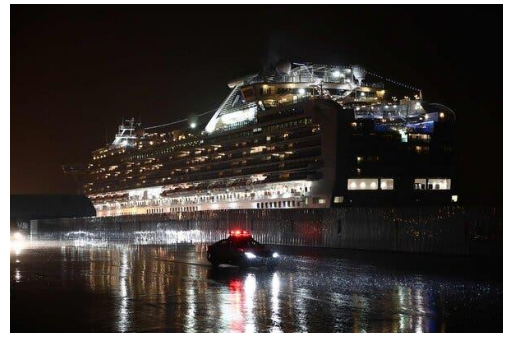
https://www.nytimes.com/2020/07/30/health/diamond-princess-coronavirus-aerosol.html
Full academic journal article https://www.medrxiv.org/content/10.1101/2020.07.13.20153049v1.full.pdf+html

Study Finds Evidence Virus Can Float in Air for Minutes or Longer

Aboard the Diamond Princess, a Case Study in Aerosol Transmission

A computer model of the cruise-ship outbreak found that the virus spread most readily in microscopic droplets light enough to linger in the air.

July 30, 2020 - By Benedict Carey and James Glanz



The Diamond Princess cruise ship, docked in Yokohama, Japan, in February. More than 700 of the 3,711 people onboard tested positive for the coronavirus. Credit...agence France-Presse — Getty Images

- In a year of endless viral outbreaks, the details of the Diamond Princess tragedy seem like ancient history. On Jan. 20, one infected passenger boarded the cruise ship; a month later, more than 700 of the 3,711 passengers and crew members had tested positive, with many falling seriously ill. The invader moved as swiftly and invisibly as the perpetrators on Agatha Christie's Orient Express, leaving doctors and health officials with only fragmentary evidence to sift through.

Ever since, scientists have tried to pin down exactly how the coronavirus spread throughout the ship. And for good reason: The Diamond Princess' outbreak remains perhaps the most valuable case study available of coronavirus transmission — an experiment-in-a-bottle, rich in data, as well as a dark warning for what was to come in much of the world.

Now, researchers are beginning to use macroscopic tools — computer models, which have revealed patterns in the virus's global spread — to clarify the much smaller-scale questions that currently dominate public discussions of safety: How, exactly, does the virus move through a community, a building or a small group of people? Which modes of transmission should concern us most, and how might we stop them?

In a new report, a research team based at Harvard and the Illinois Institute of Technology has tried to tease out the ways in which the virus passed from person to person in the staterooms, corridors and common areas of the Diamond Princess. It found that the virus spread most readily in microscopic droplets that were light enough to float in the air, for several minutes or much longer.

The new findings add to an escalating debate among doctors, scientists and health officials about the primary routes of coronavirus transmission. Earlier this month, after pressure from more than 200 scientists, the World Health Organization acknowledged that the virus could linger in the air indoors, potentially causing new infections. Previously, it had emphasized only large droplets, as from coughing, and infected surfaces as the primary drivers of transmission. Many clinicians and epidemiologists continue to argue that these routes are central to disease progression.

The new paper has been posted on a preprint server and submitted to a journal; it has not yet been peer-reviewed, but it was shown by Times reporters to nearly a dozen experts in aerosols and infectious disease. The new findings, if confirmed, would have major implications for making indoor spaces safer and choosing among a panoply of personal protective gear.

For example, ventilation systems that “turn over” or replace the air in a room or building as often as possible, preferably drawing on external air to do so, should make indoor spaces healthier. But good ventilation is not enough; the Diamond Princess was well ventilated and the air did not recirculate, the researchers noted. So wearing good-quality masks — standard surgical masks, or cloth masks with multiple layers rather than just one — will most likely be needed as well, even in well-ventilated spaces where people are keeping their distance.

The computer modeling adds a new dimension of support to an accumulating body of evidence implicating small, airborne droplets in multiple outbreaks, including at a Chinese restaurant, a choir in Washington State, as well as a recent study at a Nebraska hospital to which 13 passengers from the Diamond Princess had been evacuated.

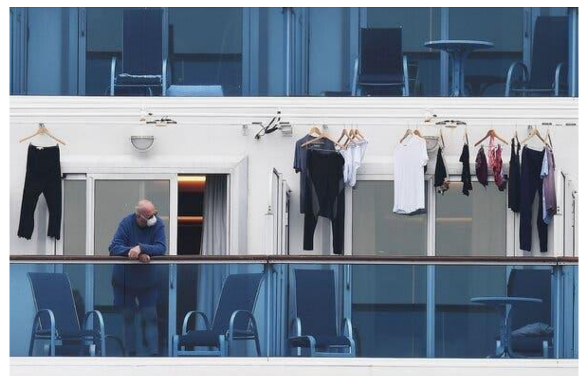
One researcher not involved in the new work, Julian Tang, an honorary associate professor of respiratory sciences at the University of Leicester in the United Kingdom, said the paper was “the first attempt, as far as I know, to formally compare the different routes of coronavirus transmission, especially of short versus long-range aerosols.”

He characterized the distances and the kinds of particles involved with a simple analogy from everyday life: “If you can smell what I had for lunch, you’re getting my air, and you can be getting virus particles as well.”

