases, however, this is precisely what does not happen. The aerosols and other pollutants that are not captured then cause a significant level of air pollution in the surrounding area.

1.2. Blowing can help with capture and extraction!

But what can be done if there is no way of moving the extraction area closer to the source of the pollutants? In this case, you can use the same method as when extinguishing a candle flame:

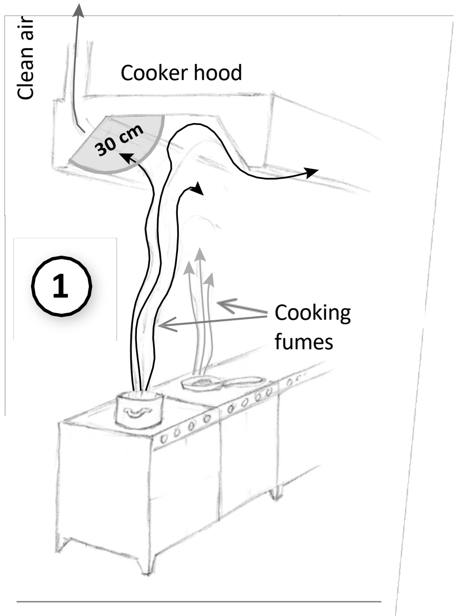
Blow instead of extract!

Applied to ventilation technology, this means that the air to be captured – along with the viruses, aerosols and other pollutants it contains – must be directed as quickly as possible, with the aid of blowing, to where the suction power of the air purifiers, cooker hoods or ventilation units is greatest – that is, directly into the area of their intake vents.

Blowing airflow for commercial kitchens

To achieve this, REVEN GmbH has developed modern cooker hoods with an integrated induction system. An induction flow reliably ensures that 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 vapours can only be drawn in (captured) within a radius of 30 cm in front of the extractor. Outside this area, the cooking vapours may enter the room air.

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

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

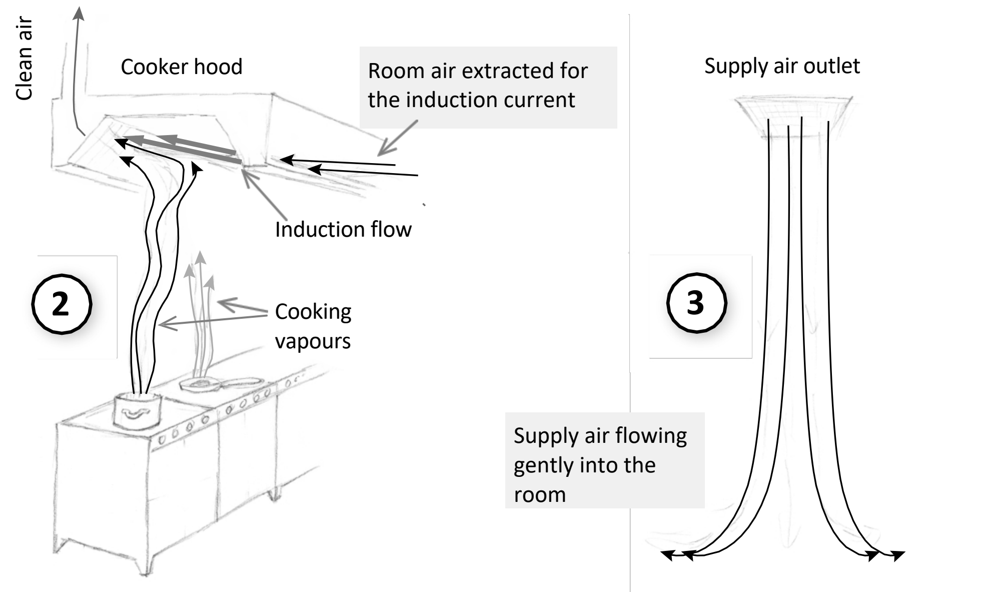


Figure 7

Additional fresh air

The extraction performance of modern cooker hoods of this type can also be enhanced by optimised fresh air injection.
In this process, the fresh air is introduced into the room with minimal turbulence using a displacement airflow. This ensures that the velocity of the fresh air is kept very low during injection and that other airflows in the room are not disrupted. This scenario can also be analysed and visualised using CFD systems.

Airflow for machine tools

The same principle can also be applied to machine tools. Here, an air flow is generated within the machine's enclosure which flows towards the air cleaner, ensuring that cooling and lubricant aerosols can be effectively captured and extracted. Optimising extraction in machine enclosures often begins 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 then flow back into the cabin? If there is no way to ensure that air flows back in, we end up with very high negative pressure in the cabin, but no targeted airflow towards the air purifier's capture area.

Practical example: Negative pressure

For instance, following the installation of air cleaners on very well-sealed grinding machines, the problem has arisen on several occasions that the machine's access door could no longer be opened because the negative pressure inside the enclosure was far too high!

2. How can something be filtered?

How can something be filtered? Essentially, this is a question just as simple as the one regarding effective extraction explained earlier. You can probably guess that, here too, the answer is not quite so straightforward.

The effectiveness of many processes in ventilation technology and air pollution control relies on efficient capture and extraction, including the removal of pollutants from the air. If, for example, virus-contaminated air in a classroom is not fully captured and extracted, it cannot be reliably cleaned of viruses. In principle, this also applies to a large welding shop in a mechanical engineering plant. The welding fumes released contain pollutants and must be fully captured and extracted. Only in this way can the indoor air be effectively cleared of all contaminants.

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

Capture,
extractio
n,
purificati
on

The third step – purifying the air – is the topic we shall be focusing on here. There are also a number of misconceptions here that I would like to clarify. 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, isn’t it! That is the obvious answer. However, separators are also becoming increasingly established in the air purification sector. Probably the best-known example of this is the cyclone vacuum cleaners produced by the global company Dyson, which operate without filters.

In principle, this technology works like a mini-tornado. The air is set in rotation, creating air vortices which, due to their high speed, fling particles out of the air. This process is also suitable for separating airborne pollutants. However, misunderstandings often arise here, as separation is frequently confused with filtration.

2.1. The misunderstanding regarding the difference between filtration and separation

Non-woven fabric

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

Glass-fibre HEPA filters

This is essentially how every type of filtration works in ventilation technology – including very high-quality HEPA filters. However, different filter materials are used here. Instead of non-woven fabric, glass fibre mats are used for these filters. These mats are also air-permeable, but the weave is much finer than that of vacuum cleaner bags. The fibres in particulate filters have a diameter of around 1 to 10 micrometres, i.e. 0.001 to 0.01 millimetres. This means they can filter out much smaller particles from the air stream than the non-woven fabric.

Metal mesh filters

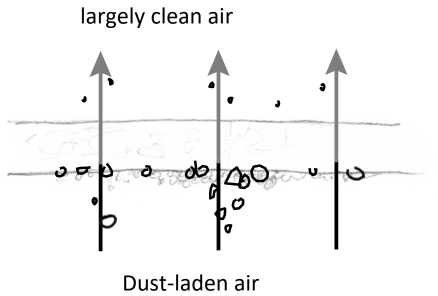
This filtering principle is also found in many standard kitchen extractor hoods for domestic use. Metal filters are frequently used in these extractor hoods. They usually consist of an aluminium or stainless steel mesh, which works on the same principle as the non-woven fabric or glass fibre mat, but with a much coarser structure.

The relatively coarse metal filter is used here because it is considerably more robust. Whether in domestic or commercial kitchens, cooker hoods are designed to separate liquid aerosols from the air stream. In this case, it is not dry dust – as with a vacuum cleaners, but liquid particles such as water and oil droplets that need to be filtered out of the air. This is a significant and very important difference that is often given very little attention.

Every type of filter collects and stores whatever is separated from the airflow. The amount of filtered material in the filter therefore increases constantly. In the case of a vacuum cleaner bag, dry dust is collected and stored until the bag is completely full of dust and needs to be replaced.
However, if the material filtered out of the air stream consists of liquid droplets, collecting these substances is often considerably more complex.
Metal mesh filters trap the small droplets of various liquids directly within the filter medium. This accumulation of different liquids can lead to serious problems!

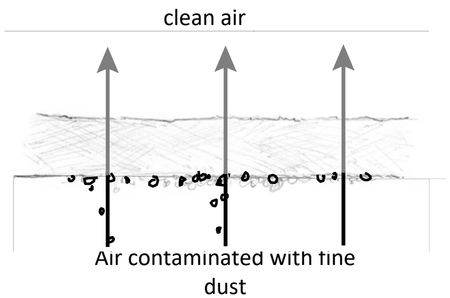
The storage capacity of metal mesh filters is often very low. This means that these filters can become blocked even with small amounts of stored liquid. For this reason, they are usually designed with a fairly coarse mesh. Whilst this prevents them from becoming blocked, it also means that many smaller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

Different filters



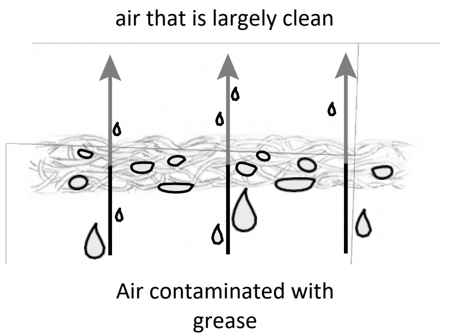
Felt filters

Fleece (e.g. vacuum cleaner bags) traps dust from the air flowing through it. However, the smallest dust particles can pass through the fleece.



Glass fibre filter

Glass fibre is finer than fleece and can filter – i.e. trap – even the tiniest dust particles in the nanometre range.



Metal filters

In the kitchen, a metal mesh is primarily used for filtering grease particles. Depending on their size, the droplets get caught in the mesh. However, the tiniest droplets can pass through the mesh.

Figure 8

Risk of bacterial growth

In food-processing plants and also in the manufacturing sector, storing liquids in filters can lead to hygiene problems. At temperatures around 20 degrees Celsius, combined with moisture, bacteria can multiply very quickly in the filters. Therefore, storing and collecting liquids over a prolonged period is often inadvisable, 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 overlooked.

An example from our company's history

I still remember well a large meeting at a global tool manufacturer. The staff showed me their production facility, which housed hundreds of grinding machines. The air purification systems in the production area were fitted with large particulate filters capable of storing up to 100 litres of liquid. The problem was this: the stored liquid was a very low-viscosity and highly flammable coolant and lubricant. With 50 filters in use, this could amount to as much as 5,000 litres of stored liquid! When, during this tour, I asked the company staff about the fire safety measures in place for these 50 air-purification systems and the relevant safety concepts, I was met with a round of alarmed faces.

My questions and concerns regarding the filters used in air purification are by no means merely theoretical musings, but relate to specific hazards; and, sadly, tragic fire disasters have already occurred because the issue of fire load was not given sufficient consideration.

Practical example: Fire in a mechanical engineering plant

In 200d, for instance, a devastating fire broke out at a mechanical engineering company in southern Germany that had an extraction system similar to the one described above. The fire damage amounted to a mid-double-digit million figure. Production halls and facilities covering over 3,000 square metres were completely destroyed. The probable cause of the fire was a faulty machine tool. The rapid spread of the fire through the ventilation duct network did the rest.

Case study: Fire at a hotel complex

A similar disaster occurred in 1980 at a large 2,000-room hotel in Las Vegas. At the time of the accident, there were approximately 5,000 people 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. To this day, this tragic event is regarded as one of the most catastrophic hotel fires in modern US history.

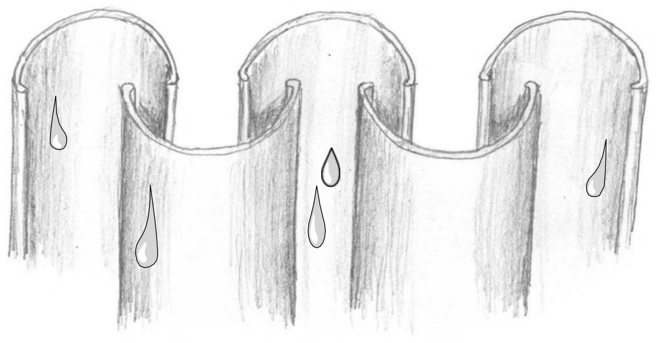
Such fire disasters ultimately led to the metal mesh filters described above no longer being used in many commercial sectors. In commercial kitchen ventilation systems, they have even been banned in many countries for years. In North America and most European countries, for instance, accumulative metal filters of this type may no longer be used in new, commercially used kitchens due to the increased fire risk.

Invention of the baffle plate separator

Following 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 compared with conventional metal mesh filters is that these separators, made from stainless steel sheets, do not retain 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

Misconception

Differences in the operating principles of filters and separators

As we have seen, filters and separators operate differently. But it is precisely these differences that give rise to misunderstandings. Often, their characteristics, modes of operation and efficiency figures are all lumped together. Sometimes, people do not even bother to clearly distinguish between the terms!

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

To clarify the differences, we must first look at some natural weather phenomena and how they have been incorporated into air purification technologies.

2.2. Cyclones can help with air purification!

You may be surprised, but that is exactly the case. Cyclonic storms such as hurricanes, typhoons, tornadoes and tropical cyclones served as fluid dynamics models in the development of modern sheet metal separators.

The first separators developed following the major hotel fire in the USA were simple baffle plate separators. Two semi-circular stainless steel plates, bent into a U-shape, are arranged in an offset, face-to-face configuration. The air flow is deflected twice as it passes through the separator: the first time when it strikes the first half-shell, and the second time when it strikes the second half-shell.

Schematic diagram of a baffle plate separator

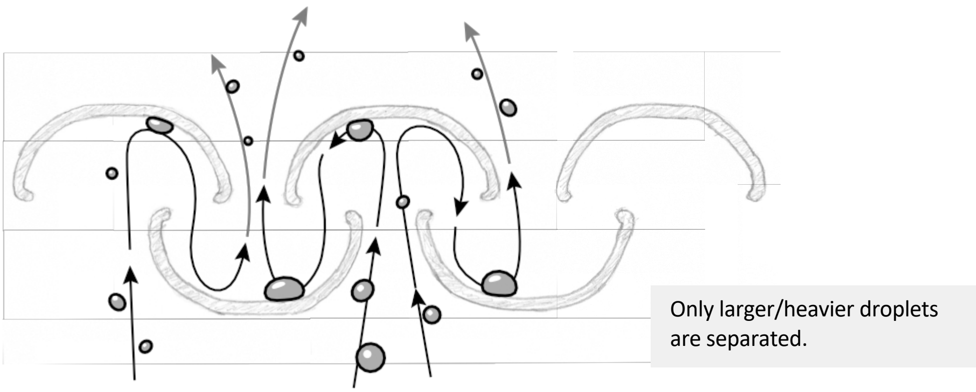


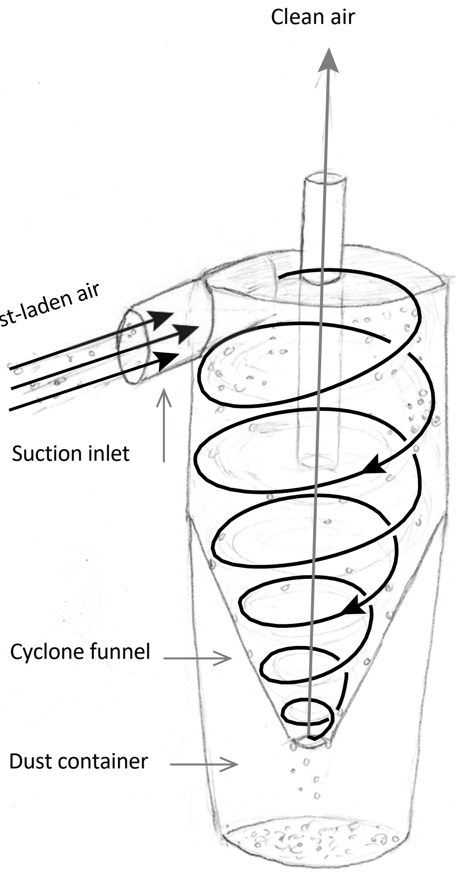
Figure 10

The U-shaped half-shells are formed with 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 airflow here. The airflow in a simple separator of this type is highly turbulent, and only very large droplets with a relatively high mass and high inertia can be separated from the airflow upon impact and deflection. Smaller airborne droplets with a lower mass 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 do not store liquid; however, 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 learnt from tropical cyclones that they succeeded in overcoming this drawback. The best-known example of this is the aforementioned company Dyson, with its cyclone vacuum cleaners. This technology operates without filters and, in principle, functions like a mini-cyclone. As in a cyclone, the air is set in a high-speed rotational flow. The higher the rotational speed, the smaller the particles that can be flung out by the airflow and thus separated.

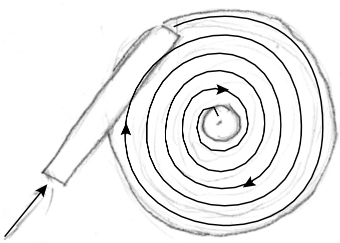
Schematic diagram of a cyclonic vacuum cleaner



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

Centrifugal force flings the dust particles against the wall.

The dust particles are collected in a dust container.



Cyclone spiral viewed from above

Figure 11

Naturally, a great deal of research and development work was required to acquire the know-how needed to generate such small-scale artificial whirlwinds in vacuum cleaners, cooker hoods and air purifiers. This certainly cannot be achieved with simply curved baffle plates. Numerical flow simulation – CFD simulation for short – is also used in the development and optimisation of cyclone technology. CFD stands for Computational Fluid Dynamics. With the help of this simulation, a wide variety of airflows can be visualised. However, this is not sufficient to optimise the separation technologies. Here, too, misunderstandings often arise in ventilation technology and air pollution control!

