Air Filter Types Explained: HEPA vs Carbon Filters vs Ozone vs EcoBreeze

Indoor air often contains a mix of particulate matter (dust, pollen, microbes) and gaseous pollutants (VOCs, odors, chemicals) (EPA, 2025; Maung et al., 2022). Research confirms that volatile organic compounds and fine particulate matter ($PM_{2.5}$/PM_{10}) are the primary indoor contaminants (Maung et al., 2022). Effective air purification thus requires different technologies targeted at these pollutant classes. The U.S. EPA and WHO emphasize that source control and proper filtration/ventilation are essential to mitigate health risks (e.g., asthma, cardiovascular issues) from indoor pollutants (EPA, 2025; Maung et al., 2022). In this context, we compare four approaches – HEPA filters, activated carbon filters, ozone generators, and the EcoBreeze system – explaining their operating principles, strengths, and limitations using scientific evidence and established standards.

HEPA Filters (High-Efficiency Particulate Air)

HEPA filters are mechanical, pleated fiber media designed to capture airborne particles. By U.S. DOE definition (cited by EPA), a true HEPA filter must remove ≥99.97% of particles ≥0.3 µm in diameter (EPA, 2024). Notably, 0.3 µm is the most penetrating particle size (MPPS); particles larger or smaller are trapped even more efficiently (EPA, 2024). HEPA media consist of layers of fine glass fibers (often borosilicate) arranged into a dense matrix (NASA, 2017). These fibers create tortuous paths and aerodynamic barriers, capturing particles via inertial impaction, interception, and diffusion (Brownian motion) (NASA, 2017).

- **Particle capture:** HEPA filters effectively remove dust, pollen, mold spores, bacteria, and even viruses (EPA, 2024). NASA's studies on the International Space Station utilize HEPA elements to trap microbial contaminants (NASA, 2017). Certified HEPA filters (HEPA H13/H14) are widely used in hospitals and clean rooms.
- **Gas/odor removal:** HEPA filters do not adsorb gases or odors, focusing solely on particulate removal (EPA, 2024).
- **Pathogens:** Captured bioaerosols remain viable but contained within the filter.
- **Byproducts & safety:** No harmful byproducts; however, saturated HEPA filters can re-emit captured particulates if not replaced regularly (EPA, 2024).

Activated Carbon Filters

Activated carbon filters employ porous carbon media (typically derived from coconut shells or coal) to adsorb gaseous pollutants onto their extensive internal surface areas (NASA, 1993).

- **Particle capture:** Limited effectiveness; generally paired with mechanical pre-filters for particulate capture (Citron Hygiene, n.d.).
- **Gas/odor removal:** Highly effective for VOCs, odors, and gaseous pollutants (EPA, 2025; NASA, 1993). Lab tests show significant VOC reduction (Gallego et al., 2013).

- **Pathogens:** Limited direct microbial control unless impregnated with antimicrobial substances (Citron Hygiene, n.d.).
- **Byproducts & safety:** Generally safe; saturation can reduce effectiveness, necessitating timely replacement.

Ozone Generators (Ozone Air Cleaners)

Ozone generators produce ozone (O_3) to oxidize pollutants but present significant health risks and limited efficacy (EPA, 2025).

- **Particle capture:** No particulate capture (EPA, 2025).
- **Gas/odor removal:** Limited efficacy and risk of creating harmful byproducts like formaldehyde and organic acids (EPA, 2025).
- **Pathogens:** High ozone levels can sterilize microbes but exceed safe human exposure limits (EPA, 2025).
- **Byproducts & safety:** Hazardous due to ozone emissions and secondary pollutants; not recommended for occupied spaces (EPA, 2025).

EcoBreeze Multi-Stage System

EcoBreeze integrates electrostatic pre-filtration and activated carbon filtration, addressing particulate matter, VOCs, odors, and microbial contaminants without ozone emissions

- **Stage 1 (Pre-Filter):** Captures large particles such as dust and pollen.
- **Stage 2 (Activated Carbon):** Adsorbs VOCs and odors; impregnated with copper and silver for pathogen control.
- **Stage 3 (Fragrance):** Synthetic fragrances engineered to eliminate harmful or reactive compounds.
- **stage 4 (Refiltration)** cleaning the air of excess fragrance, It continually filters the air maintaining air quality.
- **Performance:** Independent tests show effective odour and VOC removal without ozone.
- **Maintenance & Applications:** Ideal for commercial spaces, providing comprehensive indoor air purification in one compact system.

Comparative Table of Filter Types

Filter Type	Particulate Filtration	VOC/Odor Filtration	Microbial Control	Byproducts/Hazards
HEPA	Excellent (≥99.97% @ 0.3 µm) (EPA, 2024)	None	None (traps but does not kill)	Safe; requires regular replacement (EPA, 2024)
Activated Carbon	Limited (requires pre-filter)	Excellent (Gallego et al., 2013)	Moderate (if impregnated)	Safe; saturation reduces efficacy
Ozone Generator	None	Limited; creates harmful byproducts	Effective at unsafe ozone levels	Hazardous (EPA, 2025)
EcoBreeze	Effective (pre-filter for large particulates)	Removes 96 % of VOCs	Effective (Cu/Ag impregnated)	Safe; ozone-free

Conclusion

HEPA filters excel in particulate removal but lack VOC capture and Odour removal. Activated carbon filters effectively manage gaseous VOCs and odour pollutants. Ozone generators pose significant health risks. EcoBreeze effectively integrates particulate and gaseous pollutant removal safely. For optimal indoor air quality, activated carbon filtration remains crucial, especially when combined with particulate pre-filtration as in the EcoBreeze system.

References

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