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An Underestimated Health Hazard in the Operating Theatre.

Surgical SMOKE

By Stefan Kämper and Timur Zeytin

Surgical smoke, also known as surgical plume or electrosurgical smoke, is produced through the use of energy-based devices such as electrocautery units, lasers, or ultrasonic scalpels. These instruments burn tissue, resulting in visible smoke. While it may appear harmless at first, this smoke poses a serious health risk to operating theatre staff.

The smoke contains a complex mixture of harmful substances, including toxic gases, carcinogens, viral and bacterial particles, as well as very fine biological aerosols. Studies show that long-term inhalation of these particles can lead to respiratory diseases, eye irritation, and in extreme cases, an increased risk of cancer.

Despite the known risks, protective measures such as smoke extraction systems or respiratory masks are not yet widely established in many operating theatres. For years, international health organizations have been calling for the consistent use of technical extraction devices and improved ventilation systems to reduce exposure to surgical teams.

Overall, the handling of surgical fumes is an essential but often neglected topic in occupational safety. Raising awareness among medical staff and ensuring the use of suitable protective measures are essential to safeguarding long-term health in the operating theatre.

Why Are Filters Necessary?

Unfiltered surgical smoke can cause respiratory irritation, nausea, and headaches, as well as long-term health effects such as chronic lung diseases. Studies have also shown that infectious particles, such as human papillomaviruses (HPV), can be transmitted via smoke fumes. The installation of appropriate extraction and filter systems is, therefore, essential to minimize exposure.

Types of Filter Systems

High-performance filtration systems, typically used for removing surgical smoke, comprise multiple components.

- **Pre-filters**, which trap coarse particles
- **HEPA filters** (High Efficiency Particulate Air) for removal of particles down to 0.3 microns with an efficiency of ≥ 99.97%
- **Activated carbon filters** for adsorption of gaseous pollutants and odors.

Some modern devices also use UV light or plasma to kill germs.

Table 1 shows the main gas components, i.e., the volatile and gaseous substances, of surgical smoke:

An effective method of reducing these emissions is to use filters based on spherical high-performance adsorbents (see Figures 2 and 3).

This special form of activated carbon offers significantly higher adsorption capacity and faster adsorption kinetics compared to conventional powdered or granular carbon, as well as enhanced moisture resistance and more uniform airflow. Due to its unique electrostatic properties, it also exhibits bacteriostatic and bactericidal effects against various germ species. In systems used for minimally invasive surgical procedures, the resulting surgical smoke often requires effective filtration under conditions of high relative humidity. This can be achieved much more efficiently and effectively using filter media based on highly hydrophobic spherical adsorbents of polymer

▲ Operating theatre with an exhaust ventilation system. *Courtesy of Talamon*

origin than with conventional activated carbons. The spherical shape ensures optimal packing density and reduces flow resistance, which enhances the effectiveness of surgical smoke removal.

Thanks to its microporous structure, spherical adsorbents are highly effective in adsorbing a wide range of pollutants, particularly volatile organic compounds (VOCs) and other gaseous compounds. When used in conjunction with particle filters (e.g., HEPA filters), it forms an effective system for maintaining clean air in operating theaters.

It not only protects surgical teams from unpleasant odors but also from the long-term health damage caused by toxic or carcinogenic substances.

Suitable Filter Media from Talamon

Table 2 presents media data for suitable Talamon filter materials used in surgical smoke filtration applications. The media are presented alongside their basic characteristics, pressure losses, and adsorption values for the aromatic hydrocarbon toluene, used as a model substance for VOCs.

The comparison involves a 3-layer, a 6-layer flat media, and a dense filter foam with a thickness of 5.5 mm, all based on spherical high-performance adsorbents. The pressure loss and toluene breakthrough comparison for the media mentioned is illustrated in Diagram 1.