Misconception

Optimising the air flow is sufficient!

In many cases, ventilation engineering is solely concerned with air flow. For example, the task of introducing fresh air into a large concert hall as comfortably as possible, without concert-goers experiencing an unpleasant draught or feeling cold. The introduction of air should also be completely silent.

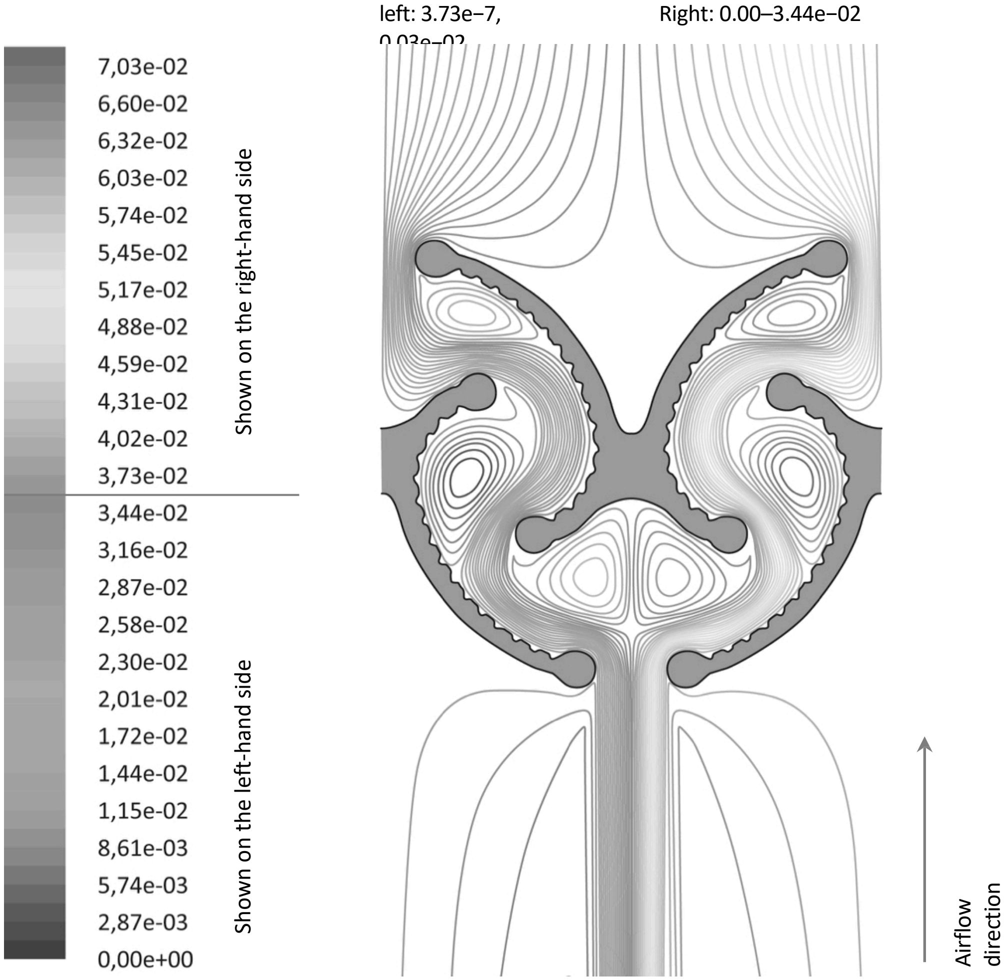
However, when optimising filters and separators in air pollution control, it is not just a matter of air flow and analysing its path and velocity. The actual task in air purification is to separate the particles carried by the air stream from the flow itself, either by filtering or by separation. Put simply, the filters function like a sieve and the separators like whirlwinds. If one wishes to optimise the functioning of separators, one must succeed in inducing small whirlwinds within them. Only then are the particles flung out of the air stream and can be separated.

Analysis of particle trajectories

Nowadays, the flow of particles can also be investigated and visualised using CFD systems. This means that we no longer look solely at the airflows, but also at the behaviour of the entrained particles or aerosols.

Do the smaller – and therefore lighter – aerosols follow the same path as the airflow? A very interesting CFD study involves visualising the different aerosol trajectories. The path of these trajectories depends on the particle size. With very high-quality CFD analyses, it is now even possible to identify the exact point within a separator where an aerosol is separated from the airflow! During the further development of our separators, we have been amazed and astonished on more than one occasion 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

An example from the company's history

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

I still remember one study in which we were all one hundred per cent convinced that, in a separator we had newly developed, small vortices with strong rotation would form very quickly and eject the airborne particles with very high efficiency. We proudly named this newly developed prototype the X-CYCLONE®.

The 'X' stands for the separator's geometry. We no longer constructed it from two simply bent U-shaped metal sheets, but gave the separator profiles a much more complex geometry. Initially, we were only able to construct these using extruded aluminium profiles. The surfaces resembled miniature versions of aeroplane 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 – spelled CYCLONE in English.

The CFD analysis of the new separator prototype was intended less as an analysis and more as a confirmation, which we still wanted to carry out for the sake of safety, despite the considerable effort involved. We knew what the result would be anyway. Or so we thought …

A CFD analysis is, in fact, very labour-intensive. As explained earlier, the investigation examines not only the behaviour of the airflow but also that of the particles in the air in detail. To be able to carry out this investigation at all, a three-dimensional model of the separator. ‘No problem,’ I thought years ago; ‘we’ve got everything we need – otherwise we wouldn’t be able to produce it.’ But I, too, had fallen prey to a misunderstanding here!

Misconception

> ***A three-dimensional model of the separator is sufficient for a CFD simulation.***

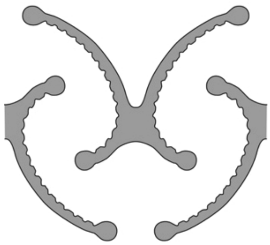
The three-dimensional spatial model

After all, for the analysis we needed not only the three-dimensional model of our separator – that is, the aluminium profiles – but also a model of the space through which the air flows. It’s actually quite obvious! When analysing the airflow in a circular ventilation duct, one naturally looks at the cylindrical space inside the duct rather than the sheet metal of the duct itself. However, this did not make our task any easier. As the geometry of our new X-CYCLONE® aluminium profile was already very complex, the space through which the air flows became all the more complex. But for the CFD analysis, it is precisely this space that needs to be modelled.

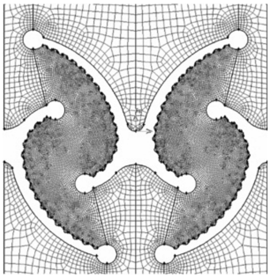
The **mesh**

Adding to the complexity of this already labour-intensive process is the fact that the space through which the air flows must also be covered with a computational grid. The English term ‘mesh’ is often used for this. How such a computational grid is arranged within this space through which the air flows, in turn, has a significant impact on the quality of the CFD analysis. However, if this process is carried out with great care, one obtains very detailed flow analyses of both the air flow and the particles, although the results can also be extremely frustrating!

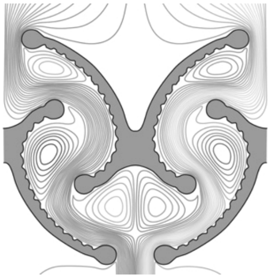
CFD analysis of an X-CYCLONE® separator



Separator profile



Mesh of the air-permeable space



CFD flow analysis of the trajectories of particles of different sizes

Figure 13

A sobering result

Every beginning is difficult – the air flows differently than expected!

For our first X-CYCLONE® prototypes, the CFD analysis yielded very sobering results. In the airflow zone, where we were absolutely convinced that small cyclones would form and then fling particles out at a rotational speed of over 10 metres per second, none of this happened! I can still picture it as if it were yesterday. The CFD analysis clearly showed an empty area, the shape of which resembled a drop about one centimetre in size.

The cause

Because the X-geometry of our profile was far too curved, the airflow could not follow this geometry, and an area developed through which no air flowed, let alone one where cyclones would have formed and ensured separation! Even ventilation experts cannot always accurately predict the behaviour of the airflow in advance.

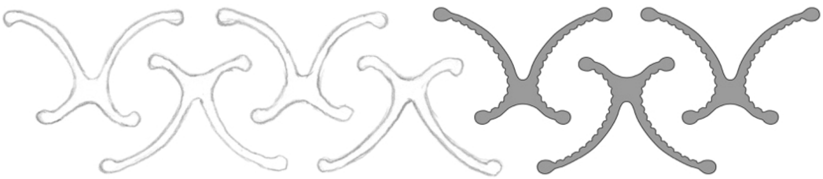
The optimisation

For our development project at the time, aimed at optimising X-CYCLONE® separation, this meant going back to the drawing board and redesigning the geometry of our separators. Essentially, it is a never-ending process of continuous development and improvement. Ultimately, we succeeded in developing products using technology similar to that found in Dyson appliances and 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-shaped profiles modelled on aeroplane wings



X-CYCLONE® separator with profiles in optimised X-geometry for optimum airflow guidance (see Fig. 15)

Figure 14

The triumph of our separators

The X-CYCLONE® separators we have developed have now become established in a wide variety 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.

Schematic diagram of an X-CYCLONE® separator

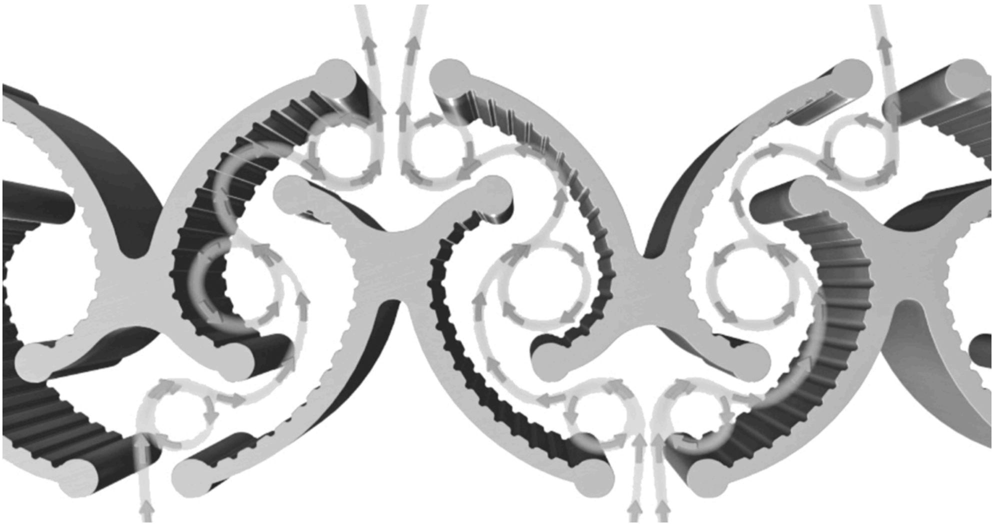


Figure 15

3. How can vapours and odours be removed?

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

Misconception

> ***There is no odour problem in air that is free of aerosols, particles and pollutants.***

Unfortunately, this is yet another misconception in ventilation technology and air quality control, which is the subject of this chapter. Let me explain this using a simple real-life example.

Practical example: Refuelling

Many of us have been to a petrol station in our cars and filled up the tank. Most of us have surely noticed the smell of petrol or diesel at some point.

The smell of petrol whilst refuelling

Figure 16

But why do we actually smell petrol whilst refuelling, even though there are usually no fuel splashes or aerosols in the air? This becomes very clear when you want to fill your tank to the brim and have to be careful that nothing overflows. When checking to see when the fuel level becomes visible in the filler neck, your nose is close to the neck and you can smell the fuel strongly – even without any spilling.

If a particle measurement were carried out in the immediate vicinity of the fuel filler neck, no fuel aerosols or particles would be detected in the air around the filler neck using standard measurement techniques. But why, then, does it still smell of fuel when refuelling? This is explained below.

3.1. The misunderstanding regarding the difference between vapours and aerosols

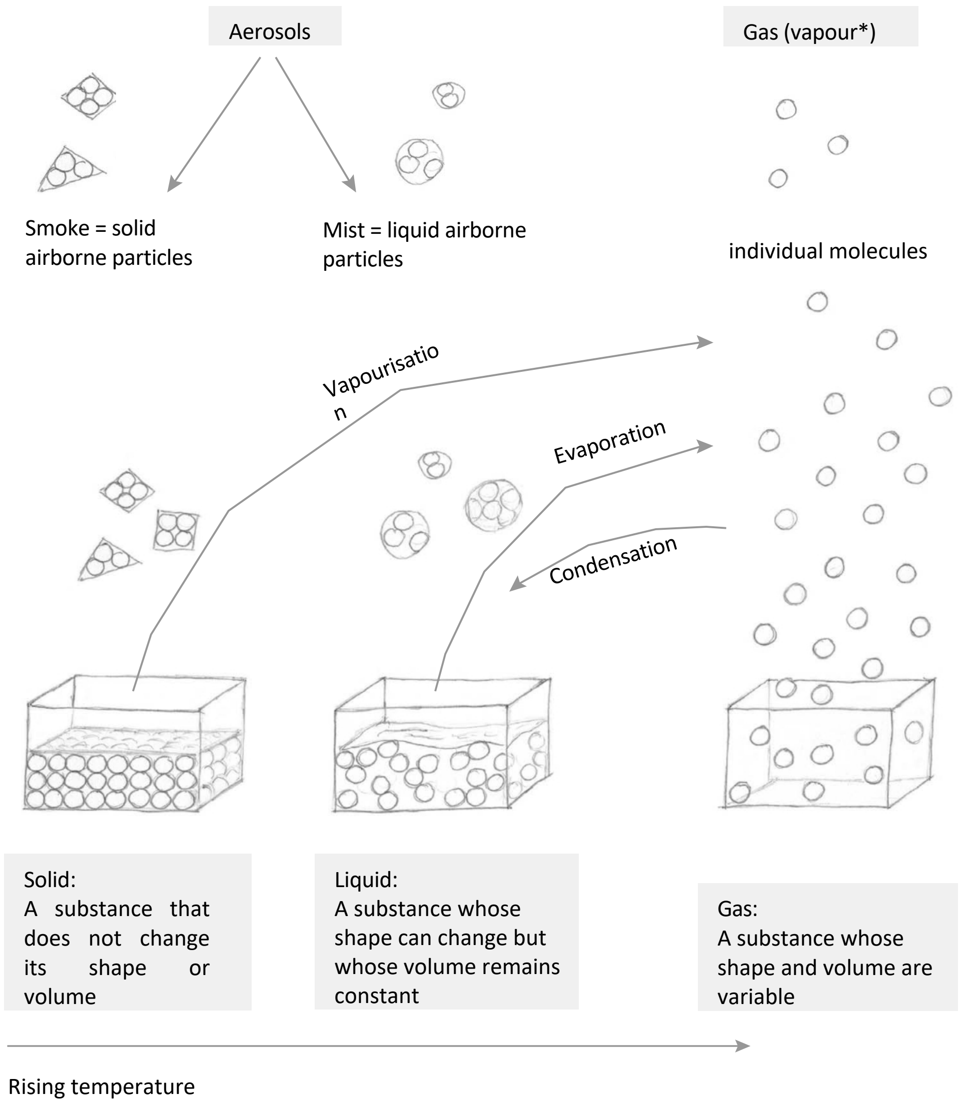
Why does it smell of petrol when refuelling, even though you can't see anything in the air? What you smell is evaporated petrol. Super Plus, in particular, is highly volatile. This means that it evaporates even at fairly low temperatures. This vapour – or, strictly speaking, gas – escapes from the fuel filler neck and causes the smell.

Misconception

> ***Aerosol-free air is clean.***

This simple example illustrates very clearly that air which is free of aerosols is by no means necessarily clean and can still pose a burden on the environment. Air pollution caused by evaporated liquids is an issue that also causes major headaches for the employers' liability insurance associations.

Difference between aerosols and gas



* Generally speaking, the term 'vapour' refers to tiny droplets suspended in the air, such as the vapour that rises when cooking. From a scientific point of view, however, vapour is the gaseous state of a substance (resulting from evaporation, boiling or sublimation).

Figure 17

Practical example from mechanical engineering

I still remember very well when I visited the employers' liability insurance association responsible for the mechanical engineering sector in Bavaria with our sales partner from Bavaria. There, we were shown studies containing measurement results that had investigated air pollution caused by coolants and lubricants on machine tools. The results revealed exactly the same phenomenon as in the petrol station example above. Analysis of the air around the machine tool showed that there was virtually no airborne contamination from aerosols and that all air quality limits were being met. Or so we thought.

When the specialists from the employers' liability insurance association then examined the proportion of evaporated coolants and lubricants from various machine tools, they found significant quantities of these in the air – in some cases, concentrations of up to 100 milligrams of coolant and lubricant vapours per cubic metre of indoor air. This meant the applicable limit values had been exceeded tenfold! How did this happen?

Initial evaporation occurs due to 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 at the tools that are machining the metal. What is often underestimated in this context is the constant draught caused by the air filters in the machine tools.

