The story of the flying particle

Once upon a time there was a particle that floated boldly and freely in the air. It was so small that with every movement of air it changed direction - sometimes up, sometimes to the left, sometimes in a circle. Together with its fellows, it formed a cloud of dust that a human could not see with the naked eye.

What seems like the beginning of a children's story is actually a little-known fact that makes the topic of occupational safety and employee protection in manufacturing companies particularly important.

Industrial air pollutants – dust and smoke

Industrial manufacturing processes such as joining, cutting or any form of surface processing generate airborne pollutants. Basically, the following types of air contaminants arise:

- Gaseous substances
- Aerosols
- Vapors/odors/gases
- Mist
- Fume/smoke
- Dust

In the following the focus will be on dust and smoke. But what are dust and smoke?

Dust and smoke basically consist of particles, i.e. the smallest particles in sizes between 0.01 µm and <10 µm. For comparison: a human hair is between 40 and 100 mµ thick. Their size varies depending on their origin. For example, welding fume can contain particles between 0.01 and 1 µm in size, whereas the particles in laser fume are rarely larger than 0.01 µm - and in the case of ultra-short pulse lasers they are even in the nanometer range.

Like smoke, dust is a finely dispersed solid. The floating ability and sinking speed (sedimentation) of dust particles depend on their size, shape, and specific weight. Dust arises in production primarily during mechanical shredding (e.g. grinding, pounding, cutting), metal-cutting processing (e.g. sawing, milling, filing, grinding, polishing, blasting), industrial processing processes with lasers, and additive manufacturing.

Pollutants that remain in the air for a long time, especially harmful gases that are not or hardly separated by settling, are particularly dangerous for people, the environment, and machines. They can spread widely and develop their harmful effects even at great distances from the place of production.

The small size of the particles is the crux of the matter, as they can be inhaled below 10 µm. If they are less than 3 µm in size, they overcome the blood-lung barrier and, therefore, are alveolar. As a result, they can accumulate in the human organism and potentially cause illness.

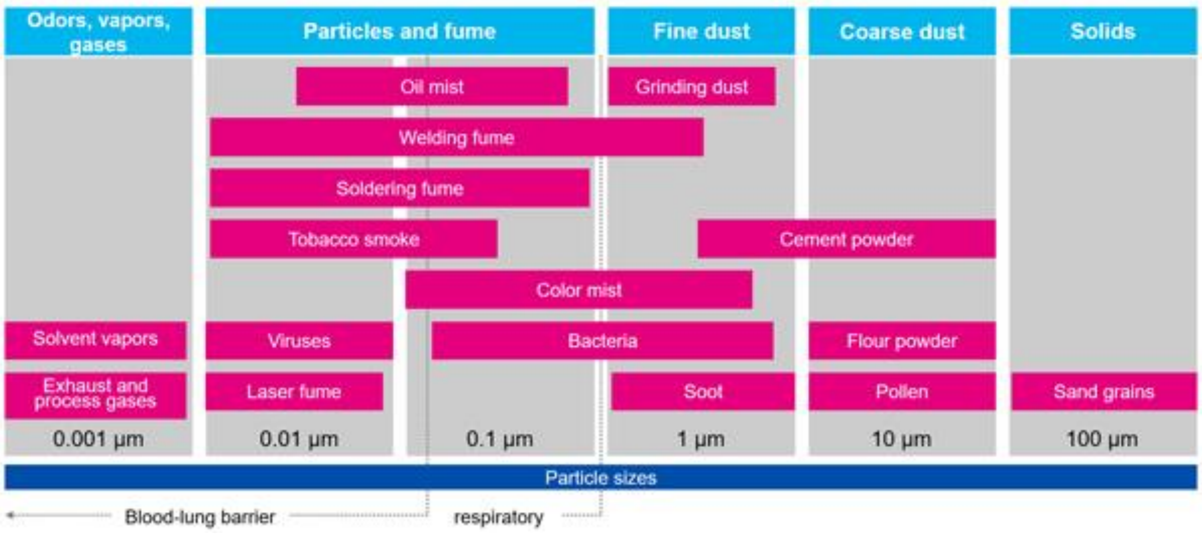

Image 1: Particle sizes

Pollutant dispersion and floating behavior

If particle sizes of airborne pollutants are less than 100 µm, it can be assumed that the particles follow the air flow almost undisturbed. For larger particles, the influence of their own momentum and gravity increases more than the influence of an existing air flow. These particles can no longer be inhaled and sediment within a short time in still air.

