SARS-CoV-2 in Droplets and Aerosols

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Topics

- 1. Transmission modes
- 2. Size distributions
- 3. Evaporation and transport
- 4. Air sampling results and challenges

Traditional Modes of Transmission



direct contact

Defined as >5 µm and happening at close-range only (<2 m)







indirect contact



Defined as <5 μm and happening mainly at longdistance (>2 m)

airborne/aerosols

The origin of the 5-10 μm cutoff is not clear. This cutoff is not supported by modern aerosol science. This distinction has hampered our understanding of transmission.

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http://www.phac-aspc.gc.ca/cpip-pclcpi/annf/v2-eng.php

Multiple Modes at Close Contact



Linsey Marr, Virginia Tech, July 2020 https://www.cidrap.umn.edu/news-perspective/2020/03/commentary-covid-19-transmission-messages-should-hinge-science

Aerosols Dilute and Spread



Linsey Marr, Virginia Tech, July 2020 https://www.cidrap.umn.edu/news-perspective/2020/03/commentary-covid-19-transmission-messages-should-hinge-science

Aerosols Can Build Up Indoors



Face Coverings for Source Control



Linsey Marr, Virginia Tech, July 2020 https://www.cidrap.umn.edu/news-perspective/2020/03/commentary-covid-19-transmission-messages-should-hinge-science

Droplets vs. Aerosols

• Distinguishing feature should be route of exposure

CONTACT with DROPLETS landing on the body

> INHALATION of AEROSOLS into the respiratory system



Transmission by inhalation of aerosols can happen at short and long range.

Why is size so important?





https://www.cdc.gov/flu/resource-center/freeresource/in/gexpl//instringerichTerchhttuply/2002/Otionsdesignedforhealthcare.com/rhinovirus/ https://phil.cdc.gov/Details.aspx?pid=23312, https://pdb101.rcsb.org/motm/132

Size Matters

- Airborne viruses are not naked!
- An aerosol is just a very small droplet



respiratory fluid



• Size determines

0.5 μm (0.2-100 μm)

- How far they can travel in air
- Where they deposit in the respiratory system

Humidity Affects Size and Chemistry



Settling Velocity and Time



Droplets Can Travel More Than 2 m

Position of droplets released from a height of 1 m



Viruses in droplets/aerosols >5-10 µm remain in air for many minutes and can travel farther than 1-2 m.

What do we know about SARS-CoV-2 in droplets/aerosols?

Virus Detection Methods

1. Total virus

- Number of genome copies (GC) determined by molecular techniques (quantitative polymerase chain reaction, qPCR)
- Reflects number of viruses with intact DNA or RNA
- Does NOT indicate whether virus is infectious or not

AN INFLUENZA VIRUS





Hemagglutinin



Neuraminidase



M2 ion channel



RNA is wrapped around the ribonucleoprotein

https://www.cdc.gov/flu/resource-center/freeresources/graphics/images.htm

Virus Detection Methods

2. Infectious virus

- Number of viruses that are able to infect cells determined by culture (growing)
- PFU = plaque forming units, number of viruses capable of forming plaques on host cells, focus forming units (FFU) are related



 TCID₅₀ = median tissue culture infectious dose, concentration at which half of cells are infected after being exposed to the sample



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Ong et al., 2020, JAMA, https://jamanetwork.com/journals/jama/fullarticle/2762692

Airborne Viral RNA in Hospitals



I estimate a viral RNA emission rate of 10,000 genome copies per minute in "small" droplets.

SARS-CoV-2 Size Distributions



SARS-CoV-2 Survival in Aerosols

C Half-Life of Viable Virus



Half-life is 1.1 hours in culture medium



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van Doremalen et al., 2020, NEJM, https://www.nejm.org/doi/full/10.1056/NEJMc2004973

SARS-CoV-2 Survival in Aerosols



Virus survives 16 hours in aerosols in culture medium at 53% RH

Sampling Challenges

- Low concentrations of ~10³ viral RNA copies/m³
- Probably need ~10⁴ copies to get 1 PFU (10 m³ air)
- Ideally want size separation



Low flow rates require 20-40 hr of sampling

Prussin II et al., 2014, https://onlinelibrary.wiley.com/ doi/abs/10.1111/1574-6968.12487;



Must must elute and extract large filter



Loss of infectivity during sampling

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https://www.vox.com/science-and-health/2020/3/11/21173187/coronavirus-covid-19-hand-washing-sanitizer-compared-soap-is-dope

Major Unknowns

- **Risk of infection** Which transmission route High Low risk risk is dominant: direct contact, Distance from the infection source (m) indirect contact with contaminated objects (fomites), contact with droplets, inhalation of aerosols?
- How much virus is released in what size droplets/aerosols at different stages of infection?

(a)

How are viruses inactivated in air and on surfaces?

Is the observed high infection risk due

to large droplet exposure or short-range

airborne exposure?

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AWARD













CE NT Center for the Environmental Implications of NanoTechnology Linsey Marr, Virginia Tech, July 2020

