How Long do Aerosol Particles Stay Airborne?

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How long do SAR CoV-2 containing aerosols stay airborne once released into the air? It's an increasingly important question as the relevance of airborne transmission of novel coronavirus becomes apparent. Yet despite the science of aerosol dynamics being very well established, it's surprising just how hard it is to find clear and understandable information on the settling rate of airborne particles.

This became very apparent to me when searching for a simple plot of settling velocity versus particle size that indicates just how slow or fast exhaled COVID-containing aerosols might stick around. I may be missing something but, apart from a bunch of old and quite technical plots and diagrams, there was pretty much nothing.

So I dug into my old aerosol research and teaching files[2] and created some!

I suspect that the plots below also fall into the category of "quite technical." But hopefully someone will find them at least marginally illuminating. They are all based on established aerosol dynamics and draw heavily on Paul Baron's Aerosol Calculator[3] (which in turn uses Bill Hinds' still-excellent intro to aerosol technology[4]), together with science that goes back to the mid-1800's.

They are also very basic — they don't directly indicate how long viable SARS CoV-2 will remain airborne in expelled aerosol, virus loading in airborne particles, or how changes in aerosol particle size with time (through evaporation for instance might affect exposure). But they do illustrate just how long fine particles stay in the air once released.

Settling Velocity

Settling velocity is the terminal velocity a particle reaches under the opposing forces of gravitational settling and air drag/resistance. Figure 1 below shows the settling velocity of unit density spherical particles in still air. This in turn allows an estimate of how quickly particles of different sizes will settle out of the air, and how long they'll remain airborne after being released.

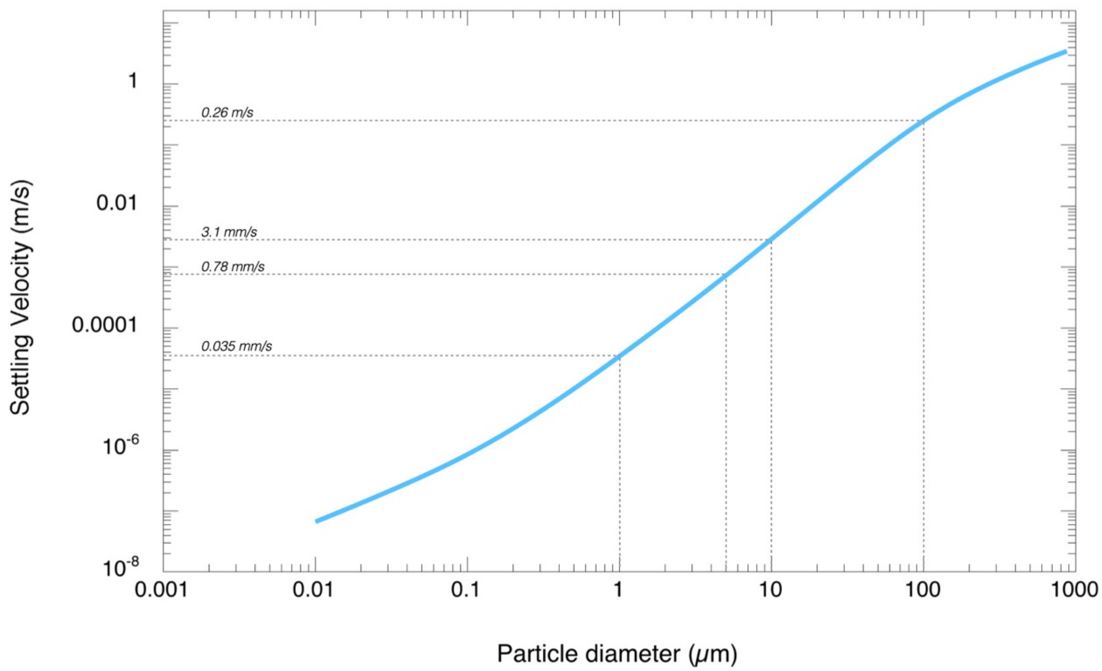

Figure 1. Aerosol settling velocity as a function of particle size, assuming spherical particles with a density of 1000 kg/m3, an air temperature of 293.15 K, and an air pressure of 101.3 kPa. Hinds (1999)[4] and Baron (2001)[3]

Settling Time

From settling velocity, the time it takes for airborne particles to settle a set distance can be estimated. Figure 2, for example, shows the time it takes for spherical, unit density particles to settle through one vertical meter in calm air.