There are a variety of factors influencing the spread of pollutants in the room, which are shown in the following table:

Influencing parameters	Variation size
Size and extent of the source	• Point source • Linear • Areal • Spatial
Condition of the substances	• Aggregate state • Temperature • Density • Pressure
Type of release	• Self-movement • External movement
Indoor air flow around the emission source	• Interfering flow
Arrangement of the source in the room	• Room coordinates
Place of release	• Location fixed/stationary • Variable in location
Duration of the emission	• Continuous • Intermittent
Amount of substance released	• Concentration • Working methods
Physical and chemical properties of the substances	• Sorption behavior • Reactivity • Agglomeration • Abrasiveness • Flammability/combustibility

Table 1: Factors influencing the spread of pollutants (source: VDMA - Association of German mechanical and plant engineering)

When releasing liquid and solid substances (mist, fume, dust), the droplet or particle size must be taken into account. Depending on their size, geometry, and density, they sink to the ground more slowly or more quickly (sedimentation). Fine and light particles can remain suspended in the air for a very long time. For gaseous substances, only the difference in density compared to the surrounding air needs to be considered.

The release and spread of airborne substances are determined by four driving forces: differences in density, differences in pressure, external forces, and diffusion. These lead to different flow characteristics and are therefore the starting point and basis for the planning and design of capturing devices.

The sedimentation behavior of the finest particles therefore depends on:

- Size, density, geometry, and surface properties of the particles
- Concentration of particles in the medium
- Medium composition
- Medium temperature
- Medium flow velocity
- Electrostatic interaction between the particles and the medium.

Fine particles tend to sediment more slowly than coarse particles. Particles with a smooth surface tend to sediment faster than particles with a rough surface. Particles that have a strong electrostatic interaction with the medium tend to sediment more slowly than particles without electrostatic interaction.
The suspension behavior of airborne pollutants can also be impressively illustrated using the sedimentation speeds. For example, a particle with a size of 100 nm, which is typically created during laser processing, has a sedimentation speed of just one meter in two weeks!