All three media exhibit low flow resistance, with the adsorptive foam being nearly "pressure-drop free." Depending on the filter system design and in cases of

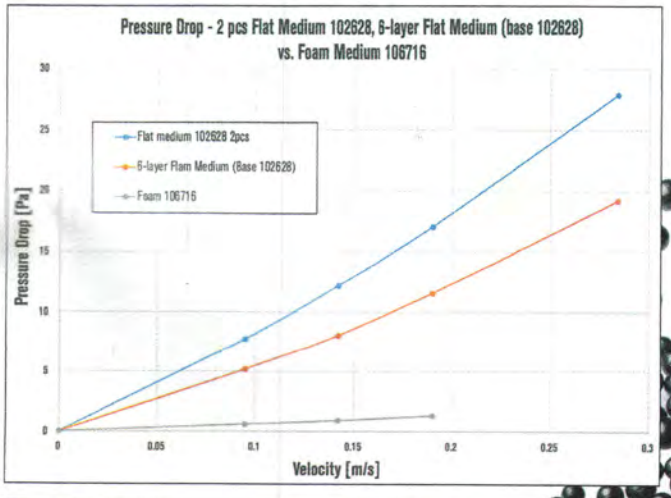
Volatile Organic Compounds (VOCs)	**Aldehydes**	formaldehyde	Irritant, potentially carcinogenic
		acetaldehyde	irritant, possibly carcinogenic
	Aromatic hydrocarbons	benzene, toluene, xylene	toxic, some of them carcinogenic
	Aliphatic hydrocarbons	alkanes and alkenes	
	Ketones	acetone, methyl isobutyl ketone	
Inorganic Gases		carbon monoxide (CO)	binds to hemoglobin, highly toxic
		carbon dioxide (CO_2)	main component, relatively harmless but problematic in high concentrations
		nitrogen oxides (NO, NO_2)	irritant, potentially toxic
		hydrogen cyanide (HCN)	highly toxic, can be produced during tissue degeneration
		hydrogen sulphide (H_2S)	toxic and has a typical foul odour
Other Gas Compounds		phenols	irritant and toxic
		polyaromatic hydrocarbons (PAHs)	some are considered carcinogenic
		acrylonitrile	carcinogenic, mainly produced when proteins are burnt

▲ **Table 1:** Main gaseous components in surgical smoke.

	Flat Filter Medium 102628 3 Layers Adsorbents	Flat Filter Medium 6 Layers Adsorbents (Base 102628)	Foam Filter Medium 106716
Thickness [mm]	2.1 ± 0.2	4.0 ± 0.3	5.5 ± 1
Area Weight [g/m²]	860 ± 60	1680 ± 120	1500 ± 250
Adsorbent Weight [g/m²]	700 ± 60	1400 ± 120	1200 ± 250
Pressure Loss [Pa]			
@ 0.1 m/s	5	8	0.5
@ 0.2 m/s	12	18	2
@ 0.3 m/s	21	30	4
Adsorption Performance @ 90ppm toluene, 0.1m/s, 23°C, 50% RH			
Initial efficiency [%]	0	0.7	7.7
Breakthrough after 3h [%]	13	13	30
Time until 50% breakthrough [min]	240	254	235
Capacity after 50% breakthrough [g/m²]	453	467	385

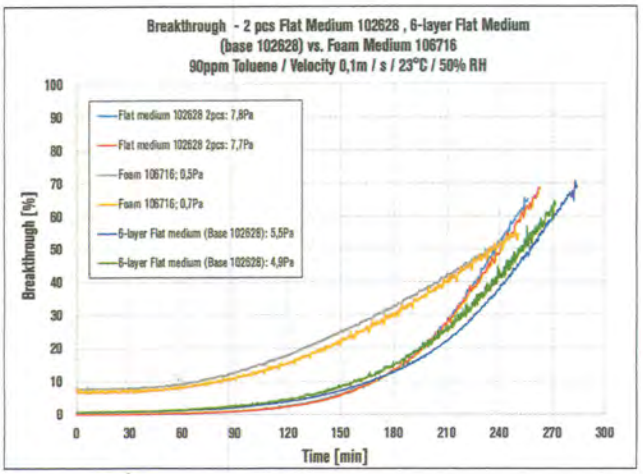
▲ **Table 2:** Overview of Talamon media data.

▼ **Diagram 1:** Pressure loss comparison.

