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Airborne Transmission of Influenza A Virus in Indoor Environments

Wan Yang

Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
In
Civil and Environmental Engineering

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John C. Little
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March 30, 2012
Blacksburg, Virginia

Keywords: influenza A virus; airborne transmission; relative humidity; size distribution; bioaerosol

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Airborne Transmission of Influenza A Virus in Indoor Environments

Wan Yang

ABSTRACT
Despite formidable advances in virology and medicine in recent decades, we know remarkably little about the dynamics of the influenza virus in the environment during transmission between hosts. There is still controversy over the relative importance of various transmission routes, and the seasonality of influenza remains unexplained. This work focuses on developing new knowledge about influenza transmission via the airborne route and the virus’ inter-host dynamics in droplets and aerosols.

We measured airborne concentrations of influenza A viruses (IAVs) and size distributions of their carrier aerosols in a health center, a daycare center, and airplanes. Results indicate that the majority of viruses are associated with aerosols smaller than 2.5 µm and that concentrations are sufficient to induce infection.

We further modeled the fate and transport of IAV-laden droplets expelled from a cough into a room, as a function of relative humidity (RH) and droplet size. The model shows that airborne concentrations of infectious IAV vary with RH through its influence on virus inactivation and droplet size, which shrinks due to evaporation. IAVs associated with large droplets are removed mostly by settling, while those associated with aerosols smaller than 5 µm are removed mainly by ventilation and inactivation.

To investigate the relationship between RH and influenza transmission further, we measured the viability of IAV in droplets at varying RHs. Results suggest that there exist three regimes defined by RH: physiological conditions (~100% RH) with high viability, concentrated conditions (~50% to ~99% RH) with lower viability, and dry conditions (<~50% RH) with high viability. A droplet’s extent of evaporation, which is determined by RH, affects solute concentrations in the droplet, and these appear to influence viability.

This research considerably advances the current understanding of the dynamics of the influenza virus while it is airborne and provides an explanation for influenza’s seasonality. Increased influenza activity in winter in temperate regions could be due to greater potential
for IAV carrier aerosols to remain airborne and higher viability of IAV at low RH. In tropical regions, transmission could be enhanced due to better survival of IAV at extremely high RH.