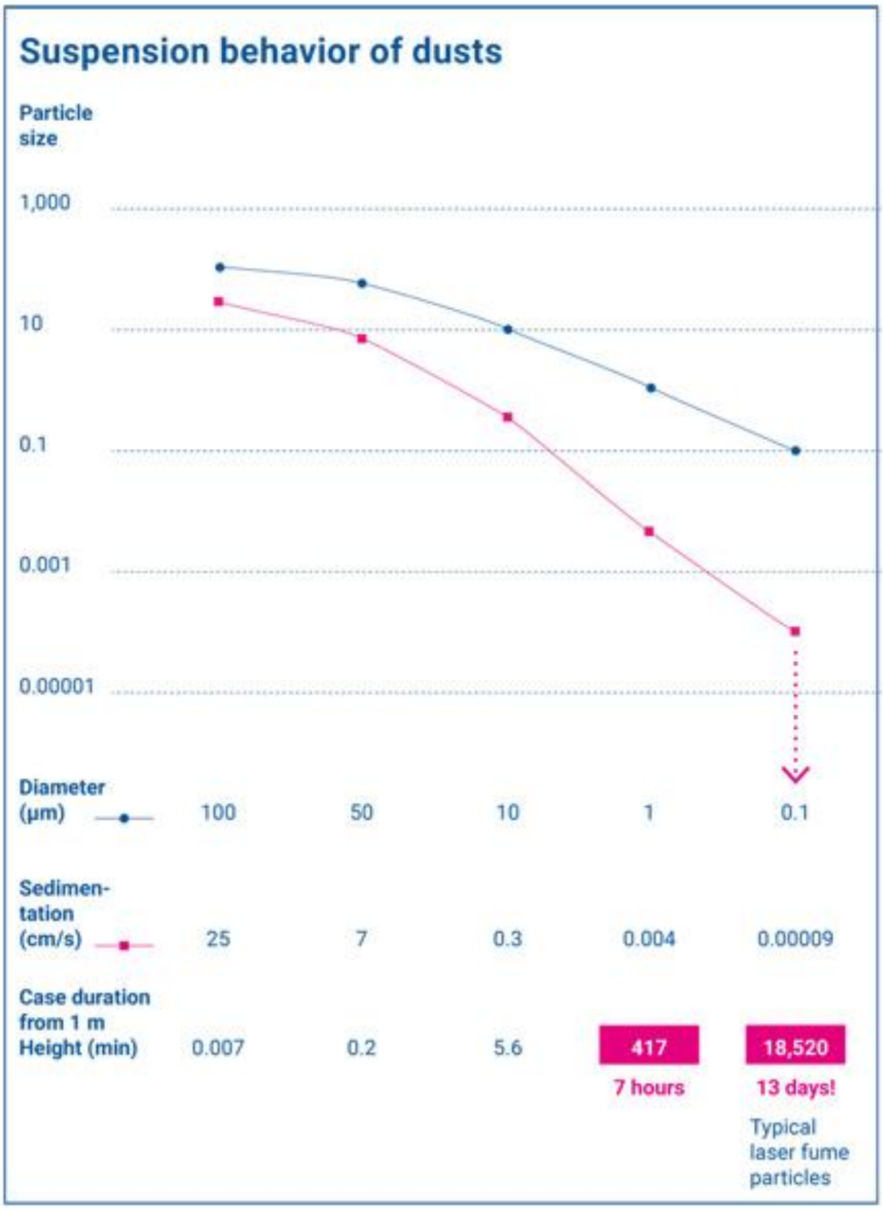

Image 2: Particle sedimentation

Effects of airborne pollutants on humans, machines, and products

Airborne pollutants are generally divided according to particle size. This classification primarily focuses on the influence of emissions on the human organism. Airborne pollutants are not only differentiated according to whether they are harmful to the brain, nerves, or respiratory tract, but also whether they are inhalable or alveolar. There are legal limit values for this in accordance with DIN EN 481.

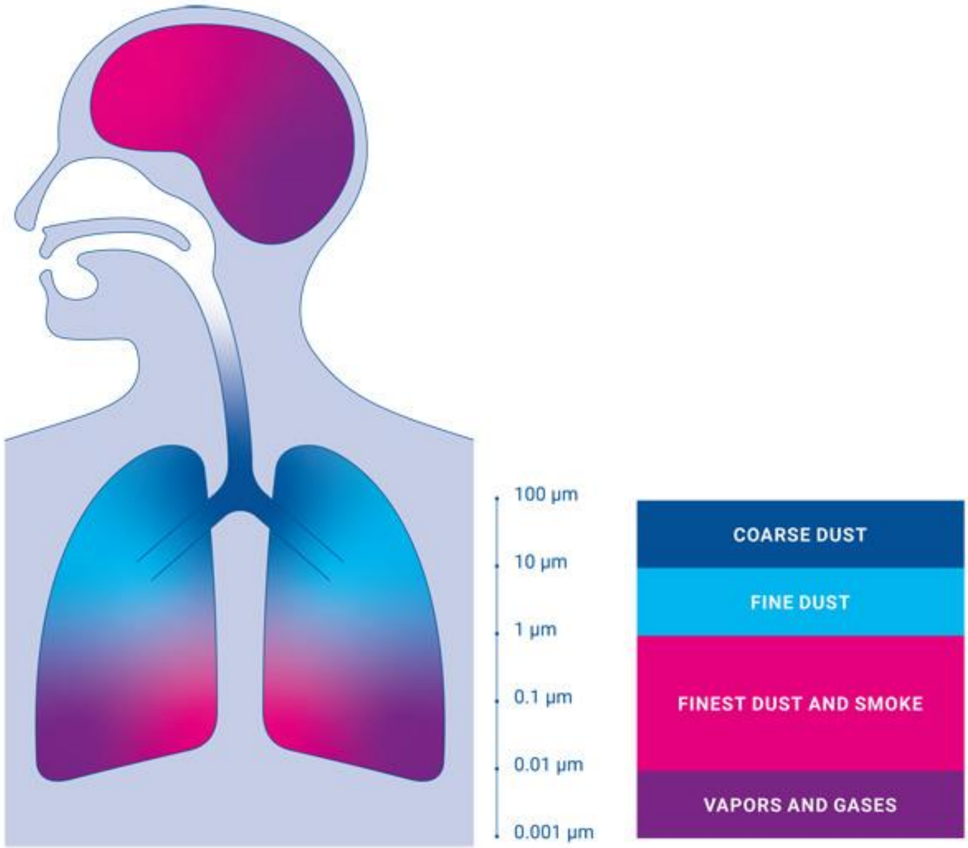

Image 3: The influence of airborne pollutants on the human organism

In addition to the potential impact on the health of employees in manufacturing companies, airborne pollutants can also impair machine functionality - and therefore also be responsible for production errors - or contaminate products. Practical examples may be the contamination of the "laser eye" or the mirrors of a laser system by sticky laser dust, or the settling of corrosive particles on an electronic assembly.

Implications for capture and filtering

It was shown that airborne pollutants follow the air flow almost undisturbed and can therefore spread widely. The negative effects on people, manufacturing equipment, and products are also known.