Another researcher, Linsey Marr, a professor of civil and environmental engineering at Virginia Tech who studies airborne transmission of viruses, had a more vivid description of the finding: the “garlic breath” effect.

“As you’re close to someone, you smell that garlic breath,” Dr. Marr said. “As you’re farther away, you don’t smell it.”

The “garlic breath” effect would suggest that powerful ventilation in buildings — primarily using outside air, or very well filtered — could reduce the transmission of the virus. The study found that small particles also had some ability to spread it at longer distances, presumably beyond the range of breath odor.



A passenger on the Diamond Princess during a quarantine period in February.

From the start of the pandemic, scientists have grappled with the mechanisms of coronavirus spread. Early on, surface transmission was widely emphasized; larger droplets, which travel on more ballistic trajectories, like a stone through the air, and strike mucus membranes directly, are now favored by a number of researchers.

Other possibilities are candidates as well, said Dr. John Conly, an infectious disease physician and infection control expert with the University of Calgary in Canada who has done consulting with the World Health Organization.

“We’re getting surprises all the way along,” Dr. Conly said. “This paper I find interesting, but it has a long way to go to be able to get into a line of credibility, in my mind.”

Dr. George Rutherford, a professor of epidemiology at the University of California, San Francisco, was equally skeptical. He said that, outside of hospital settings, “large droplets in my mind account for the vast majority of cases. Aerosols transmission — if you really run with that, it creates lots of dissonance. Are there situations where it could occur? Yeah maybe, but it’s a tiny amount.”

Dr. Tang and other scientists strongly disagree. “If I’m talking to an infectious person for 15 or 20 minutes and inhaling some of their air,” Dr. Tang said, “isn’t that a much simpler way to explain transmission than touching an infected surface and touching your eyes? When you’re talking about an outbreak, like at a restaurant, that latter seems like a torturous way to explain transmission.”

In the new analysis, a team led by Parham Azimi, an indoor-air researcher at Harvard's T.H. Chan School of Public Health, studied the outbreak on the Diamond Princess, where physical spaces and infections were well documented. It ran more than 20,000 simulations of how the virus might have spread throughout the ship. Each simulation made a variety of assumptions, about factors like patterns of social interaction — how much time people spent in their cabins, on deck or in the cafeteria, on average — and the amount of time the virus can live on surfaces. Each also factored in varying contributions of smaller, floating droplets, broadly defined as 10 microns or smaller; and larger droplets, which fall more quickly and infect surfaces or other people, by landing on their eyes, mouth or nose, say.

About 130 of those simulations reproduced, to some extent, what actually happened on the Diamond Princess as the outbreak progressed. By analyzing these most "realistic" scenarios, the research team calculated the most likely contributions of each route of transmission. The researchers concluded that the smaller droplets predominated, and accounted for about 60 percent of new infections over all, both at close range, within a few yards of an infectious person, and at greater distances.

"Many people have argued that airborne transmission is happening, but no one had numbers for it," Dr. Azimi said. "What is the contribution from these small droplets — is it 5 percent, or 90 percent? In this paper, we provide the first real estimates for what that number could be, at least in the case of this cruise ship."

The logic behind such transmission is straightforward, experts said. When a person is speaking, he or she emits a cloud of droplets, the vast majority of which are small enough to remain suspended in the air for a few minutes or longer. Through inhalation, that cloud of small droplets is more likely to reach a mucus membrane than larger ones soaring ballistically.

The smaller droplets are also more likely to penetrate deeply into the respiratory system, down to the lungs. It may take a much smaller viral load — fewer viruses — to cause infection in the lungs than higher up, such as in the throat. This, at least, is the case for other respiratory viruses, like the flu.

Brent Stephens, an engineering professor at the Illinois Institute of Technology in Chicago and a co-author on the paper, said the findings were important in shaping, for example, measures that should be taken as college students return to campus.

The first, he said, should be "really enforcing mask policies." Another, he said, is to recognize that there is a "huge variability in mask quality," and material that actually stops small aerosols when someone is breathing, speaking, coughing or sneezing is crucial. Surgical masks are good, he said, but single-ply fabrics often are not.

As various transmission routes come into clearer focus, they will provide specific guidelines on how to reopen schools, offices, restaurants and other businesses.

"The value of this model is that it allows for recommendations and guidance to be specific to each unique environment," said another co-author, Joseph G. Allen, an expert in indoor air quality and an assistant professor at Harvard's T.H. Chan School of Public Health.

Dr. Allen said those environments ranged from restaurants to dentist offices. In each case, he said, there are low-cost solutions that sharply improve ventilation and filtration — most buildings fall well short of optimal levels — and in turn reduce the risks of airborne infection.

"To me, this is an all-in moment," Dr. Allen said. "We need better ventilation and better filtration, across the board, in all our buildings."

Benedict Carey has been a science reporter for The Times since 2004. He has also written three books, "How We Learn" about the cognitive science of learning; "Poison Most Vial" and "Island of the Unknowns," science mysteries for middle schoolers.

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A version of this article appears in print on July 31, 2020, Section A, Page 6 of the New York edition with the headline: ***Study Finds Evidence Virus Can Float in Air For Minutes or Longer****.*