Coolant vapours in a machine tool

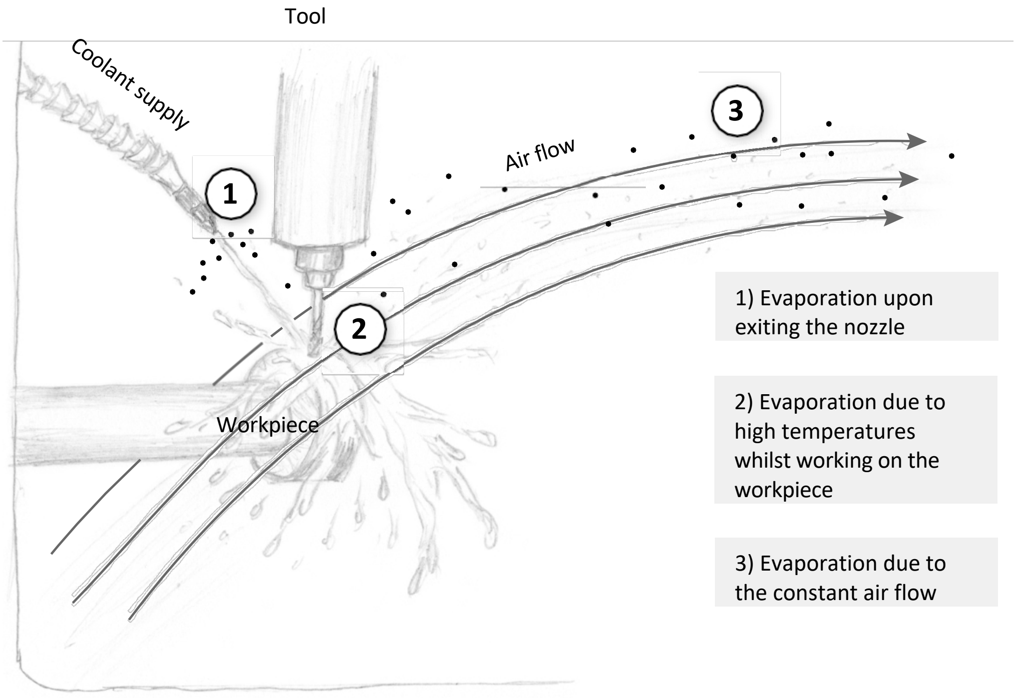


Figure 18

Remember what we established in Chapter 1: for extraction and suction, we need a high volume of exhaust air and an air flow directed towards the extraction point. This air flow can certainly be compared to wind blowing across the surface of a large lake. This air flow alone causes water to evaporate, be absorbed as humidity and carried away with the air flow. We see similar effects in a machine tool or, indeed, when refuelling. As a result, immense quantities of liquid are transported in vapour form along with the air. These vapours can lead to significant health risks and odour nuisance.

Example: Food industry

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

Practical example: Deep-frying systems

In the food industry, we have marvelled at potato crisp deep-frying plants that are the size of a large bath. Hundreds of thousands of potato crisps are deep-fried in this tank every day, releasing immense quantities of vapour in the process. This vapour consists largely of evaporated oil from the frying fat and evaporated water that was still bound within the crisps prior to frying. Here, too, we observed the phenomenon described earlier: when analysing the process exhaust air using particle measurement, no air pollution whatsoever could be detected; the air appeared clean and barely contaminated. Nevertheless, it was already visually apparent that the exhaust air from this processing operation could not be clean, as it looked like the steam plume from an old steam locomotive. Furthermore, much like at the petrol station, a strong odour was noticeable. Although this was more pleasant than the smell when refuelling, it nevertheless clearly indicated air pollution.

Example: a domestic kitchen

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

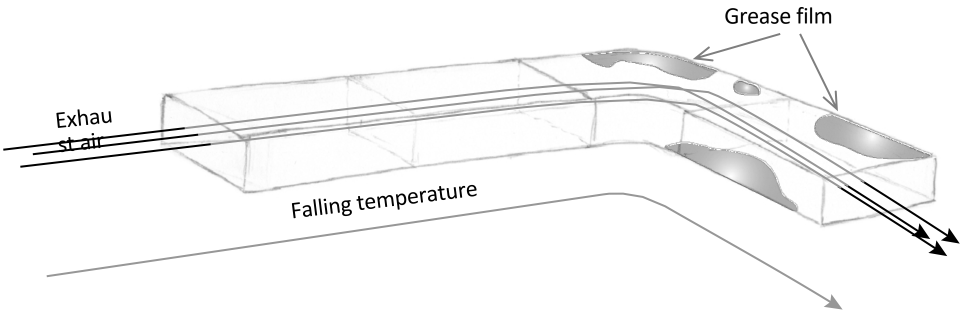
Condensation of the vapourised liquids

In industry and commercial kitchens, these vapourised liquids cause major problems in the process exhaust air. This is because these vapours not only cause odour nuisance, but can of course also condense again when the exhaust air cools down sufficiently. The vapourised 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 very often run for long distances.

Hygiene issues and fire hazards caused by long exhaust air ducts

Whether it is a cooking process in a large hotel kitchen or a processing operation in an industrial plant, the air that is captured and extracted directly at the source must then be transported a very long way through the exhaust air duct before it finally leaves the building and is expelled by large ventilation units. During its long journey through the ventilation duct – often constructed from rectangular sheet metal sections – the air cools down. As a result, the evaporated liquid condenses and accumulates in the exhaust air ducts and the ventilation unit. These deposits not only pose a hygiene problem but also present a fire hazard.

Long exhaust air ducts and their hazards



As the air travels outwards, it cools down further and further. This causes vapours to condense, forming films of water and grease within the exhaust air duct – a breeding ground for microorganisms and a potential source of fire.

Figure 19

European standards require consideration to be given to vapours and their condensation

Air that is free of aerosols and particles is therefore by no means necessarily clean. What is often perceived as an odour nuisance is usually vapour. For this reason, European standards such as DIN EN 16282 also stipulate that, in addition to air purification in commercial kitchens using filters and separators, attention must also be paid to the evaporated liquids and their condensation! To this end, these – some of which are at very high concentrations – must be measured and analysed.

3.2. FID analysers can be helpful in analysing airborne contaminants!

FID analysers can provide an indication of how much evaporated liquid is present in the air. FID stands for flame ionisation detector. An FID analyser helps to determine the amount of vapourised volatile organic compounds. Colloquially, people often refer to ‘total C’ in the exhaust air; this refers to the vapour-form hydrocarbons present in the air. If, for example, we want to find out how much evaporated fuel reaches our noses whilst refuelling, such a measuring instrument would be the ideal piece of equipment. FID measuring instruments are equally useful for analysing evaporated coolants and lubricants in the manufacturing industry or in food production facilities.

Measuring particle and vapour levels

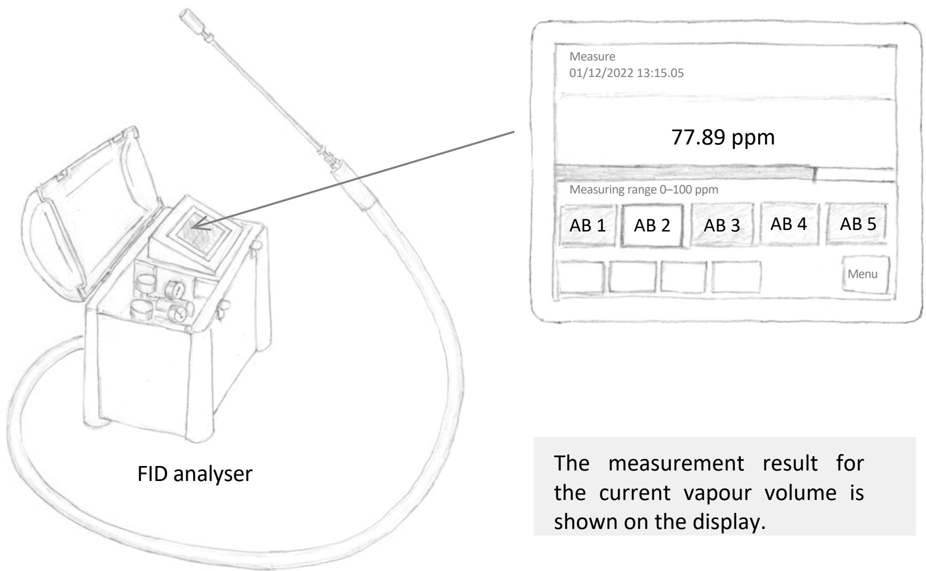


Figure 20

Analysis of air pollution

When analysing the exhaust air from the processes mentioned above, the actual concentration is usually determined by the sum of airborne aerosols and vapours. The result of such a comprehensive analysis often shows that there are 80 milligrams of vapour and only 20 milligrams of aerosols in one cubic metre of indoor air. Applied to this example, that would mean we have a total of 100 milligrams of pollutants in one cubic metre of indoor air. Whether this pollution consists of a coolant and lubricant in a mechanical engineering workshop or frying oil in food production or a hotel kitchen is something we can disregard at this stage, as the problem and the task at hand are essentially the same: we must deal with both.

Misconception

There is no need to measure evaporated liquids.

We must consider both the evaporated liquids and the airborne aerosols derived from these liquids. A common mistake in ventilation technology and air quality control is failing to measure and analyse these airborne contaminants at all. If anything is measured at all, it is, at best, the particle concentration of the aerosols. It is virtually never the case that both vapours and aerosols are analysed. This was also confirmed by discussions with colleagues from the Bavarian employers' liability insurance association.

During operation, small white clouds rise from deep-fat fryers in commercial kitchens or from large collection bins containing hot metal shavings in manufacturing plants or similar facilities. 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 vapour rising from commercial containers contains oils and coolants or lubricants.

These substances are often the source of strong odours and are given far too little attention and investigation.

Carrying out 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 determined from these measurements: purifying the air by removing these vapours.

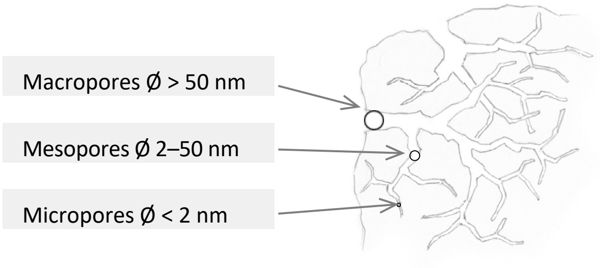
Approach 1: Activated carbon

One possible solution, for example, is the use of activated carbon filters. Put simply, activated carbon functions as a kind of molecular filter. It is highly porous and contains numerous very small pores that can absorb vapours through adsorption. The vapours are thus bound to the surface of the activated carbon. However, this only works as long as the activated carbon is not overloaded by aerosols produced during condensation.

Disadvantages of using activated carbon

Activated carbon filters are often only installed in the ventilation unit at the end of a long exhaust air duct run. By the time the exhaust air reaches this point, it has already cooled by several degrees and the vapours begin to condense. As a result, the many small pores in the activated carbon become clogged far too quickly and thus become ineffective. If the condensing vapours are oils, this, in combination with activated carbon, creates a fire hazard in the truest sense of the word!

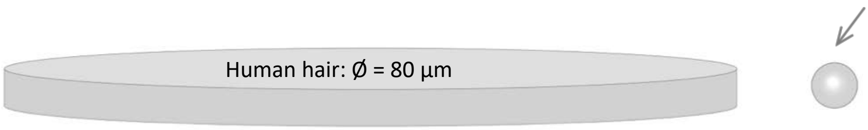
Use of activated carbon



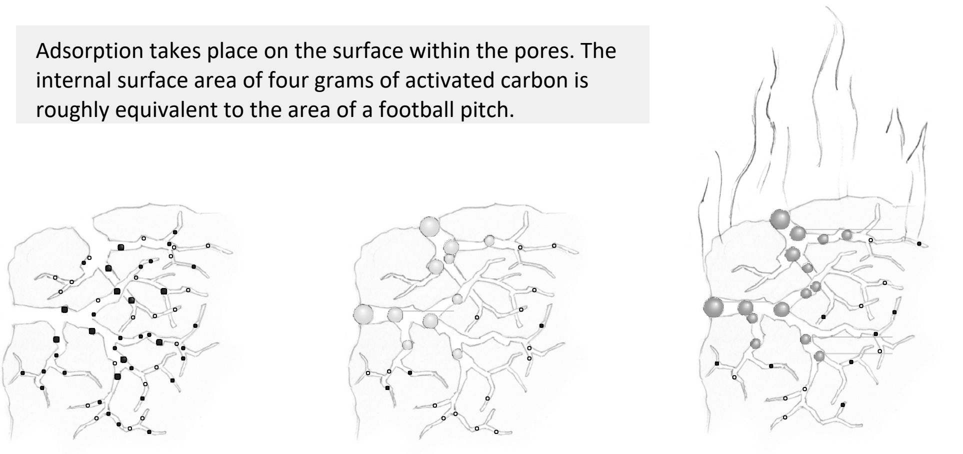
Enlarged section of an activated carbon granule

Size comparison:
The diameter of a human hair is approx. 80 µm, that of a fine dust particle 5 µm,
that of a large mesopore is 0.05 µm (= 50 nm = 0.00005 mm)

Fine dust particles: Ø = 5 µm



Adsorption takes place on the surface within the pores. The internal surface area of four grams of activated carbon is roughly equivalent to the area of a football pitch.



Bound vapours

Pores blocked by condensed vapours

Fire hazard due to condensed oil vapours

Figure 21

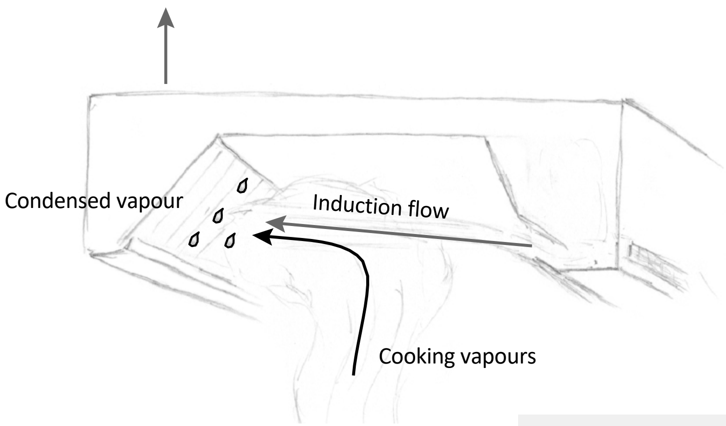
Approach 2: forced condensation

Another way of managing the evaporated liquids and reducing their volume is through forced condensation directly during collection and extraction.

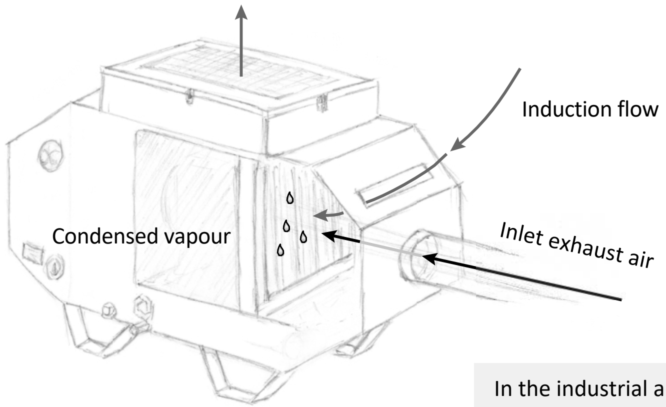
As described in Chapter 1, we at REVEN GmbH have developed collection systems that not only extract but also blow air. In this process, the air to be captured – along with the aerosols, viruses and pollutants – is transported as quickly as possible, with the aid of forced blowing, to the area where the extraction capacity of the air purifiers, cooker hoods and ventilation units is greatest – that is, directly into the area of their intake openings.

To this end, we have developed both modern cooker hoods and industrial air purifiers that are equipped with an additional device for assisted blowing. In the case of the cooker hood, this ensures that rising cooking vapours flow quickly and directly from the cooking appliance into the filter and intake area, where they are captured or extracted. Furthermore, this has enabled us to force the condensation of evaporated liquids. The air in the induction flow – that is, the blown-in air stream – is always a few degrees colder than the air to be captured. This temperature difference helps us to trigger the condensation of evaporated liquids directly during the capture and extraction process, both in our advanced extraction hoods and in our air purifiers 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 duct.



In the industrial air cleaner: vapours condense before the X–CYCLONE® separator due to the cooler induction flow and are separated.

Figure 22

Advantages of forced condensation

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

4. How can viruses and odours be neutralised?

Neutralising odours and completely removing viruses and bacteria from the air is a task that requires several steps. It begins with efficient capture and extraction; this is followed by the use of highly effective aerosol filters or separators, and in this context, the condensation of 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.

Misconception

> ***UV irradiation solves all problems relating to viruses, bacteria and odours.***

A widespread and persistent misconception in ventilation technology and air purification is the belief that one need not give much thought to all these steps, from capture and extraction through to separation and condensation. Simply fit any old lamps that produce ultraviolet light into air purifiers and exhaust air systems, and everything will be fine. This, or something similar, is what the promises of many market competitors – which I keep hearing time and again – suggest.

There are a great many misunderstandings and pieces of misinformation regarding the functioning and effectiveness of air purification technologies that use ultraviolet radiation. It starts with the fact that many manufacturers fail to inform users about the actual scope of application of ultraviolet radiation. One important aspect that absolutely deserves attention is the question: 'What is the aim 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'll agree that these represent distinct tasks, and that eliminating viruses from exhaust air cannot, in fact, be the same as removing oils and fats.