That danger cannot be seen in every case. In addition, the effects often only appear at a later point in time. It is not uncommon for this topic to be inadequately addressed and therefore of utmost importance to safely capture and separate pollutants. Particularly a strong focus must be placed on the level of capture, which is generally neglected far too often and does not receive the necessary attention. Too often only filter classes are issued. However, the overall efficiency of an extraction system is measured by the components 'capture efficiency' and 'separation efficiency'.

The following graphics show this impressively:

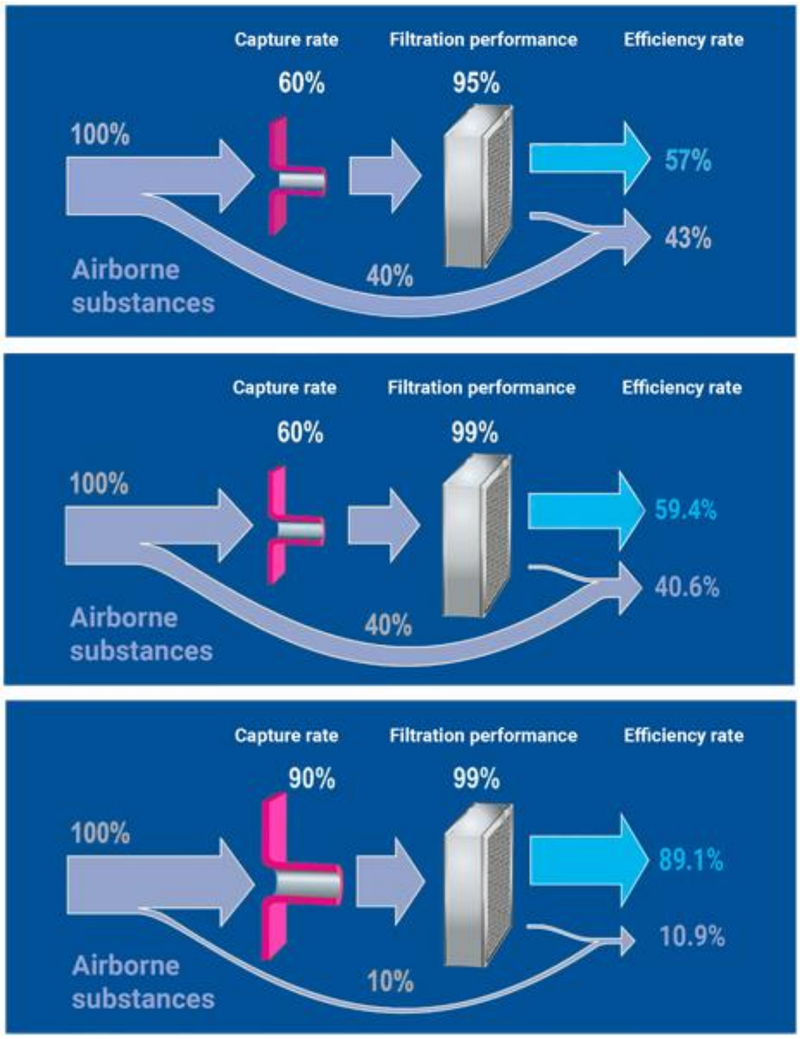

Image 4: Dependence of the extraction system efficiency on the degree of capture and separation (source: VDMA - Association of German mechanical and plant engineering)

The design of the capture/collection is therefore the most important step for efficient air purification. It is important to understand the background sufficiently or to seek appropriate advice.

There are different solutions for pollutant collection on the market, which are basically divided into three types or systems: closed, half-open and open.

Closed systems enclose the emission source on all sides. Harmful substances are removed through suction openings, after-flow openings ensure air balance.

Half-open systems are enclosures of the pollutant source with an open side for handling and inflowing ambient air as well as an exhaust connection.

Open systems are form elements that are offered in various versions. Their utilization is defined by shape, geometry, and material. They are usually mounted on extraction arms, whose use is also defined by the amount and type of pollutant. Guidelines and workplace situations regarding ESD, fire and explosion protection may require special designs.

The diameter of the extraction arms and their installation – directly on the filter system, as table or wall mounting, etc. – are also defined by their practical utilization. Capturing elements can also be attached to suction hoses or pipes.

There are also other aspects that must be considered when designing the capture:

- Workplace ergonomics
- Easy handling and trouble-free operation are prerequisites for user acceptance
- Sufficient dimensioning of the air output
- Number of hazardous substances released per unit of time (emission rate)
- Direction of spread
- Speed of spread
- Distance from the emission source to the collection device
- Air flows in the room and their effects on the suction field.