Assuming this is a representative distance between the point of release and floors or desks (and to be honest, it's a little on the low side), the horizontal axis provides a rough idea of how long particles of a given size are likely to hang around in the air — again, assuming the air is undisturbed.

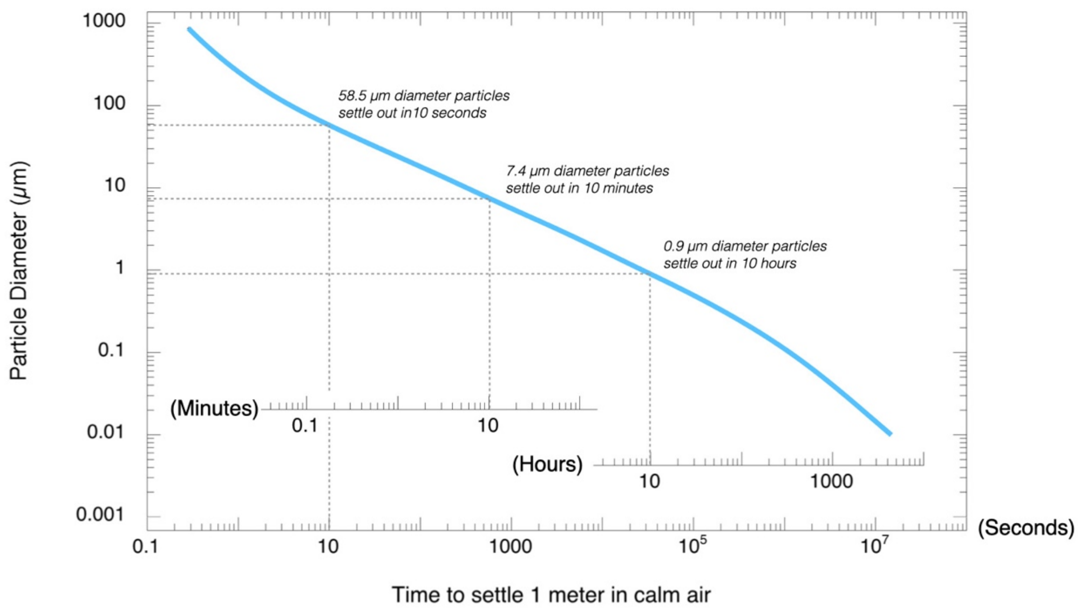

Figure 2. Aerosol settling time over 1 meter as a function of particle size, assuming spherical particles with a density of 1000 kg/m3, an air temperature of 293.15 K, and an air pressure of 101.3 kPa. Hinds (1999)[4] and Baron (2001)[3]

Aerosol Concentration Reduction When the Air Isn't Calm

Of course, in most rooms where people are expelling SARS CoV-2 containing aerosol, the air (along with the particles) is constantly being disturbed. In this case, a rough idea of the rate at which aerosol concentration reduces over time through settling is given by a well-established model of stirred settling.