That is why we should first discuss what we actually want to use ultraviolet radiation for in our ventilation system. Which UV-C system is used depends on the specific task at hand. The various functions of such systems can include the following:

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

These three tasks alone already cover three completely different areas, each of which requires the use of very different UV-C systems. There is no single system capable of performing all three tasks.
Added to this is the task of so-called ‘fat burning’, which is shrouded in myths. We’ll explain what this is all about later.

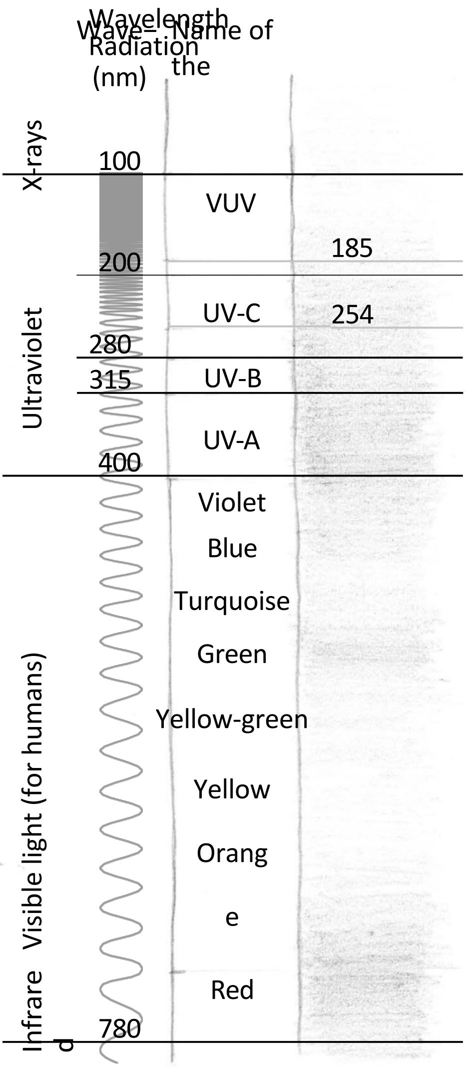
We therefore need a UV-C system that is specifically designed for one of these tasks. But even then, it remains questionable whether the task in question can really be tackled satisfactorily.

4.1. The misunderstanding regarding UV-C radiation

UV-C systems are frequently integrated into domestic air purifiers. 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 from these devices could kill dangerous viruses. But how is something like that supposed to work?

Visually, such UV-C systems resemble conventional fluorescent tubes, such as those found in lighting systems in large offices. They are available in various sizes. When a UV-C tube is switched on, it does not emit white light like office lighting, but glows with a bluish hue, as seen in sunbeds. This blue light is artificially generated short-wavelength UV-C radiation with a wavelength of approximately 250 to 280 nanometres.

Electromagnetic spectrum



UV-A and UV-B

These are the only UV rays that reach the Earth. Humans rely on them to produce vitamin D in the body. They cause the skin to tan. However, in excessive doses, this 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 is used for sterilisation. In particular, 254 nm is 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 from the ultraviolet spectrum is used to produce ozone. This method only works with special quartz tubes.

Figure 23

The Wavelength Factor

For UV-C systems, the wavelength range of the radiation is important, as this is the only way to kill bacteria and viruses or prevent them from multiplying further by damaging their genetic material. This knowledge has long been utilised in medical technology, for example for the disinfection of surgical instruments and medical tools. These disinfection units are often rectangular boxes that resemble standard domestic microwave ovens. UV-C tubes are integrated into these boxes, enabling the interior to be irradiated within a wavelength range of 250 to 280 nanometres. Objects placed inside such an ultraviolet steriliser are disinfected by the UV-C radiation.

The time factor

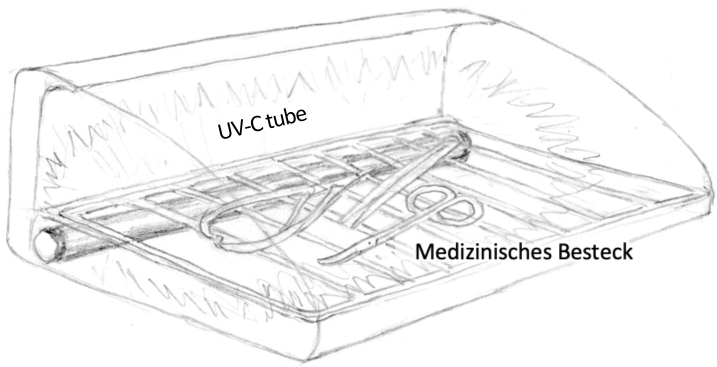
The data sheets for these UV-C sterilisers repeatedly point out that complete germ-free conditions – in other words, sterilisation – can be achieved after an irradiation time of just 30 seconds.

On most UV-C sterilisers, a disinfection time of between 30 seconds and 60 minutes can be set, much like the time setting on a domestic microwave.

Wavelength + time = desired result

We have thus identified an initial area of application for which there are many technical solutions, products and practical experiences: if we wish to render viruses and bacteria on objects such as scissors, knives, pliers, needles, etc. completely harmless, we require 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 they are truly sterile. Thus at least, that is the recommendation of the manufacturers of UV-C sterilisers, which have been used in medical technology for many years.

Disinfection in a UV-C steriliser



This modern steriliser operates in two stages:

- 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 using ozone.

Figure 24

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

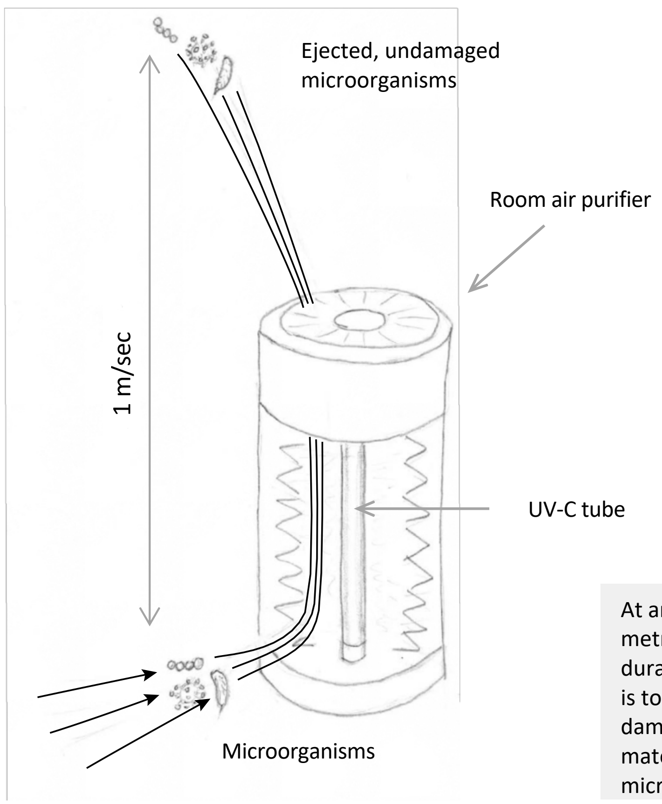
Actually, the answer is quite simple and obvious: if we want to kill bacteria and viruses in an air stream, we need the same ultraviolet radiation, and this must act on the viruses and bacteria for a certain duration.

Misconception

Sterilising the air works in exactly the same way as sterilising objects.

As simple and obvious as that sounds, this is where the problems in ventilation technology begin. In ventilation units and air purifiers, we are dealing with flowing air, 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 airflow – 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 the air in one second



At an air velocity of one metre per second, the duration of UV-C exposure is too short to actually damage the genetic material of the microorganisms.

Figure 25

This fact in itself presents the first problem and a major challenge. As we have learnt from the description of sterilisers 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?

In an exhaust air system with an air velocity of one metre per second, a thirty-metre-long exhaust air duct fitted with UV-C tubes would be required. 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 carried by the air are exposed to UV-C radiation in these devices: in such systems, the radiation has only one second to act on viruses and bacteria. This is far too short a time for sterilisation.

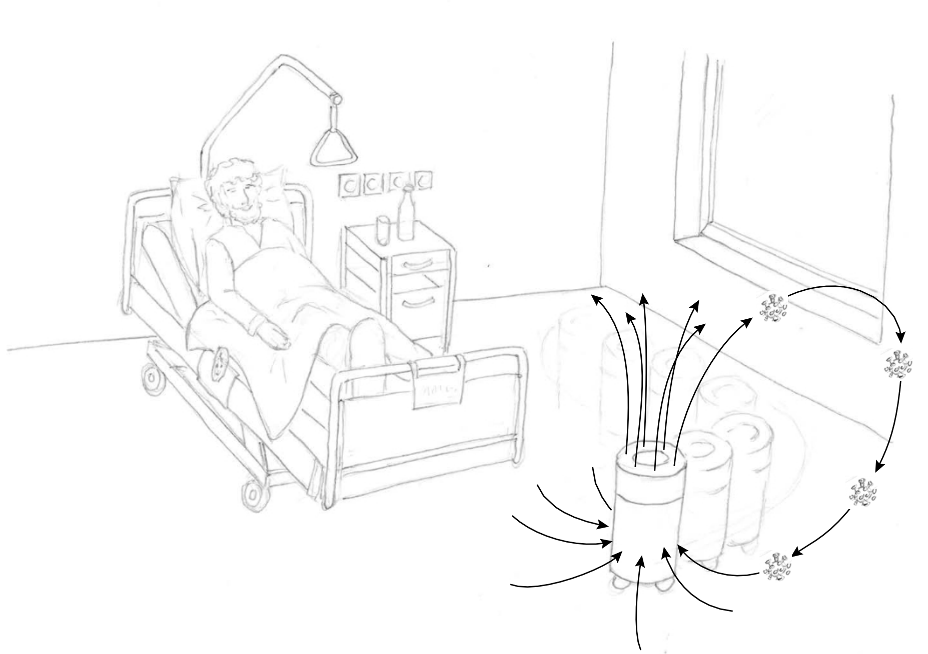
It is therefore not enough simply to install UV-C tubes in a ventilation unit or an air purifier, and in most cases it does not make sense either. So what can be done?

One option would be to repeatedly pass the air through 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 move autonomously into a room and purify the air there. To do this, they draw in the air and blow it out again. In the process, the air is exposed to ultraviolet radiation. This process is repeated continuously in the room for a specific period of time. As you might expect, this ensures an exposure time of at least thirty seconds.

Disinfection robots in hospital rooms



Only when the same air is circulated through the disinfection robot in a ‘continuous loop’ (simplified illustration) 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 supply air is blown and from which the stale, contaminated exhaust air is extracted, the situation is completely different.

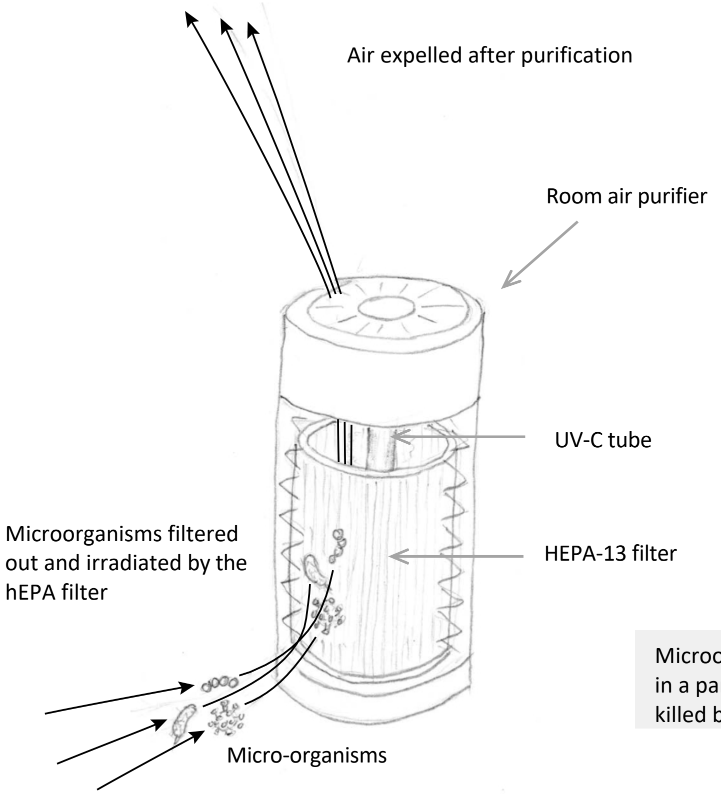
There isn’t enough time

Even with simple, small room air purifiers, the process of drawing in, purifying and expelling the air takes barely more than a second. It is therefore clear that in such compact air purifiers, we cannot under any circumstances sterilise the air using UV-C irradiation alone. There is simply not enough time for that.

Use of HEPA filters

The performance of compact room air purifiers can be improved by fitting HEPA filters. These are high-performance filters capable of filtering even very small particles, as well as viruses and bacteria, from the air. In combination with UV-C radiation that irradiates this high-performance filter for a sufficiently long time, the viruses and bacteria on the filter can be killed.

Accessories: Particulate filters



Microorganisms trapped in a particulate filter are killed by UV-C radiation.

Figure 27

There are numerous comparable examples. Ultimately, it always comes down to exposing viruses and bacteria to the appropriate ultraviolet radiation for long enough to cause sufficient damage to their genetic material and prevent them from multiplying. True sterilisation can only be achieved through complete destruction. To put it in more scientific terms:

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

The factor of radiation intensity

The radiation intensity depends on the tubes; more precisely, on their power output per square metre of irradiated surface area. The more power we use in watts, the shorter the required exposure time. If low-power UV-C LEDs are used, which deliver only a few watts of power per LED light, a correspondingly long exposure time is required. The relationship is relatively simple: the higher the radiation output and the longer the exposure 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 assist in this process. Upon closer examination of this question, we encounter one of the greatest misconceptions in the field of ventilation technology and air purification. However, this is more of a mystery than a misconception, and it can be described by the following question.

4.2. Can UV-C radiation remove aerosols?

If the claims made by many manufacturers in the ventilation sector are to be believed, then this is indeed the case. It is often claimed that ultraviolet radiation from UV-C tubes is capable of removing oils and fats from the exhaust air stream. This myth is particularly widespread in commercial kitchen ventilation. According to some manufacturers, it is not so much the aerosol separators I described in Chapter Two, but rather UV-C systems that are said to keep kitchen ventilation systems free of grease and oil.

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

Misconception

> ***UV-C radiation purifies the air of fats and oils.***

Many manufacturers claim that a suitable UV-C system installed in the kitchen extract ventilation system can remove all these forms of fats and oils from the airstream 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 yet been demonstrated even once at a reasonably scientific level.

We now know just how complex the reliable elimination of bacteria and viruses using UV-C radiation is. Purifying the air of aerosols and droplets of oils and fats using ultraviolet radiation is, however, something entirely different!

It starts with the size and properties of these airborne contaminants: a virus is many times smaller than an oil aerosol. Furthermore, viruses and bacteria do not simply evaporate or break down in any other way. Ultraviolet radiation damages their genetic material so severely that they can no longer reproduce and die off.

When it comes to purifying exhaust air of oils and fats, it is claimed that these substances are completely broken down and eliminated as a result – at least, that's what the grandiose promises suggest! How is something like that supposed to work?

Misconception

> ***Fat is completely broken down by photolysis.***

Manufacturers put forward the most far-fetched claims on this subject. For instance, specialised UV lamps are said to be capable of breaking down grease in the air via photolysis. This is said to reduce the grease content by 95 per cent 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, one repeatedly hears the statement: 'That's what we've observed!' or 'We've been installing such systems for many years and we've observed this time and again; we can't be mistaken!'

In most cases, there is no measurement technology whatsoever, no measurement logs, and never any studies that even begin to support these statements and observations. The promises and assurances are justified on the basis of decades of experience and the company's own observations, which could not possibly be wrong over such a long period.

Practical example: exhaust emissions

The VW Group, too, has decades of experience in developing diesel engines and was certain it could not be mistaken regarding the exhaust emissions of its engines.

Where does this excessive zeal come from? Why do so many manufacturers in the commercial kitchen ventilation sector use this technology?
Because it is an extremely lucrative business. Purchasing the tubes is straightforward, integrating them into an extract air system is a task any reasonably experienced electrician can manage, and so, with a truly manageable amount of effort, you have upgraded your kitchen ventilation system by many thousands of euros!

Misconception

> ***A kitchen ventilation system is certainly enhanced by the use of UV light.***

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

To answer this properly, 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 fats and oils 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 the case with tubes made from synthetic quartz glass. The key here is that ultraviolet radiation in the 185-nanometre wavelength range is not filtered out by this glass and can therefore be emitted. This is the basic prerequisite for producing ozone.

2. The ozone is intended to oxidise fats and oils

So, when the correct tubes are used and radiation of the correct wavelength is applied, ozone is generated in the ventilation system. Ozone is essential for having any effect at all on oils, fats and many other substances. However, it is a very powerful oxidising agent. For this reason, it is also harmful to health and is even suspected of being carcinogenic. In kitchen exhaust air, however, attempts can be made to use it to oxidise oils and fats. But I am deliberately emphasising here: attempts can be made!

Research report from the USA

Recent studies from the USA show that, whilst this oxidising effect on oils and fats does exist, it is not very efficient. Oils and fats are only partially oxidised, and these studies do not support the claim that oils and fats can be completely eliminated. On the contrary! Given ozone's high potential for danger, the question arises as to whether the production of ozone in such systems does more harm than good to the environment! The research report in question was published in 2020 by ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) and is entitled 'Research Project 1d14: Determining the Effectiveness of UVC Systems on Commercial Cooking Effluent'.

