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Efficiency of HEPA filters

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Does a High Efficiency Particulate Air (HEPA) filter offer full protection against viral cross-contamination?

Particulate matter (PM) in the air, whether in solid or liquid form, can affect our health. Particularly those particles below 2.5 micrometers (also known as microns; µm) represent a hazard, as they are able to enter our bloodstream. Nanoparticles can be as small as 0.1 right down to 0.001 µm.

Sizes of some well-known bacteria and viruses are as follows:
Influenza A virus: 0.08 - 0.12 µm
HIV: 0.08 µm
Hepatitis C virus: 0.05 µm
Mycobacterium tuberculosis 1.0 µm

The very common staphylococci (e. g. staphylococcus aureus) are spherical cells of about 1 µm that grow in clusters.

The coronavirus species COVID-2019, MERS-CoV and SARS-CoV range in size from 0.06 to 0.2 µm.

It is widely believed that HEPA filters are only capable of capturing particles sized 0.3 µm or larger. However, this belief is based in part on an incorrect understanding of how HEPA filters work. The fact is that particles of around 0.3 µm are the hardest to catch (1); for this reason, that size is used to measure the effectiveness of HEPA filters. Much smaller nanoparticles are in fact easier to catch. But why is this so?

For larger particles, the HEPA filter acts like a net as we would expect. Particles greater than 0.3 µm in size simply cannot get through: either they do not fit through the holes or they hit the filter fibers due to inertia. For smaller particles, on the other hand, it would seem logical that they can simply go through the holes. However, this is not the case. The tiny mass of particles less than 0.3 µm means they do not fly straight; instead, they are bounced off other molecules as they collide with them and thus move in completely random patterns. As a result, they hit the filter fibers and then remain stuck in them. This is the principle of Brownian movement.

Tests carried out by the NASA (1) showed that HEPA filters are highly effective in capturing an extremely high percentage of up to 100% of nanoparticulate contaminants, as well as the larger particles greater than 0.3 µm. For particles of around 0.3 µm there is just a small drop in efficiency; this size is thus called the most penetrating particle size (MPPS) in standards for HEPA filters.

According to European standards, there are 17 classes of filters – the higher the class, the greater the efficiency. Classes E10 to E12 are Efficient Particulate Air (EPA) filters, H13 and H14 are HEPA filters, and U15 to U17 are Ultra Low Penetration Air (ULPA) filters. These classes are covered by the European standard EN 1822, which assesses the filtration performance of the filter for the MPPS. According to this standard, a HEPA filter must remove at least 99.95% of particles sized 0.3 µm or larger (2). US government standards require a filter to remove 99.97% of particles sized 0.3 µm in order to qualify as HEPA (3). In other words, for every 10,000 particles sized 0.3 microns in diameter, only three of them may pass through.

References

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