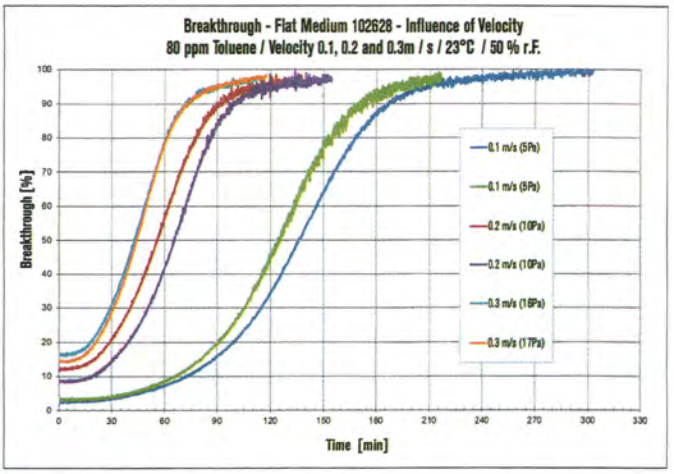


▼ **Figure 2:** Spherical polymer-based high-performance adsorbents. *Courtesy of Talamon*

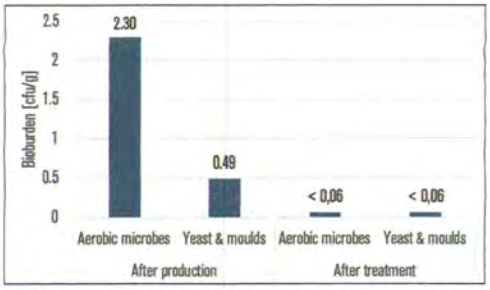
▶ **Figure 3:** Pore structure of spherical high-performance adsorbents. *Courtesy of Talamon*



▲ **Diagram 2:** Toluene breakthrough comparison.



▲ **Diagram 3**: Influence of face velocity on adsorption performance.



▲ **Diagram 4:** Comparison of bioburden load before and after post-treatment.

higher face velocities or flow rates, a low flow resistance can be a decisive factor for application suitability.

Diagram 2 illustrates the breakthrough curve for the VOC toluene at a typical face velocity of 0.1 m/s for all three media.

The two types of flat media differ mainly in their initial breakthrough behavior compared to the dense 5.5 mm foam medium. The flat media show virtually no initial breakthrough, whereas the 'pressure drop-free' foam has an initial breakthrough of approximately 8%. However, from around 50% breakthrough, the foam medium exhibits a lower breakthrough than the two flat media types.

Another critical factor in filter system design is the face velocity, which significantly affects adsorption performance. Diagram 3 illustrates the impact of face velocity on the breakthrough characteristics of the VOC toluene, using the 3-layer flat medium 102628 as an example. By reducing the face velocity from 0.3 m/s to 0.1 m/s, the initial breakthrough can be lowered from approximately 18% *to 2%, greatly extending the breakthrough times.*

Armed with knowledge of pressure loss and adsorption characteristics, a suitable filter medium can be selected depending on the specific requirements of the application.

Reduction of Bioburden Through Special Post-Treatment

The microbiological quality of the filter medium is given special attention during the manufacturing process. The targeted use of synthetic carbon with antibacterial properties significantly reduces the natural bacterial load. This results in a comparatively low initial load of 2.8 CFU/g on average, consisting of 2.30 CFU/g of aerobic microorganisms and 0.49 CFU/g of yeasts and moulds. However, these values alone are insufficient for applications in a medical environment, particularly for further processing in clean rooms. Therefore, a special post-treatment was validated, reducing the bacterial load to below 0.06 CFU/g.

Diagram 4 illustrates a comparison of microbiological contamination (bioburden) before and after treatment.

Combined with consistently implemented hygiene measures during production, this ensures that the material meets the strict requirements for clean-room processing without affecting the structural or functional properties of the filter medium.

Safety is Worth the Investment

*Ultimately, adsorptive filters for surgi*cal fumes are an important occupational safety measure in operating theatres. They protect healthcare staff from harmful emissions and reduce the risk of nosocomial infections. Despite the initial investment, the long-term benefits in terms of safety, hygiene and health protection clearly outweigh the costs. IFN

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