3. Effective grease removal at source

Given ozone's minimal effect on oils and fats, the primary focus in kitchen exhaust systems must therefore be on capturing, extracting and cleaning the exhaust air via filters and separators, so that the exhaust air is already largely freed of oils and fats in this way. If the exhaust air also has a strong odour, this is due to evaporated oils and fats. For this purpose – and this purpose alone – a UV-C system that produces ozone may then be used to a limited extent. However, the potential hazards of such systems must not be overlooked.

Appropriate use of UV radiation in kitchen extractor hoods

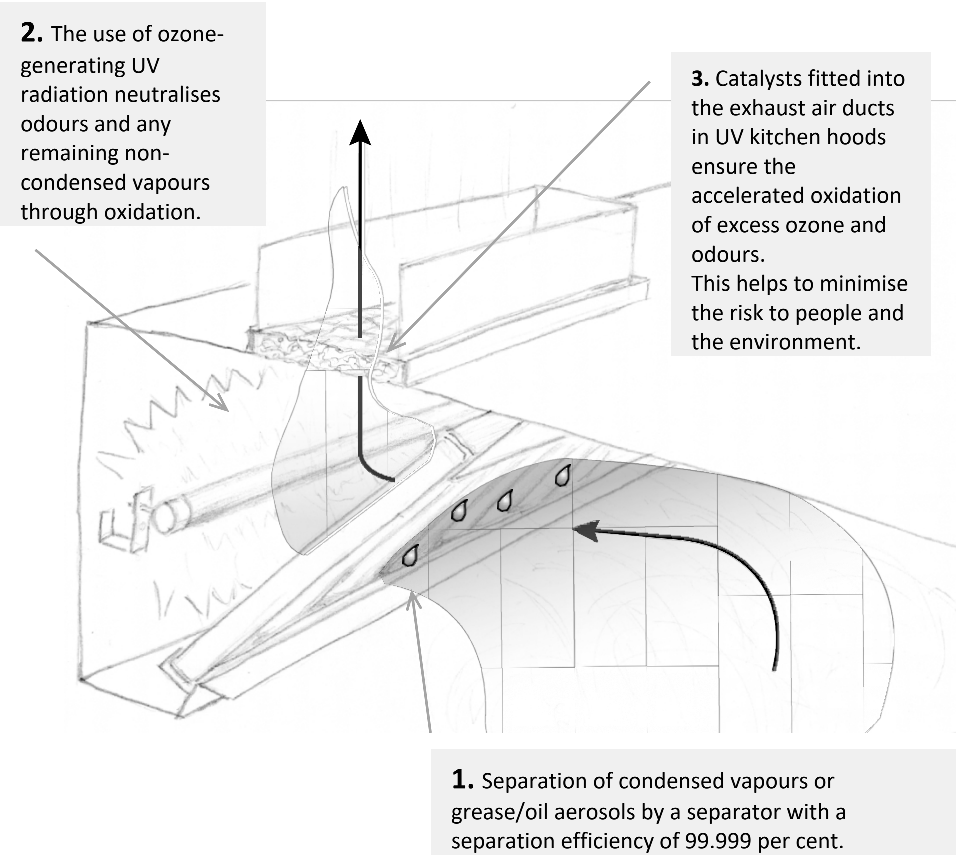


Figure 28

4. Ozone is a potential carcinogen

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

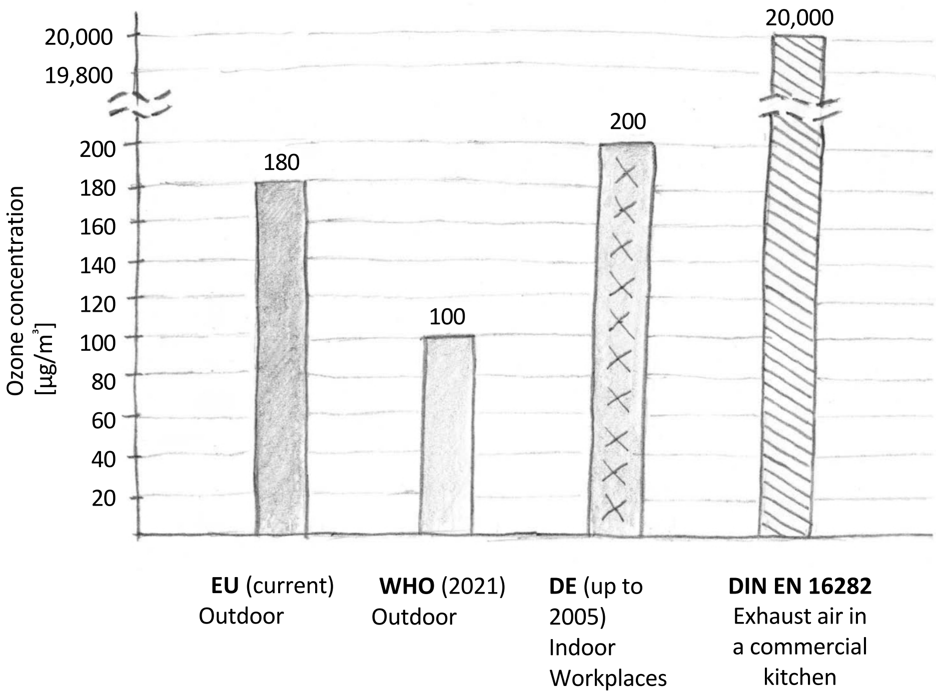
For this reason, all limit values for indoor ozone levels have now been abolished in Germany. In cities, ozone alerts are even triggered regularly when outdoor ozone levels are too high. When levels are high, the public is advised not to exercise outdoors and to stay at home where possible. However,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

Practical example: kitchen ventilation

On several occasions, I have personally encountered chefs who told me about fluorescent tubes behind the filters in their cooker hoods and were unsure whether these were still working. When I then told them and their kitchen staff that these were not fluorescent tubes, but UV-C systems that generated dangerous radiation and released gases harmful to health, I was met with looks of sheer horror on more than one occasion.

So much for the list of facts, which makes no claim to be exhaustive and could certainly be expanded to include a few more points.

Ozone limit values



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

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

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

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

Figure 29

Measurement technology, for example, is another issue. You cannot even imagine how many manufacturers sell ozone-generating systems but do not have any suitable measurement technology to determine the concentration of this dangerous ozone gas.

Misconception

> ***Oils and fats have 'disappeared' because they could not be measured (using certain techniques).***

There are also manufacturers who, using suitable particle measurement technology, claim to provide verifiable evidence of the removal of all oils and fats. In such cases, a simple temperature measurement would often suffice. Why? In some systems, dozens of UV-C tubes are installed in the exhaust air duct or the kitchen hood. These become very hot during operation and thus heat up the entire surrounding space. As a result, many oils and fats evaporate.

5. How can airflows be made visible?

At the start of the pandemic in 2020, we observed an ‘interesting’ trend in Germany. Not only did the range of compact air purifiers suddenly skyrocket, but there were also suddenly hundreds of ventilation experts and aerodynamicists in Germany. Thousands of diagrams illustrating airflow in open-plan offices or classrooms were produced and displayed everywhere. What did all these diagrams have in common? They were brightly coloured and featured lots of arrows. These usually pointed towards an air purifier positioned in a corner of the room, intended to rid the air of viruses and pollutants.

Now, as we have seen in Chapter 1, it is extremely complicated to draw air in – for that reason alone, it should by now be clear that an air purifier in the corner is simply not capable of drawing in all the air in a classroom or open-plan office. No matter how many colourful arrows point towards the air purifier, the air will not flow in that direction (see Fig. 5)!

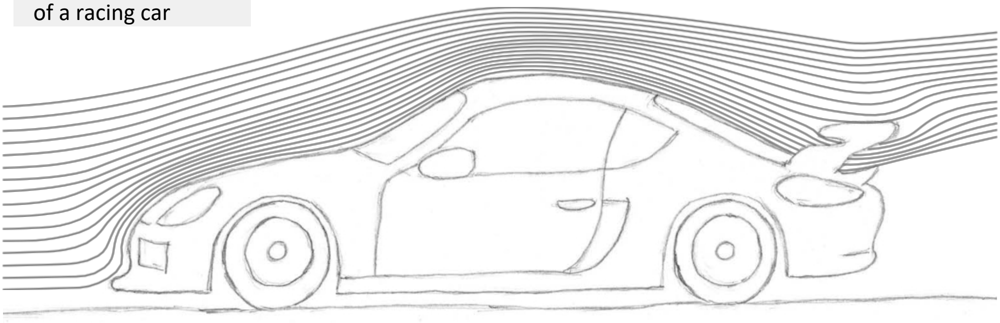
Most of these colourful diagrams therefore simply depict entirely fictitious airflows that have nothing to do with reality. But how can one determine and visualise the actual path of these airflows?

Basic research into the analysis of airflows

The Hermann-Rietschel Institute at the Technical University of Berlin conducts extensive fundamental research into this topic. Representatives of the institute have the following to say about the analysis of air flows and the effectiveness of ventilation measures: ‘To assess how well air renewal and the removal of pollutants work within a room, and in detail at every point within it, we use what is known as ventilation effectiveness. This can be determined using numerical flow simulations and/or measurement techniques. In all our projects, we use these methods to evaluate indoor air flows and develop innovative, effective forms of ventilation.”

Visualisation of air flows

Visualisation of the aerodynamics of a racing car



Flow simulation has long been established in aircraft and racing car design. The calculation and visualisation of airflows are now also being used for optimisation in indoor air technology.

Figure 30

What does this mean for us? We therefore need flow simulation and the appropriate measurement technology. This is precisely what we have already mentioned in the previous chapters, for example in connection with aerosol filtration or UV-C technology. How is this method applied to airflow?

5.1. The misunderstanding caused by colourful illustrations of airflows

The colourful images with their many arrows neither represent a numerical flow simulation nor are they based on measurements from a complex series of tests. In most cases, they are purely fictional representations of air flow that have nothing to do with actual conditions. They are, in the proverbial sense, plucked out of thin air and do not even come close to representing reality!

Misconception

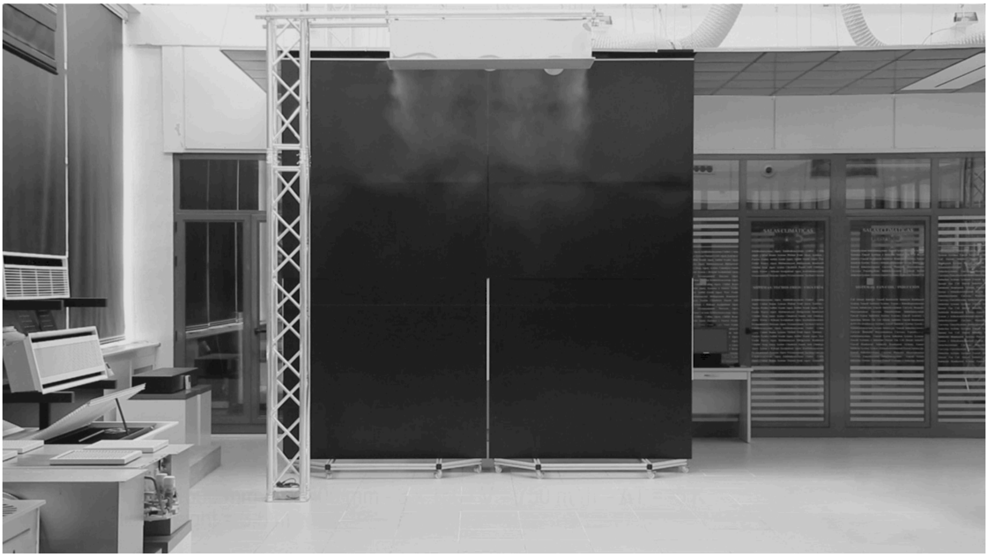
> ***The path of the airflow is predictable.***

A widespread misconception in ventilation engineering is the hasty assumption that one knows in advance how the air will behave. In Chapter 2, we highlighted the erroneous interpretations and false conclusions this can lead to during product development. After all, even we in our team made this mistake – back then, during the development of our X-CYCLONE® technology.

The SChAKO CFD Competence Centre

Our SChAKO Group even has a dedicated team for flow simulations and measurement technology. At SChAKO IBERIA in Spain, we have established a CFD Competence Centre. This team focuses primarily on precisely the task that the Hermann Rietschel Institute at the Technical University of Berlin so aptly summarised! At our CFD Competence Centre, we visualise air flows using numerical flow simulations and suitable measurement equipment.

The SCHAKO laboratory in action



An insight into the test setup for visualising supply air flows

Figure 31

Misconception

> ***Visualisation models correspond to reality.***

Standards and guidelines are also frequently based on the same misconception as the illustrations 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 illustrations with colourful arrows. The images show the cooking unit in a kitchen and the airflows from this cooking unit to the cooker hood. Further arrows pointing into the room are intended to represent the flow of fresh supply air into the kitchen. These are usually drawn as straight vertical or horizontal arrows, suggesting a flow that is sharply defined.

An arrow running vertically upwards from the hob, extending all the way to the cooker hood, is intended to represent the air that is extracted directly and immediately from there – one has to ask oneself what this has to do with reality? Certainly very little to do with the actual air flow. This is a model designed to illustrate the thermal currents above a hob. These thermal currents create an upward air flow. This is captured and extracted by the cooker hood above the cooking unit. This is the model set out in the VDI guideline VDI 2052. There is no doubt that this is a model from which much 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 extractor fan

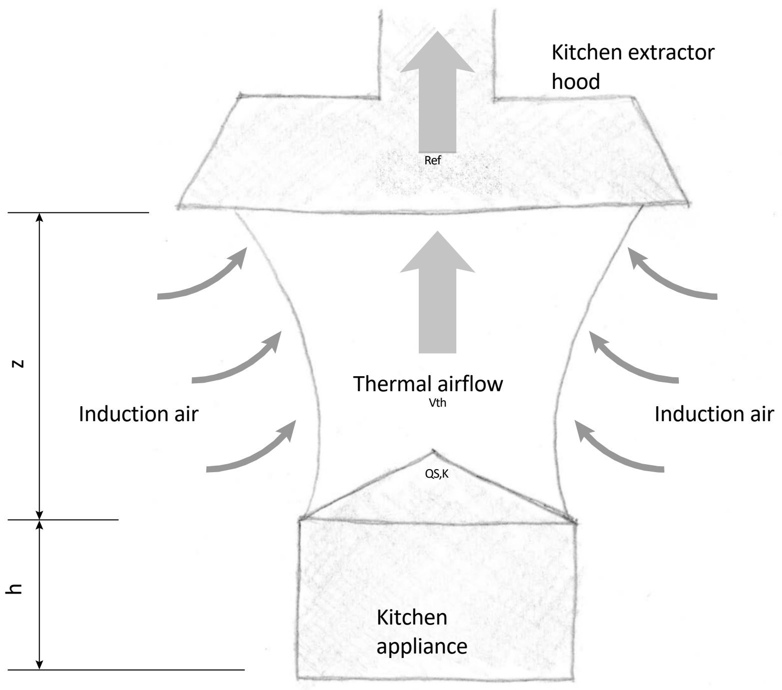


Illustration based on the flow model in VDI Guideline 2052:
The diagram and the direction of the arrows do not indicate the actual behaviour or the real path of the individual air flows

Figure 32

The actual path of air flows and its significance

As we have already learnt, conventional kitchen and extraction hoods can only extract cooking vapours rising upwards directly to a very limited extent. Very often, these vapours accumulate in conventional extraction hoods without being extracted immediately. As a result, vapours that have initially been captured may even flow back out of the kitchen hood.

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

5.2. CFD simulations make airflows visible!

Well-executed CFD simulations reveal all the physical parameters of an airflow across the entire area. This means that the function and efficiency of a ventilation system can also be demonstrated and verified. In Chapter 1, we have already shown in detail that conventional extraction hoods can only directly extract vapours rising upwards within a very limited area around the extraction point. As little as 50 centimetres away from the filters and the extraction point, we can no longer detect any extraction using measurement techniques. This is very easy to see in a CFD simulation, and the air flows show that vapours are also escaping back out of the cooker hood. Vapours and air flows initially captured by the cooker hood therefore escape again and are not extracted!

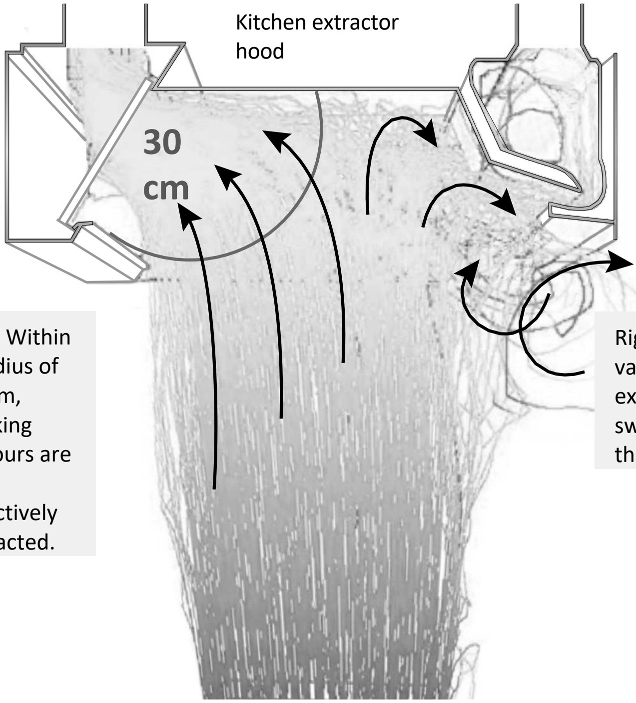
Misconception

> ***All rising vapours are extracted from a cooker hood.***

This observation refutes the model's assumption that all air flowing upwards from the hob into the hood is extracted immediately. We already know from the previous chapters how to address this issue and what product developments are required as a result of these findings.

