Understanding the Physics of the SARS-CoV-2 virus in an Indoor Environment

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Original research: https://scimedjournal.org/index.php/SMJ/article/view/166

Source: The City University of New York

Credits:

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Summary:

The current global pandemic of the respiratory disease known as COVID-19 has certainly become a persistent fear and constant part of our lives. To understand the spread of the virus and subsequently ascertain effective practices to curb the spread of the disease, it is necessary to understand the way the virus can be transported through the air in the form of aerosols. An aerosol is the suspension of particles light enough to be carried by air. The tiny respiratory droplets produced by coughing and sneezing are the major driving force in the spread of the disease. The research article [1] provides a concise discussion of this airborne transmission in indoor environments from a physicist's perspective and provides recommendations on the basis of the results obtained to curb the spread of the virus.

There are 3 phenomena that drive the movement of aerosols: Gravity, Convection and Diffusion. Gravity pulls the particles down against the drag produced by air; Convection moves the particles along with the surrounding air, where light hot air rises and dense cold air settles; while diffusion simply moves the aerosols from regions of high to low concentration.

The falling velocity and falling time (from a height of 2m) of infectious particles can be computed by using the Stokes Law(1), Newton's Second Law of Motion (2) and Newton's Second Equation of Motion(3) where a is the acceleration due to gravity. The terminal velocity is found when drag force f is equal to force due to gravity F.

$$f = 6\pi\eta r v_{down} \tag{1}$$

$$F = ma \tag{2}$$

$$y = y_0 + v_0 t + \frac{1}{2}at^2 \tag{3}$$

Using equation (1) and (2) for an isolated virus, we find the terminal velocity to be negligible. Hence it follows convection to move through air for the duration it can survive in dry air. For respiratory droplets above 1000μm in diameter, the air resistance is negligible and the falling time is calculated using equation (3). For droplets under 100 μm in diameter, time is calculated using the downward speed from equation (1) to account for air resistance.

In case of respiratory droplets, the amount of time the virus remains active in the air is simply depends on the amount of time the respiratory droplets remains suspended in the air and the evaporation time of the droplet. By comparing the falling times with the droplet evaporation time

scale developed by Wells [2] for pure water droplets at 18ºC, it is found that somewhere between 100 µm and 200 µm in diameter is the boundary where droplets reach the ground before significant evaporation. Smaller droplets remain in the air as droplet-nuclei.

Research [3] indicates that 95% of the droplets that form a part of respiratory ejecta are between 2µm and 100 µm, which points to the possibility of the above findings being involved in the infection process. But research at MIT [4] has also pointed out that even the largest droplets can stay suspended in the air for over 10 minutes. This suggests that convection in the air is the primary means of distribution of these virus laden particles.

The authors used SimScale, a computer aided engineering software, to study these convection patterns in indoor environments. It is revealed that airflow indoors can quickly spread the virus.

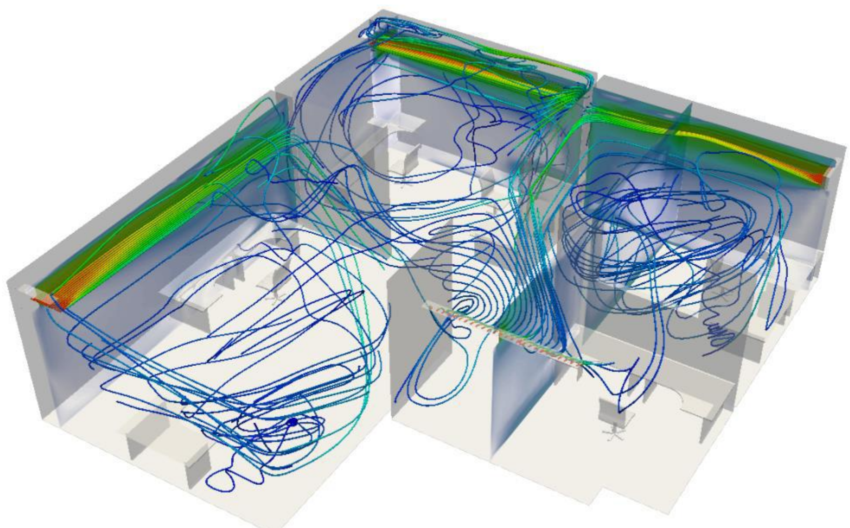

Figure 1: The airflow pattern in an office illustrates how infection can be carried between cubicles by convection;Simulation by SimScale

Furthermore, the research at MIT [4] on the spread of a sneeze also indicated that sneezing and coughing release not just individual droplets but rather a multiphase turbulent cloud. This dramatically alters the evaporation rates of the droplets, from under a second to minutes. Droplets less than 50µm can remain suspended in the cloud long enough to reach height of up to 6m where ventilation systems can be contaminated. Researchers at Loughborough University [5] attempted to create a mathematical model characterizing the vortex dynamics of this expiratory cloud instead of relying on off-the-shelf software such as SimScale. It is important to note that while their model confirmed that small droplets can reach height where ventilation systems may get contaminated, the model contradicts the fallout distance of 2.5 m of droplets of 30μm diameter predicted by [4]. According to the researchers, these droplets can travel much farther if vorticity (the rotational circulation of particles of a fluid about some instantaneous axis) within the cloud is accounted for. Researchers at the University of Twente [6] conducted a numerical simulation on the evaporation times of respiratory droplets to revisit the research by Wells. They revealed that on increasing ambient relative humidity, the lifetimes of droplets went up by over 2 orders of magnitude in comparison to Wells' predictions. Although still a preprint, their findings paint a grim picture that should not be ignored. But there is a ray of hope; researchers at the Indian Institute of Sciences and the University of Toronto [7] have produced models that show that the most infectious droplets start off as 10μm-50μm in diameter, which most surgical masks can protect against.

In Conclusion, there is little argument for a stationary 6-feet separation between people in indoor spaces as airflow created by ACs, windows, moving people etc. can make locations beyond 6 feet more dangerous than anticipated, especially when indoor air is not exchanged with outdoor air. The virus accumulates in these confined spaces, where it can persist for long periods of time. The authors of the article [1] recommend computational studies of public places and wearing of face mask to mitigate the issue along with redesigning of ventilation and Air Conditioning systems to reduce viral load in the long run.

This review has certainly just scratched the surface of the underlying complexities and variations in the spread of a disease like COVID-19 and brings into question the norms set to prevent infection. There must be many other factors regarding infection that are not commonly accounted for in preventive measures; the work of the authors of the mentioned papers bring us one step closer in bridging this gap. Lastly, the research makes us wonder about each time when we were indoors with strangers in the past few months.