Environmental Control System, Infectious Diseases and Passengers in Airplanes:

Airborne Modes of Transmission

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February 7, 2020

Infectious Disease Transmission

- SARS in 2003 (26 countries, 5 continents) 8000 infected, 774 died Wilder-Smith 2006 Travel Medicine and Infectious Disease 4(2): 53-60
- H1N1-A in 2009 (6 continents) 60.8 million cases, 274,304 hospitalizations, and 12,469 deaths in United States https://www.cdc.gov/h1n1flu/estimates_2009_h1n1.htm
- Coronavirus in 2020 28,140 cases, 564 deaths as of 2/5/2020



Environmental Control System



Animation: Courtesy of Boeing

Size of Various Viruses



Cough Aerosol Particle Optical Size Distribution



Noti et al. 2013. PLoS ONE 8(2):e5748

Modes of Cough













Particle Droplet Transport in a Cabin

Particle source: coughing from a person



An animation of coughing process in an aircraft cabin



z | x ----- Y



Particle Transport for Cough with Mouth Covering Methods

Exhaled particle transport in the first 5 s



Chen et al. 2014. Indoor Air, 24(6), 580-591.

Breathing and Talking



Breathing



Flow rate measurements

Talking

Coughing Flow Rate



Gupta, Lin and Chen, 2009. Indoor Air, 19: 517-525.

Particle Transport in a Cabin due to Cough



Validation of Particle Transport Modeling

Particle transport in the first-class cabin of an MD-82 airplane



Facility at Tianjin University, China





Z

Chen, et al. 2014. Indoor Air, 24, 81-92.

Comparison of Numerical and Experimental Results



Unsolved Mystery

Flight from Hong Kong to Beijing in 2003 11 202 20 19 21 <u>00</u> 00 $\omega \sim$ LMD -DEF 0000 000 000 000 88 008 008 000 80 000 8 Ø 0 8 0 0 8 0 808 0 0 0 0 0 0 0 0 00 888 000 000 008 008 ABC 88 $\overline{\odot}$ 68 7 rows Ø No illness (person interviewed) 🛉 Index patient Ø No illness (person not interviewed) Crew member Probable case of SARS Empty seat

Olsen et al. 2003. N Engl J Med 349: 2416-2422



Particle Transport due to a Moving Subject in a Cabin



Mazumdar et al. 2011. Atmos Environ 45(33), 6019-6028.



Airflow due to a Moving Subject in a Cabin





Poussou et al. 2010. Atoms Environ 44(24): 2830-2839

Typical Airflow Pattern in a Cabin





Courtesy of Feng He, Tsinghua University, 2016

Conclusions

- Environmental system performance, airborne infectious diseases, and passenger health may be connected.
- Airborne particles with viruses can be from coughing, breaking, talking, and sneezing of passengers.
- Airflow pattern in existing airplanes could cause cross contamination between passengers.
- Airborne particles could be carried by a moving subject to several rows away.