CFD flow pattern of a kitchen extractor hood

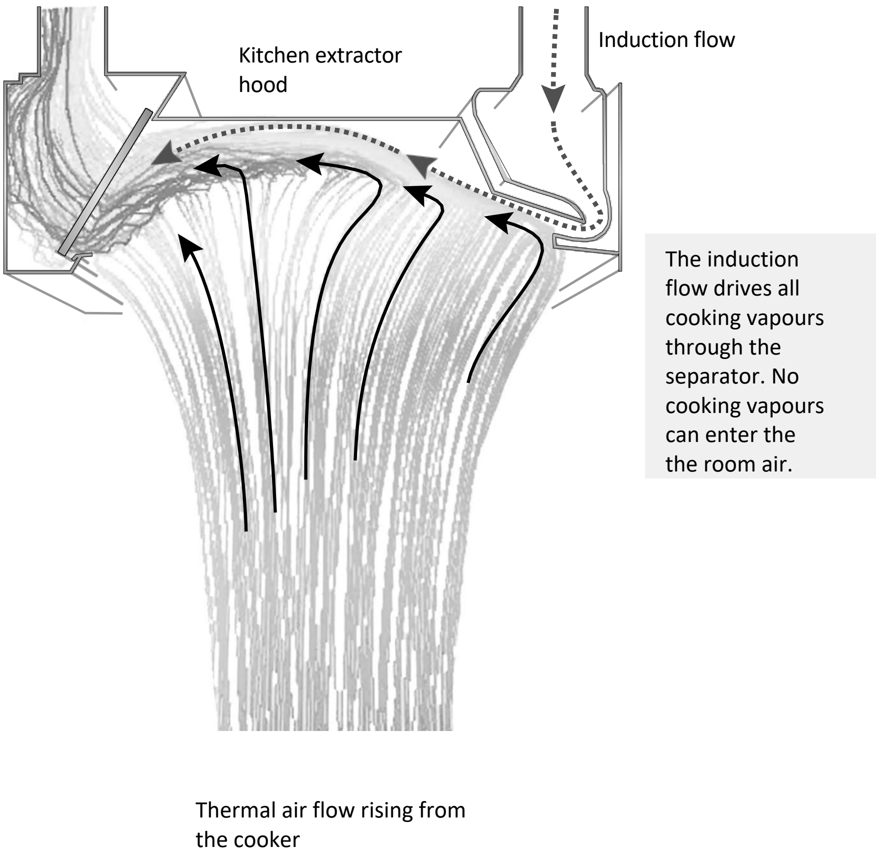
without an induction current



This CFD simulation of the airflow in one of our cooker hoods clearly shows how, during intense cooking, cooking vapours outside the extraction radius swirl and re-enter the room air.

Figure 33

CFD flow diagram of a kitchen extractor hood with induction current



The CFD simulation demonstrates the efficiency of an induction flow.

Figure 34

So in this chapter, too, we can see just how many misunderstandings currently exist in the fields of ventilation technology and air quality control. I have already explained that such misunderstandings also arose at REVEN GMBH in the past. To conclude this series, here is one further example:

In industry, it is not unusual to use what is known as ‘source air technology’ to introduce fresh air into rooms. This involves a low-intensity fresh air supply. In other words, the fresh air usually flows into the room at a low velocity through fine perforated plates. Such diffused air systems are ideal where maximum comfort is required, as the low air velocity ensures a gentle and draught-free supply of fresh air. Ideally, this also results in what is known as stratified airflow. In this process, the fresh air does not mix intensively with the air already in the room; rather, thanks to this clever method of supply, layers form within the room air, comprising both fresh, unspent air and spent or polluted air. Ideally, these different air layers influence and interfere with one another as little as possible. How can this be achieved in practice? Many manufacturers solve the problem with attractive ‘colourful diagrams’ featuring numerous arrows, similar to the model in the VDI guideline.

We at REVEN, too, fell prey to the fallacies of this model around 20 years ago. We designed new supply air products into which metal sheets were integrated in several layers. These were perforated sheets – that is, sheets with thousands upon thousands of small holes. These serve to even out the air flow.
In our view, this was intended to fan out the fresh air flow nicely, so that it ‘trickles’ evenly and slowly into the room. You can imagine it 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: Spring air systems – our assumption

Based on this principle, we developed the REVEN® air diffusion systems around 20 years ago, as our team was 100 per cent certain that such systems would cause only very finely dispersed fresh air to ‘trickle’ into the room, forming a clearly defined, distinct layer of air separate from the stale exhaust air, and that these two airflows could not influence one another in any way. Just as illustrated in the many models mentioned above *models outlined above: neat blue arrows showing how the supply air flows in a straight line into the room and forms a layer of fresh supply air there, without disturbing the exhaust air shown by the red arrows, so that the latter can flow undisturbed into the extraction hood, where it is directly captured and extracted.*

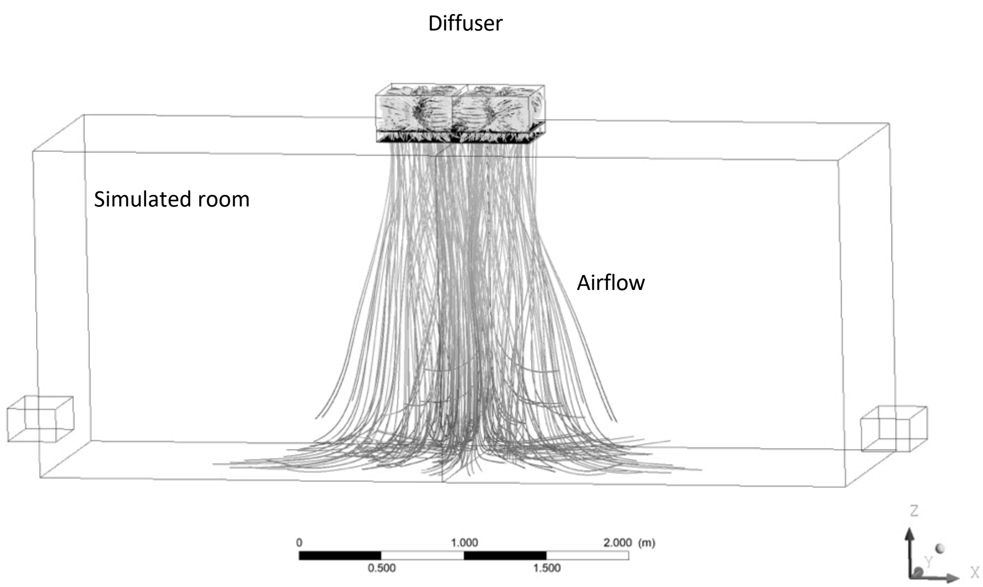
Practical example: Source air systems – doubts

I still remember when, back in 2017, I presented our source air products to an expert from the Spanish SCHAKO CFD team. Using lots of great colourful little diagrams with arrows, I explained to him everything our supply air products are capable of. When he took a close look at our design and analysed the relevant design drawings, he began to have doubts that quickly dampened my optimism. "Sven, we'll need to run simulations and carry out measurements; I have my doubts as to whether everything is quite as you've just explained it 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 taken aback. Shortly after passing through the last perforated plate, the incoming fresh air fanned out, forming the exact 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 carried out metrological tests on our old supply air diffuser in the flow laboratory and used smoke machines to visualise the air flows. This investigation yielded the same result as the CFD analysis. By then, at the very latest, it was clear to me too that we at REVEN had been completely mistaken!

CFD analysis of our diffuser



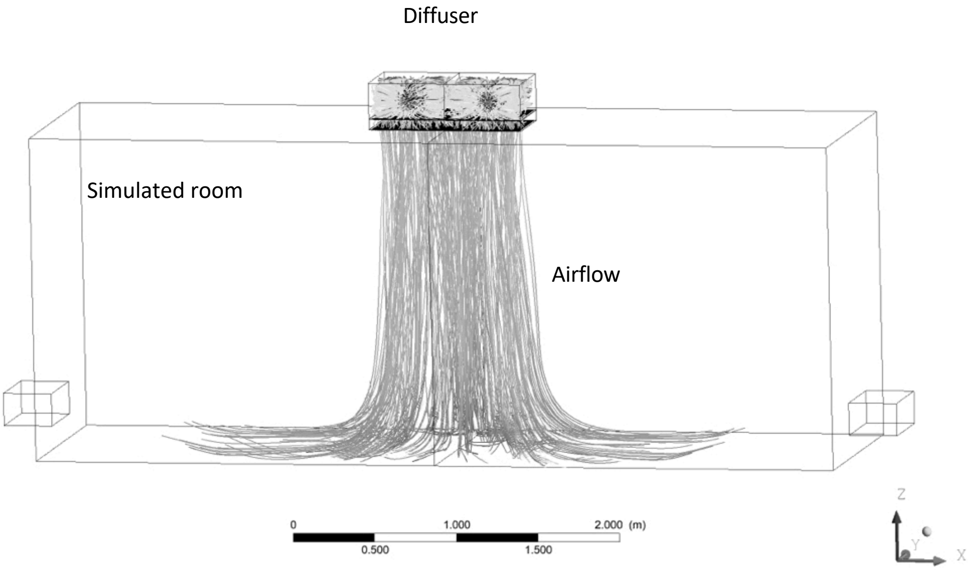
The CFD simulation shows the spreading out of the supply air flowing in from the ceiling.

Figure 35

Case study: Supply air systems – optimisation thanks to CFD

True to the saying ‘forewarned is forearmed’, we subsequently began in 2017 to do exactly what we should have done from the outset. We optimised the efficiency of our supply air products using CFD simulations and measurement technology, achieving a level of efficiency that comes very close indeed to the colourful diagram with the blue arrow pointing downwards from the ceiling towards the floor.

Optimisation of the source diffuser

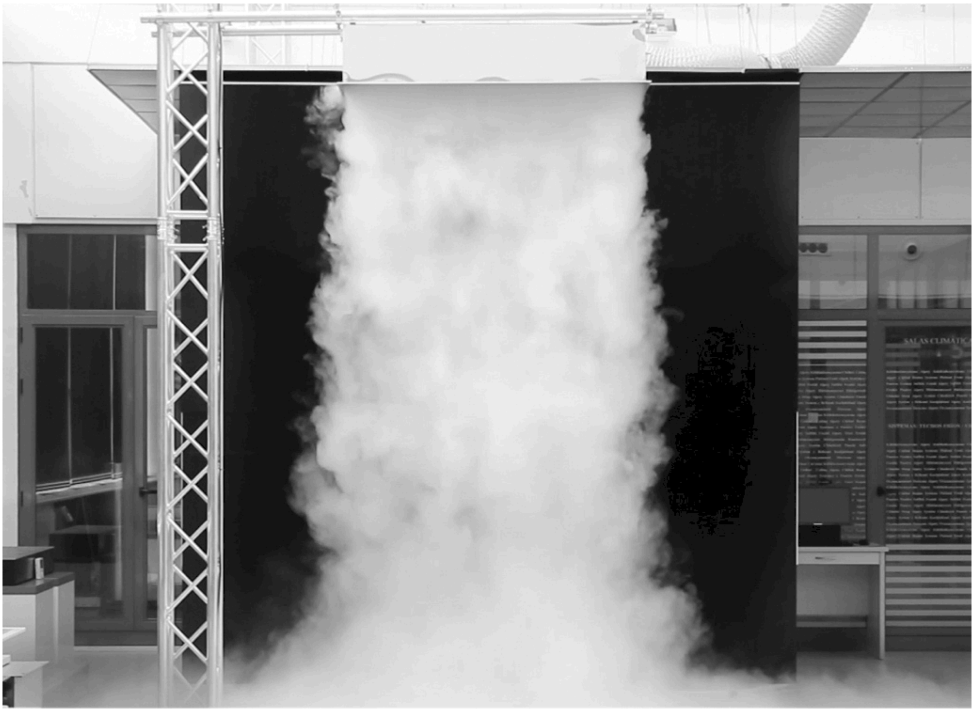


The CFD simulation shows how the supply air flows in a straight line from the ceiling to the floor.

Figure 36

However, achieving this flow pattern required around 12 months of work involving numerous CFD analyses and flow simulations. The result was ultimately a truly efficient supply air system, free from any misunderstandings. Many thanks to the SCHAKO CFD team!

Visualisation of the airflow in an efficient supply air system



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

Figure 37

6. How can air pollution be measured?

For many years, there has been a consensus that polluted air is unhealthy. During the pandemic, we have learnt just how dangerous virus-contaminated air can be to our health. I would therefore like to list here the various substances that can contaminate or pollute the air. Air pollutants include, amongst others:

1. *Viruses and bacteria*
2. *Particulate matter, 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 so-called PM standard was defined in the USA in 1987. PM stands for particulate matter and refers to the proportion of solid or liquid particles in the air. These solid or liquid particles are often components of aerosols. Consequently, aerosols are a mixture of air and particles. Here, too, there are often misunderstandings and the terms are confused.

Misconception

> ***An aerosol is another word for a particle.***

A particle suspended in the air on its own is not yet an aerosol; this only comes into being in combination with the surrounding air. The term ‘PM10’ therefore refers to the presence of tiny particles in the air with a diameter of 10 micrometres (0.01 millimetres) or less. By way of 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 airborne PM10 particles can consist of both solid dust particles and small liquid oil droplets. Put simply, an aerosol always consists of a gas – usually air – and a solid or liquid particle suspended in the air.

Size and composition of an aerosol

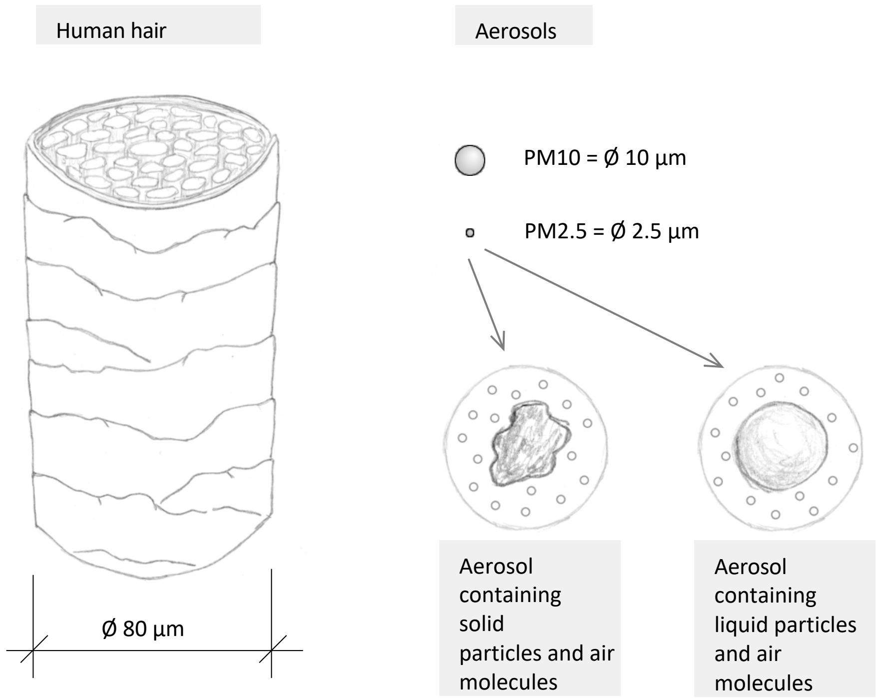


Figure 38

The terms PM10 or PM2.5 refer 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 specifications can be used to infer the actual shape and size of a particle.***

Specifying a diameter actually assumes the shape of a sphere. But how can that be? Do dust particles, grains of sand, viruses and all other forms of air pollution always have the shape of a sphere? Of course not! These particles often have a completely different shape!

Assigning PM values to individual particles

But how, then, can all these particles be defined by a diameter such as PM10, PM2.5 or PM1? This is achieved by means of a trick: one simply compares the actual particles, which have any arbitrary shape, with particles that have a spherical shape and exhibit the same behaviour in the air as the actual particles. In doing so, factors such as flow behaviour are taken into account, as well as the diffusion behaviour and the density of the particles. The aim is to identify which geometrically spherical particle exhibits the same behaviour as the actual particle in relation to these factors. The spherical particle with the same flow and diffusion behaviour can thus be defined as PM10, PM2.5 or PM1. The diameter determined in this way is also referred to in scientific literature as the aerodynamic diameter.