Using a ten times reduction in aerosol concentration as the benchmark, figure 3 below indicates how long this is likely to take as a function of particle size:

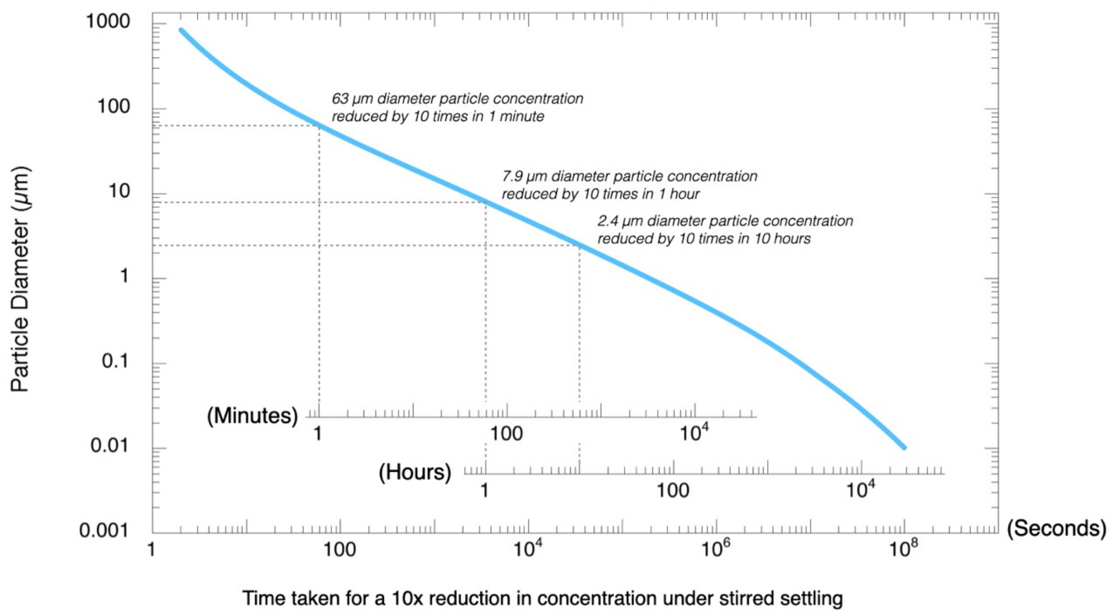

Figure 3. Aerosol concentration reduction over time as a result of stirred settling, assuming spherical particles with a density of 1000 kg/m3, an air temperature of 293.15 K, and an air pressure of 101.3 kPa. Hinds (1999)[4] and Baron (2001)[3]

Using the Plots

Of course, these plots only provide first order estimates of how long particles will remain in the air, as other factors will come into play in practice, including ventilation rates and particle/ microdroplet evaporation rates. Yet they do illustrate just how long particles remain airborne, and in the absence of good ventilation, just how long it takes to reduce airborne concentrations.

And the clear indication is that aerosol particles smaller than 10 micrometers or so hang around for some time — certainly long enough to be carried between people who are some distance apart.

The science behind the calculations can be found in multiple aerosol dynamics textbooks (I still use Hinds' Aerosol Technology[4] as my primary go-to – I'd also recommend Kulkarni, Baron and Willeke's Aerosol Measurement[5]). The science here is also covered in my old aerosol dynamics lecture notes.[2] And the calculations themselves are all available in Paul Baron's Aerosol Calculator.[3]

References

1 Maynard, A. D. *How long do aerosols stay airborne?*, <https://therealandrewmaynard.com/2020/07/17/how-long-do-aerosols-stay-airborne/> (2020).

2 Maynard, A. D. *An introduction to aerosol dynamics*, <https://therealandrewmaynard.com/2020/04/02/an-introduction-to-aerosol-dynamics/> (2020).

3 Baron, P. A. *The Aerosol Calculator*, <https://therealandrewmaynard.com/2020/05/27/the-aerosol-calculator/> (2001).

4 Hinds, W. C. *Aerosol Technology: Properties, Behavior, and Measurement of Airborne Particles. Second Edition*. 2nd edn, (Wiley-Interscience, 1999).

5 Kulkarni, P., Baron, P. A. & Willeke, K. *Aerosol Measurement: Principles, Techniques, and Applications, Third Edition*. (John Wiley & Sons, Inc., 2011).