To optimize the required (capture) air flow, the collection device must be:

- Positioned as close as possible to the emission source (twice the distance requires four times the airflow)
- If possible, arranged in the direction of propagation of the airborne substances
- Adapted to the flexibility required by the work

For effective capture of airborne substances:

- The velocity of the air in the extracted air flow must be greater than the dispersion velocity of the air pollutants
- Interfering air currents must be kept away from the suction field of the capture device with partitions in the working area
- Supporting air currents in the room should be utilized by the position of the detection device

Other parameters, e.g. noise generation at a detection device and material properties such as electrical conductivity, temperature and abrasion resistance, also play a critical role.

Filtration principles

The actual filtration process begins after the particle capture. Filtering separators are basically divided into two types: filter devices with storage filters or cleanable filter elements.

- Extraction systems with storage filter elements are used at low mass concentrations of particles. They offer the advantage of low investment costs and high flexibility.
- Extraction systems with cleanable filter elements (also referred to as cartridge filters) are used primarily for high mass concentrations of particles. They require little maintenance and generate low energy costs. Additionally, these filter elements offer a long filter service life, i.e. they rarely need to be replaced.

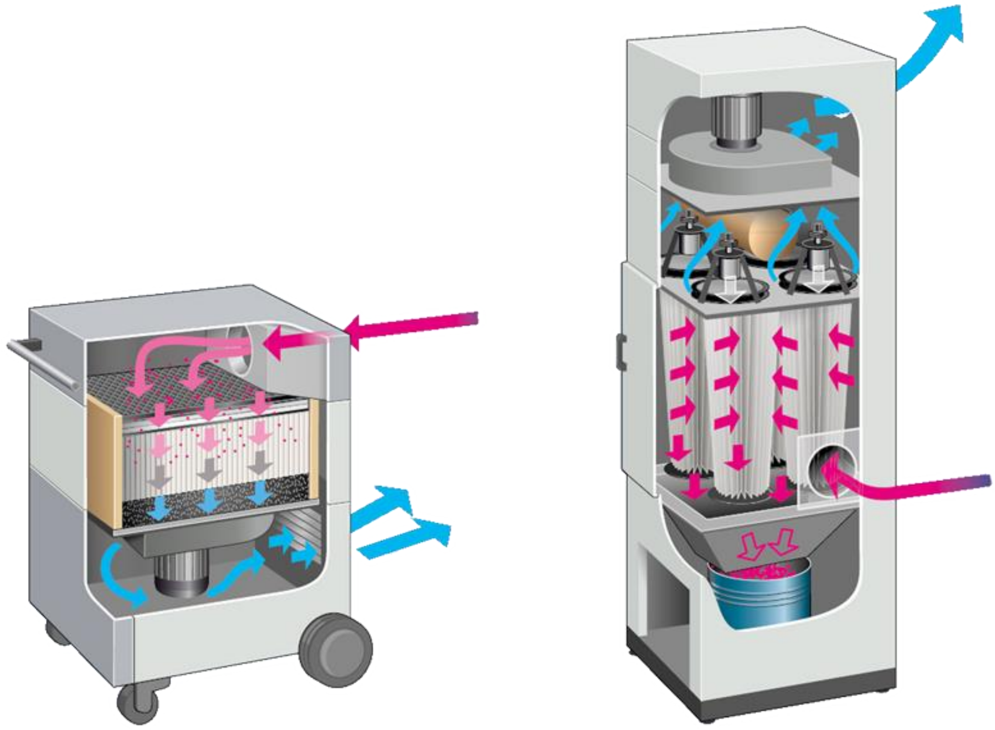

Image 5: Filter devices with storing (left) vs. cleanable (right) filter elements

When designing the overall system, there are other aspects that must be considered which are listed here as examples. It is important to note whether the substances have the following properties, i.e. if they are:

- Flammable or hot
- Explosible
- Aggressive
- Abrasive

There are further important parameters for the design and efficiency of an extraction system. For example, material transport speeds and collection speeds play critical roles in operating an extraction and filtration system economically and sustainably.

The journey of the flying particle …

… will therefore only come to an end if all the parameters and influences of correct removal are considered and incorporated into an overall solution. Only in this way airborne pollutants can be optimally removed from the ambient air in manufacturing companies − and employees, systems and products be sustainably protected.

Authors:
Alexander Jakschik, Managing Director ULT AG
Stefan Meissner, Corporate Communications with ULT AG

Contact:
ULT AG, www.ult-airtec.com, ult@ult.de