Types, shapes and sizes of particles

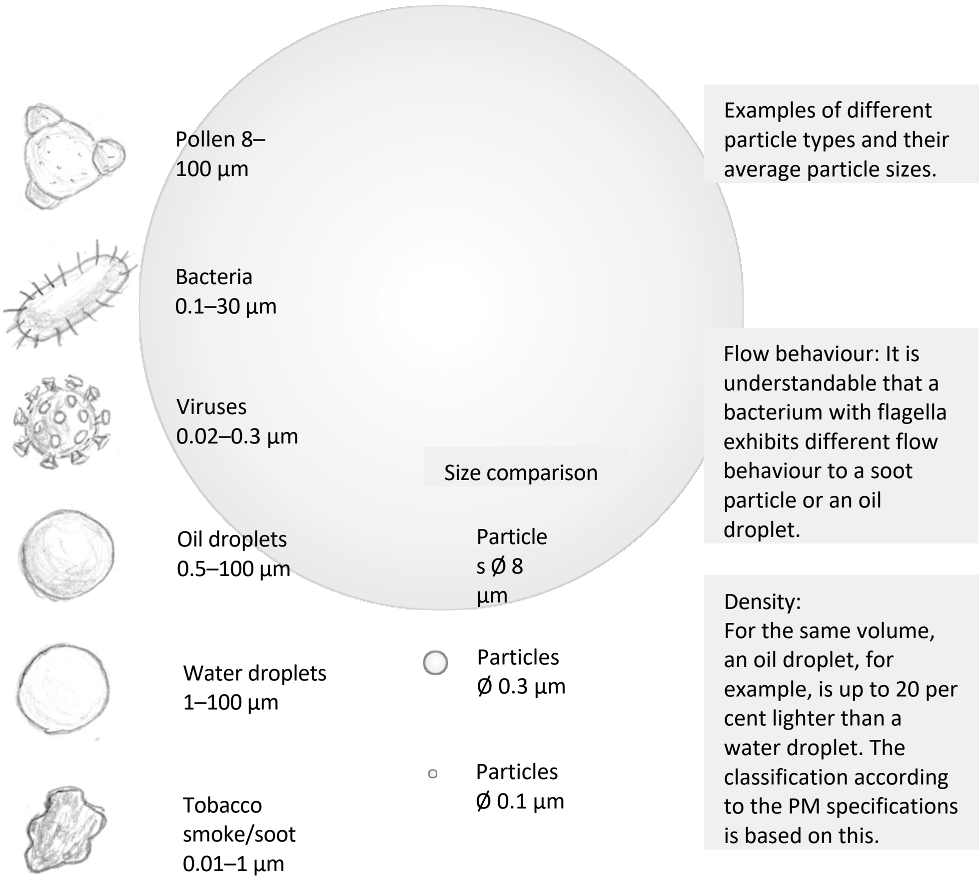


Figure 39

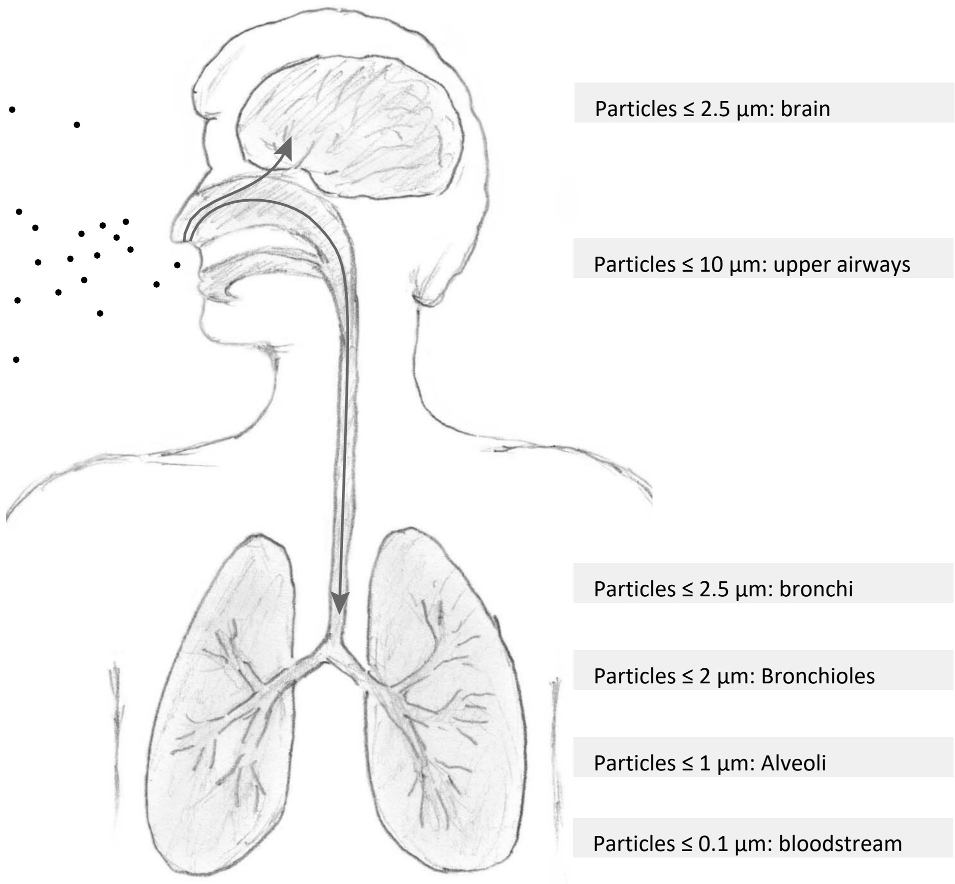
PM10 particles can be inhaled

When air pollution standards were defined in the USA in 1987, the initial focus was on investigating air pollution in the PM10 range, i.e. particles with a diameter of 10 micrometres or less. Why this size range? Because particles of this size are no longer filtered out and trapped in the mouth and nose when inhaled. They reach the lungs.

PM2.5 particles reach the alveoli

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

Particle uptake through inhalation



It is now well established that PM10 particles can cause damage to the upper respiratory tract and PM2.5 particles to the lower respiratory tract. According to the latest studies, particles smaller than 2.5 µm can enter the brain directly via the olfactory nerve or the bloodstream, where they impair cognitive function.

Figure 40

One of my interviewees recently summed it up as follows in my new podcast ‘Luftpost’:

‘What we breathe in indoors in a production environment are often substances that do not belong in our bodies and which should not be allowed to enter our bodies!’

But here, too, there are major misunderstandings regarding ventilation technology and air quality control!

6.1. The misunderstanding regarding indoor air quality

After more than two decades working in our industry, it's still a mystery to me why there are such serious misunderstandings regarding indoor air quality. For some inexplicable reason, people always assume that the air surrounding them indoors is of acceptable quality and free from any significant pollution.

Misconception

> ***Indoor air quality is usually safe.***

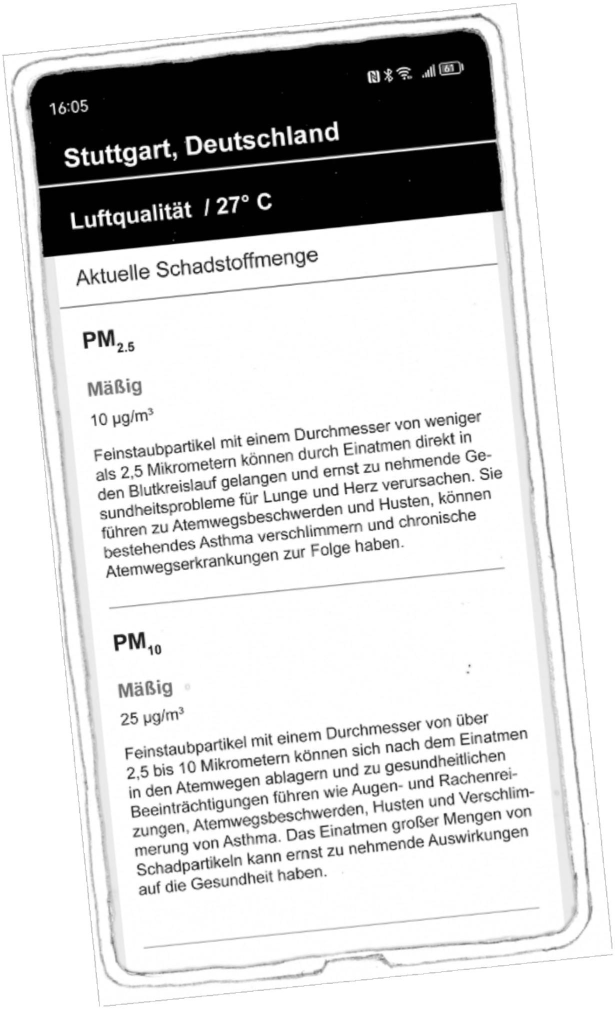
For over a decade, we have been committed to raising awareness on this issue, but we are hardly being heard. We are often met with puzzled looks that reveal people find it hard to believe what we are saying! Why is that? What are we trying to explain? Essentially, it is a fairly simple matter: namely, how air pollution is managed in major German cities compared to how indoor air pollution is managed.

Particulate matter measurements in major cities

In our major cities, people talk about air pollution and consider driving bans when the limit value of 50 for PM10 particulate matter is exceeded over a prolonged period. To determine these levels, measurements are taken at a monitoring point in the city to establish how many PM10 particulate matter particles are contained in one cubic metre of air.

To explain it simply once again: you have a volume of one cubic metre of city air, and using suitable measuring equipment, you can determine how many particulate matter particles with a diameter of 10 micrometres or less are contained in this cubic metre of city air. The particle’s volume can be calculated from its diameter; its weight can be determined using its density; and the total weight of pollutants in one cubic metre of urban air is calculated from the measured number of particles. This total weight is expressed in micrograms.

The importance of outdoor air quality



The growing importance of air quality can be seen in the detailed breakdown of pollutants provided by today's weather apps.
The current readings for the selected city are displayed – along with an explanation of the potential effects of the pollutants.

Example:
Stuttgart on 14 July 2023
at 4.05 pm

PM10: 25 µg/m³

PM2.5: 10 µg/m³

Figure 41

Current limit values for outdoor air pollution

If, for example, this results in a total weight of 20 micrograms, this constitutes low levels of air pollution according to WHO standards and therefore acceptable air quality. For example, the EU's Particulate Matter Directive stipulates that the daily average concentration of PM10 particulate matter is 50 micrograms per cubic metre of urban air and may be exceeded on a maximum of 35 days per year.

Global efforts to lower limit values

Discussions and efforts are currently underway worldwide to further lower these limits, for example to 40 micrograms of particulate matter per cubic metre. There is also an increasing global focus on PM2.5 particles rather than PM10 particles. So much for the situation in major cities.

Indoor air pollution

How does this compare with indoor environments? That is, in rooms where, for example, cooking takes place or where modern machine tools machine metal workpieces.

Practical example: Indoor measurements

Here at REVEN GmbH, we regularly measure indoor air pollution. How do we do this? Using exactly the same measurement technology and methodology as described earlier for measurements in city centres. 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.

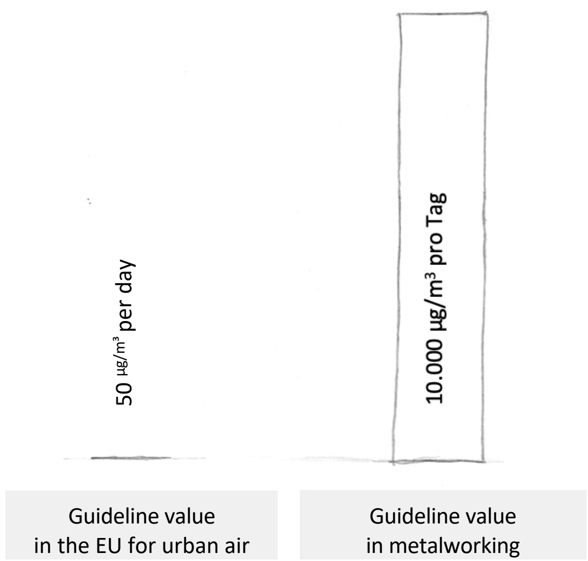
The result obtained in this way yields an air quality index of, for example, 10,000, 50,000 or 100,000. These are on a completely different scale to those found in cities! We have even had to present a measurement result of 500,000 to our customers! This means that one cubic metre of indoor air contains up to 500,000 micrograms of pollutant particles! And this is by no means a rarity in production facilities!

Official recommended limit values for mechanical engineering

A review of the relevant guidelines and standards also makes it clear that such high levels of pollutant contamination are by no means uncommon. The following recommendation applies to mechanical engineering in official guidelines:
For water-miscible cooling lubricants used in metalworking, as well as in glass and ceramics processing, a limit value of 10 milligrams of these substances per cubic metre of indoor air is specified; the same applies to 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 major cities! If such a level were measured in Stuttgart city centre for a week, not a single car would be allowed on the roads there during the day, and the media across the country would be reporting on it.

Comparison of limit values for particulate matter (PM10)



The guideline value for metalworking, at 10,000 µg/m³, is 200 times the maximum amount of PM10 pollutant particles that a person should inhale in a single day according to EU guidelines.

This level clearly poses a health risk.

Figure 42

By contrast, if such air pollution is measured in a mechanical engineering workshop or a hotel kitchen, hardly anyone takes any notice. Not even the representatives of these sectors pay much attention to the issue. Quite the opposite – against their better judgement, these conditions are hushed up, as rectifying them would cost money.

Significance of the measurement results for employees

As a reminder: the EU's Particulate Matter Directive stipulates that the daily average concentration of PM10 particulate matter in urban air is 50 micrograms per cubic metre and may be exceeded on a maximum of 35 days per year.

If the above-mentioned 10 milligrams are measured in a mechanical engineering plant, this means that employees at that plant have to work on around 200 working days a year whilst being exposed to a maximum of 10,000 micrograms of pollutants.

Practical conclusions

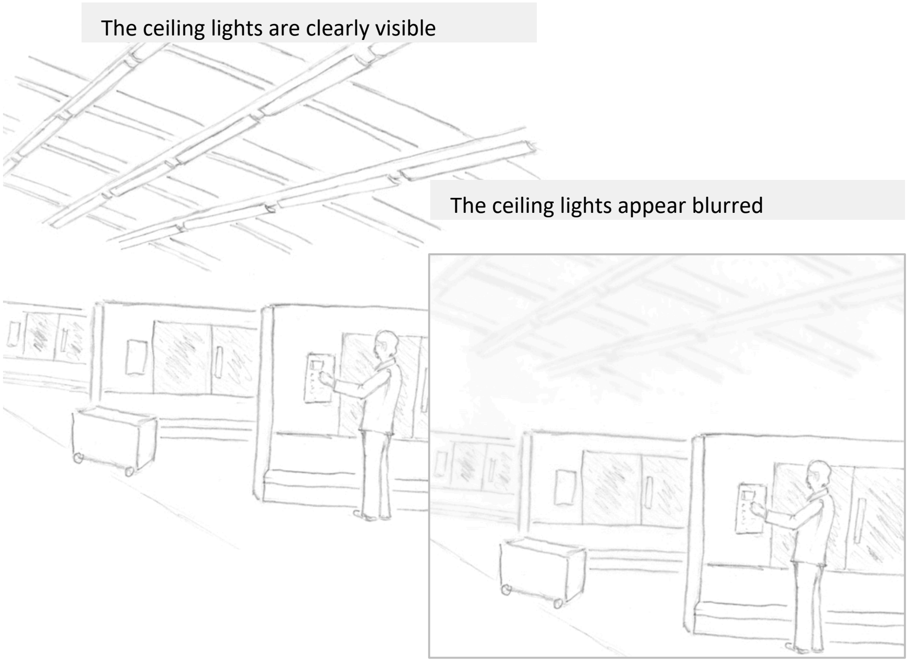
Over the past 20 years, we have carried out tens of thousands of measurements of indoor air pollution around the world. In doing so, we have visited production facilities of all kinds, where a wide variety of products are manufactured using a diverse range of materials. However, the following pattern emerged time and again in all our measurements:

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

A simple method for assessing air quality

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

A simple way to assess air quality



If the ceiling lights in a room cannot be clearly seen, the level of air pollution is very high, at around 10,000 $\mu g/m^3$.

Figure 43

Discrepancy between the assessment of outdoor and indoor air quality

This comparison with the much-discussed air pollution in German city centres highlights the discrepancy that leaves people looking astonished and bewildered when it comes to indoor air quality. We are then often asked how such differences can be justified.

In our view, they simply cannot be justified. All attempts at explanation by those responsible are nothing more than flimsy excuses to avoid urgently needed investment.

Quite simply, nobody is 'aware' of the risks this poses to everyone involved. Concentrations of fine particles that are considered seriously harmful to health outdoors are regarded as still acceptable indoors at 200 times that level? Who will bear responsibility for this risk in future?

Ventilation system manufacturers need to rethink their approach

We too, as manufacturers of ventilation systems and air purifiers, must address this issue! Why? Because even within our industry, there are hundreds of manufacturers of ventilation systems for commercial kitchens or engineering firms who do not even have the most basic measurement technology to measure and analyse such air pollution, even to a limited extent.
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, in commercial kitchens, all pollutants must be captured, extracted and subsequently separated from the exhaust air stream, as we have learnt in the previous chapters.
If both of these are achieved – that is, the capture and extraction as well as the separation of pollutants from the exhaust air stream – then you have

a) a truly good, modern and efficient ventilation system and
b) good air quality with very low levels of pollutants in the rooms.

Lack of verification of compliance

Now my question to you: How many newly installed commercial kitchens do you think are checked for compliance with the standard at the time of commissioning? About as often as the stated fuel consumption of new vehicles? Or as often as the electricity consumption of new heat pumps?
Out of 1,000 newly installed commercial kitchen ventilation systems, this is checked in fewer than ten!

Practical example

I have seen on several occasions that competitors have approached us when a client has insisted on this check, and asked us to carry out the measurements for them, as they do not have the necessary measuring equipment themselves!

