

Evaporation of Emitted Droplets Are An Important Factor Affecting the Lifetime of the Airborne Coronavirus

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The highly infectious SARS-CoV-2 novel coronavirus has resulted in a pandemic leading to the Corona Virus Disease 2019 (COVID-19). More than a million people are already impacted, with infected numbers expected to go up. There are three possible pathways conjectured for infection: direct contact (e.g. handshaking) with an infected individual; indirect mode via fomite (e.g. contact with objects contaminated with the virus and then entry through the nose or mouth); and airborne mode where an individual inhales aerosols containing the viable virus followed by deposition in the respiratory tract. While there is a clear understanding of reducing the spread by physical distancing and hand washing, there is not a clear mechanistic understanding of the airborne spread of this virus and remains a point of contention. The first clarification is on the use of the term aerosol: by definition it is a suspension of particles (including droplets) in a gaseous medium, in this case, air. Both large particles or droplets (e.g. from coughing or sneezing) and smaller particles (e.g. resulting due to evaporation) are both aerosols as long as they remain airborne. Large particles or droplets will have a shorter lifetime and deposit (due to aerosol phenomena of settling), whereas smaller particles or droplets will remain airborne longer. The fate and transport, and resultant lifetime of the airborne particles and droplets are to be determined by using concepts of aerosol physics.

There are many studies conducted on the airborne spread of viruses causing diseases such as SARS and measles, however none of the studies (Tellier et al., 2019; Kutter et al., 2018) couple the transport characteristics with the aerosol dynamics of the droplet. Modeling studies have ranged from simplistic to complex ones using CFD to unravel the airborne spread (Yu et al., 2004). While several have reported potential airborne transmission (Service, 2020) and reasonably long airborne life times of 3 hours of the SARS-CoV2 virus in laboratory studies (van Doremalen et al, 2020), others have reported disagreements by experts (Lewis, 2020). A glaring omission in all these studies is a coupling of the aerosol phenomena (such as evaporation, particle diffusion) to accurately establish the lifetimes of the droplets. For example, the characteristic time for evaporation of a 10 μm droplet is 0.036 s at a relative humidity of 25%; compared to a settling time of about 500 s. Figure 1 (left) outlines a comparison of the evaporation time and the settling time for droplets ranging from 0.1 to 1000 μm ; and as illustrated, for any particle smaller than $\sim 100 \mu\text{m}$, the evaporation of the emitted or exhaled droplet has to be considered. Coupling evaporation of the droplet as it settles, we estimate the horizontal distance traversed (Dhawan and Biswas, 2020). The emitted particle (or droplet) will decrease in particle size, thus increasing the horizontal distance traversed and its airborne lifetime (Figure 1(right)).

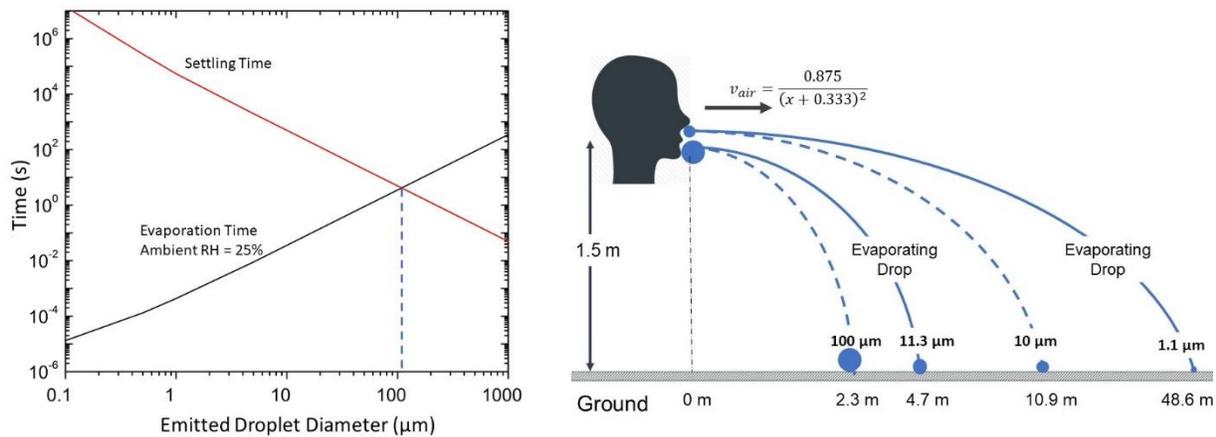


Figure 1 (Left). Representative evaporation time and settling time calculated for droplets of different initial sizes. A guideline is that for any droplet less than 100 μm , evaporation cannot be neglected. (Right) Trajectories of a 10 μm and 100 μm particle emitted with a typical initial velocity of release indicating the greater spread in the horizontal direction when evaporation is accounted for. The life time of the 10 μm particle increases from 8.3 min to 12 hours (will be intercepted prior); and for a 100 μm particle from 4.9 s to 39.4 s.

There are three conditions, sneezing, coughing and exhaling (breathing) under which a symptomatic or asymptomatic individual will release droplets potentially with the virus. The following are typical size distribution parameters of the droplet size distributions

	Particle Size Distribution of Emitted Droplets		
	Speaking (Breathing)	Coughing	Sneezing
	Chao et al (2009)	Chao et al. (2009)	Duguid (1946)
N_{total} (# / m^3)	1.51×10^5	2.37×10^6	2.74×10^8
Geometric Mean Size (μm)	16.3	13.4	8.86
Geom. Std Deviation	3.6	3.48	2.21

From the resultant size distributions of all three cases, it is clear that evaporation of the droplet has to be considered. The aerosol dynamics (such as droplet evaporation) coupled to particle transport models (settling, diffusion) will provide accurate estimation of lifetimes and help propose strategies to minimize the spread of this highly communicable disease. Models that also account for the survivability of the virus during transport of emitted droplets has to be considered (Hogan et al, 2006); and controlled experiments to validate them with robust measurement tools (Li et al., 2017) have to be conducted (Dhawan and Biswas, 2020).

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