Ozone – an example of air pollution caused by gases

When it comes to air pollution caused by gases, we face a very similar situation and observe the same phenomenon here too. I would like to illustrate this using ozone as an example. We have already discussed the potential hazards of ozone in Chapter 4. In many European countries, the limit value for ozone in indoor spaces remains set at a maximum of 200 micrograms per cubic metre of indoor air. This was also the limit previously in force in Germany, although it has since been abolished. In Switzerland, however, this limit still applies. According to the classification criteria for carcinogenic substances set by the German Research Foundation (DFG), ozone is classified as a substance that has not yet been sufficiently studied but is suspected of causing cancer in humans.

Weather app showing high outdoor ozone levels

The weather app lists the highest pollutant levels 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 am

O_3: 104 µg/m³

Figure 44

Ozone – outdoor limit values

The Federal Environment Agency provides information on the outdoor limit value and the associated health risks. It warns that ozone in the air can lead to reduced lung function, inflammatory reactions in the airways and respiratory complaints. A limit value of 180 micrograms of ozone per cubic metre of urban air. This value is referred to as the information threshold. If the concentration exceeds this value, behavioural recommendations and warnings are issued to the public via the media. At a concentration of 240 micrograms of ozone per cubic metre of urban air, the alarm threshold is exceeded and an alarm is triggered. It should also be noted that outdoor ozone levels may not exceed an average of 120 micrograms per cubic metre of urban air over an eight-hour period on more than 25 days in a calendar year.

Ozone – limit values in the context of kitchen ventilation

Currently, however, experts in the field of kitchen ventilation still cite a permissible limit 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 at which many national industry associations were also involved. Only a mischievous person would think ill of this!
This standard states that the concentration of ozone in the exhaust air from 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 believe that the differences in the assessment of indoor and outdoor air quality highlighted in this example also speak for themselves and require no further explanation. In fact, in this case too, it should be clear to everyone what needs to be done, namely to completely prevent the formation of ozone, whether indoors or outdoors!

However, to achieve this goal, air pollution must be measured and analysed. More on how this can be achieved in a moment.

6.2. Particle measurements make air pollution visible!

What measurement techniques can be used to measure pollutants in the air? What measurement techniques can be used to verify the efficiency of a ventilation system? Essentially, this is not complicated and has already been described in Chapter 3. To accurately determine the level of air pollution, it is recommended to use

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

We have already described FID measuring instruments in detail in Chapter 3. Particle and aerosol measuring instruments have long been the state of the art for cleanrooms. For decades now, there has not been a single operating theatre in a hospital or a microprocessor production facility where particle counters are not used to verify the functioning of the ventilation system during commissioning. Essentially, this simply provides proof that the air inside such a cleanroom is truly clean and free from even the smallest particles. This is the purpose of the particle counter.

How particles are measured

Particle counters use complex optics and laser beams to analyse whether minute particles are present in the air. In the process, the number of particles is counted and, at the same time, their size is analysed – that is, their aerodynamic diameter is determined.

Portable particle counter

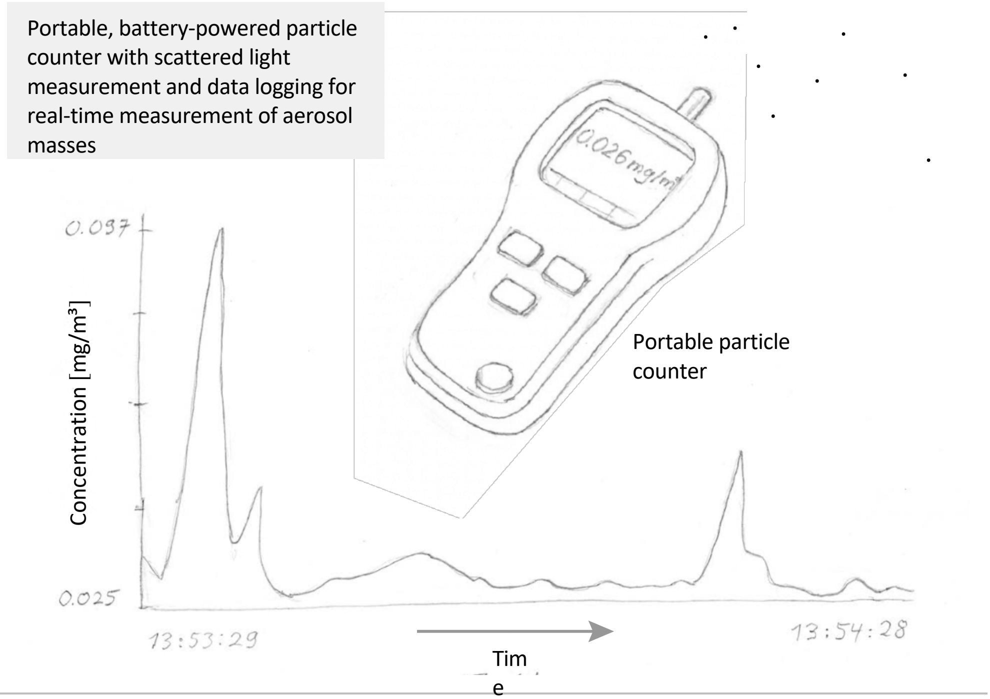


Figure 45

Particle measurement technology must be adapted to the situation

Just as in cleanrooms, it is also possible to analyse the ambient air and determine the particle concentration in production facilities, commercial kitchens or mechanical engineering workshops. In principle, the procedure is exactly the same, albeit with one major and important difference:

The number of particles differs enormously compared to cleanrooms! Whilst in cleanrooms the aim is to check whether PM10 particles are present in the ambient air at all, in the ambient air of a kitchen or production facility the number of particles present in one cubic metre of ambient air is measured. This often amounts to ten thousand times or even more than in a cleanroom! 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 heavily contaminated rooms 25 years ago, we tried to use conventional particle counters, as there was hardly any more suitable measurement technology available at the time. As one might imagine, these initial measurements were often impossible to validate, lacked traceability and were of very poor quality, as the particle counters were completely overwhelmed by the high particle concentrations. An initial approach to improving the situation was the controlled dilution of the air to be analysed. This involved diluting the air to be analysed, for example, 1,000-fold with clean, particle-free air using appropriate dilution stages. This diluted air was then measured using conventional particle counters, and the result was extrapolated by a factor of 1,000. The simultaneous further development of particle counters ensured that the instruments later became less sensitive to very high particle concentrations and that the measurement results became increasingly accurate.

Modern devices ensure precise measurements

Today’s particle counters can analyse even heavily contaminated indoor air with the same accuracy that has been the norm in cleanrooms for decades. The industry simply needs to be genuinely committed to this precise measurement and willing to invest in modern measurement technology.

Too few measurements are being carried out

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

Unfortunately, this is no misunderstanding!

> ***The optimal functionality of ventilation systems is simply taken for granted, without any measurement evidence.***

The flawless operation of a ventilation system, the efficiency of capturing and extracting pollutants from the air flow, as well as their separation and filtration – all of this is tacitly assumed and taken for granted. The attitude is: 'It'll sort itself out somehow and be fine.' Most people don't really want to know whether 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 just how complex the tasks involved in ventilation technology – such as intake and extraction, filtering and separation, and the supply of fresh air – actually are. For these reasons, measurement technology is essential to verify that the indoor air is truly free of pollutants. There is no excuse for not using this measurement technology on a regular basis.

Lack of measurement evidence for ozone air purifiers

Similarly, suitable measuring equipment can also be used to detect hazardous gases such as ozone. However, the same attitude prevails here as with the particle measurement technology described above: amongst the thousands of suppliers of ozone air purifiers, you will struggle to find one who can provide you with evidence, using suitable measurement technology, that their products do not cause more harm than good as a result of the ozone they generate.

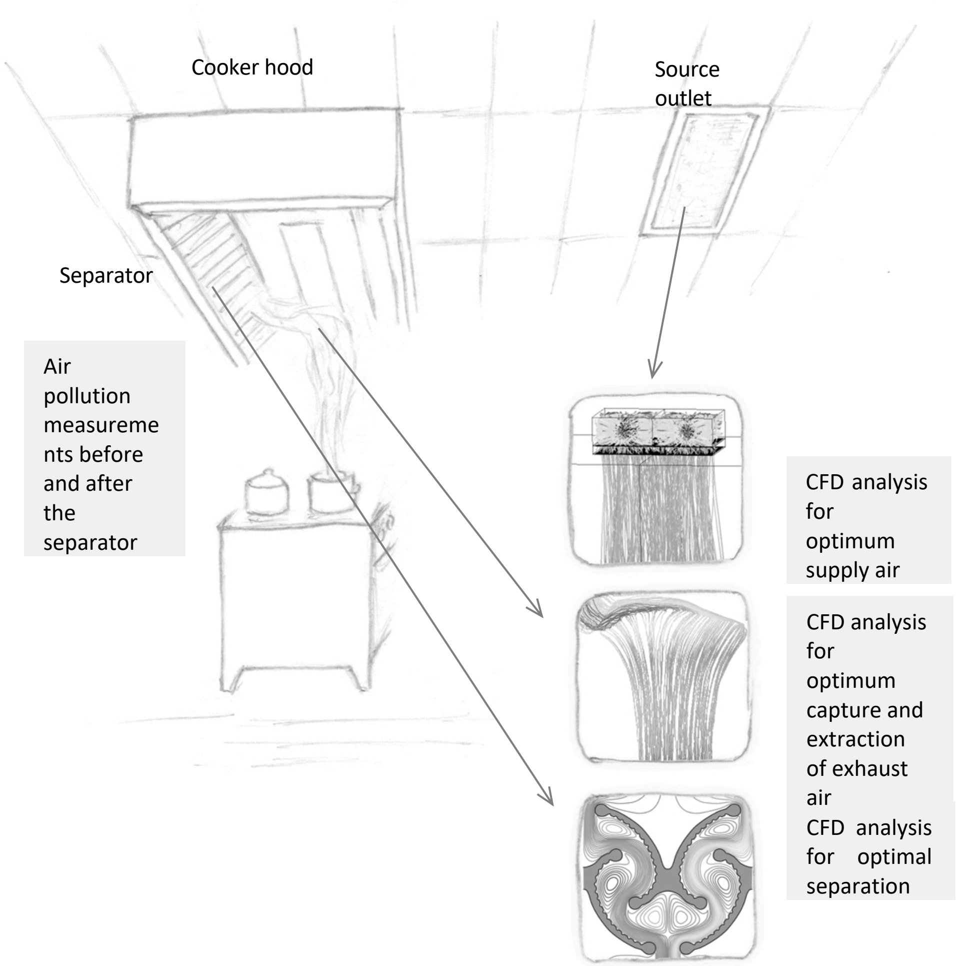
Reputable ventilation technology is scientifically sound

As in the previous chapters, it is evident here once again that reputable product development in ventilation technology and air purification requires a scientifically sound approach. Grand promises in attractively designed advertising leaflets may all too often lead us to believe otherwise in our industry. You must remain vigilant and question such promises.

Conclusion

I hope that my comments have helped to raise your awareness of this topic and provided you with some interesting information. We have now come full circle – from efficient capture and extraction in Chapter 1 to the appropriate measurement techniques for determining the efficiency of ventilation technology and air purification in Chapter 6, we have covered everything.

Scientifically sound ventilation technology



At Rentschler REVEN, the functionality of kitchen ventilation systems is tested and optimised using scientifically based methods.

Figure 46

Concluding remarks

You have now read all the chapters of this book, which originally came from our podcast ‘Misconceptions in Ventilation Technology and Air Quality Control’. I hope I have been able to provide you with some food for thought. A competitor recently criticised the content of the podcast. They claimed the whole thing was too superficial and that they had expected more from me. As mentioned elsewhere, my aim was to make topics relating to ventilation technology and air quality control easily accessible and as entertaining as possible. I did not set out to write a scientific paper. The topics in our ventilation sector tend to be niche subjects that do not interest the general public. That is why it was important to me to explain any misconceptions in a simple and understandable way, even to those outside the industry. I hope I have succeeded in doing so.
We have written this book based on this podcast. It also contains many interesting illustrations to visually reinforce the individual points.

It is important to me to make our industry attractive to the next generation, as air quality is a vital issue and will remain so in the future. That is why we should approach this subject with care and a sense of responsibility.
My colleagues in sales will be carrying this book with them in future and will be happy to give you a copy to help illustrate the various topics when you discuss new projects, new processes and new plans with them. After all, we want our technologies and our products to be understood!

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

Alongside our book project, we've now also launched a new podcast. It's called 'Luftpost'.

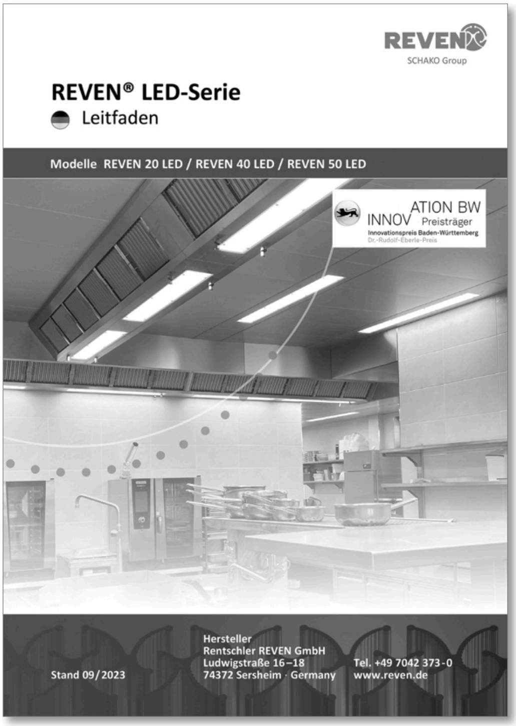
This new podcast series is all about clean air. I introduce people and companies who are involved in the fields of air purification and ventilation technology. I interview key figures from a wide variety of sectors and discuss the technologies involved. I chose this title because of the associations the term evokes. In the past, news and messages were often sent by airmail. I want to share the latest news on clean air and a healthy environment in my podcast 'Luftpost'.

You can find it at **reven.news/luftpost**; the first episodes are now online.

If you're involved in the ventilation or air pollution control sector, we'd be happy to co-host an episode of the podcast. I'd also be happy to visit you for this. Simply contact me at**marketing@reven.de** .

Interesting content from REVEN

The guide to LED lighting



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

In commercial kitchens in particular, the right lighting is of great importance. Therefore, aspects such as brightness, contrast and colour should be considered and taken into account during the planning stage. This is where our lighting management system offers significant advantages.

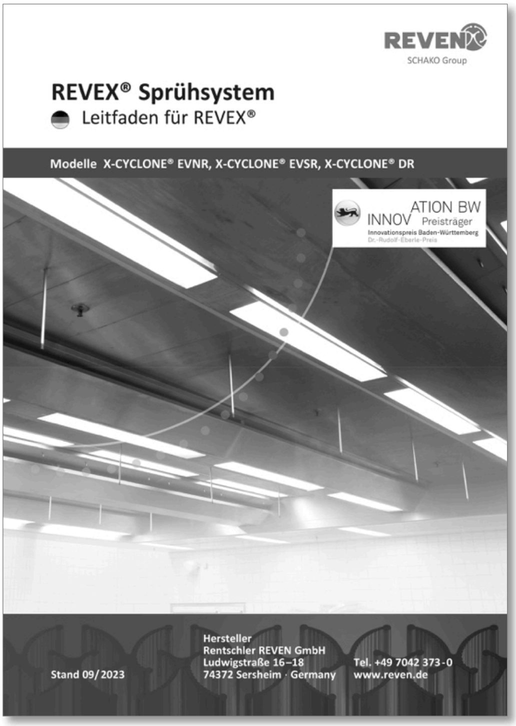
In this LED guide, we explain which factors are important for good lighting and how REVEN® LED luminaires meet these requirements.

The RSc Control Brochure

To improve the energy efficiency of ventilation systems in commercial kitchens, Rentschler REVEN offers the intelligent RSc control system. The system continuously adjusts the supply and extract air volumes to match cooking activities, fully in line with the innovative Industry 4.0 standard.

In our brochure, you can find out the technical details that need to be taken into account 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 the system functions correctly, reduces the risk of fire and prevents the growth of microorganisms within the system. It also protects the health of kitchen staff.

Misconceptions in ventilation technology and air quality control

The book

The response to the podcast was so overwhelming that turning it into a book practically happened of its own accord. The feedback speaks for itself:

'... the podcast on airflows left me wanting to know more ...'

"… I'd like to congratulate you on the interesting podcast
'Misconceptions in Ventilation Technology and Air Quality Control' and thank you for the information …"

"... thank you very much for the truly interesting podcast. I'd be delighted if there were more to come. I've been a project manager in ventilation engineering for over 20 years and have learnt a great deal that I can apply in practice and to future projects. I'd be delighted if I could work with you on the next kitchen ventilation system ..."

"... I'd like to congratulate you on the podcast. The subject matter is very easy to understand, even for people like me who aren't that familiar with the subject..."

"... As a regular listener to your podcast, I'd like to take this opportunity to order the reference book announced for 2023. I look forward to more episodes on the topic of air – our most precious resource ..."

cci Buch is a brand of cci Dialog GmbH Also available as an e-book

• VENTILATION • ACCLIMATISATION • COOLING

cci-dialog.de

ISBN 978-3-922420-74-3
9 783922 420743
€ 47,00 (D)