AIRBORNE INFECTION IN HEALTHCARE ENVIRONMENTS: IMPLICATIONS TO HOSPITAL CORRIDOR DESIGN

by

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Several studies have linked nosocomial transmission airborne diseases to airflow in healthcare settings. Quasi-experimental methods are developed to observe the aerodynamic transport behavior of synthetic respiratory particles in corridors of a hospital. Computational models, validated by experimental results, are then developed to explore the spatial relationships of supply-exhaust air ventilation in patient corridors. The aim of this study is to determine optimal HVAC design strategies to contain and remove airborne contaminants in healthcare environments.

In addition to occupant comfort, hospital HVAC systems are designed to provide ventilation and directional airflow to contain, dilute and remove contaminants including airborne disease. Of 183 epidemiological studies published worldwide from 1960-2005, however, only 10 studies were deemed by a panel of international experts as having conclusively demonstrated the effectiveness of ventilation to control the spread of airborne disease in healthcare settings.

Two experimental tests were conducted; one placing patient corridors under directional airflow and the second placing the corridors under non-directional airflow. The purpose

of these tests was to observe the spatial-temporal movement of artificially-generated aerosols with respect to particle size and ventilation mode and to assess the probability of contamination from infectious sources inside and outside of the patient area. Next, computational fluid dynamic (CFD) models were developed and validated by experimental results to test several ventilation rates with modified supply-exhaust air system configurations in patient corridors.

Results suggest that dissemination of bio-aerosols in hospital corridors could be exacerbated by directional airflow caused by either the spatial arrangement of supply-exhaust air ventilation, or, the pressure relationship between the corridor and surroundings spaces. Within the non-directional or ‘neutral’ airflow regime, modified supply-exhaust air system configurations reduced average particle concentration 30% and transport distance more than 60% without increasing air change rate. Aerosols $\leq 0.5\mu m$, however, were observed more than 30m from the source with comparatively less regard to airflow mode or supply-exhaust air system configuration. Ventilation arrangements can potentially reduce concentrations and improve distributions of particles. And, higher ventilation rates do not necessarily culminate in better results.

To

Whom I wish to come soon

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Latin Symbols

c	= contaminant concentration (kg/s)
c_0	= Supply air contaminant concentration (kg/s)
c_i	= initial contaminant concentration (kg/s)
c_e	= ending contaminant concentration (kg/s)
C_c	= Cunningham slip correction factor (-)
C_D	= Drag coefficient (-)
C_p	= Heat capacity at constant pressure (J/kg.^{o}K)
D	= Number of disease cases
dp	= Particle diameter (m)
$d_{i,j}$	= Rate of deformation tensor (-)
$\vec{\boldsymbol{g}}$	= Gravitational acceleration vector (m/s^2)
g	= Skewness (-)
I	= Number of infectors (-)
K	= Turbulence Kinetic Energy (m^2/s^2)
n	= air change rate (hour^{-1})
$n(t)$	= Brownian force (N)
p	= Breathing rate per person (-); Pressure (Pa)

$\bar{p}$ = Time averaged pressure (Pa)

p' = Pressure fluctuation (Pa)

q = quantum generation rate (-)

Q = Ventilation Rate (m^3/s)

P_T = Probability of transport (-)

R^2 = Determination correlation (-)

Re = Reynolds number (-)

S = Number of susceptible (-)

$\vec{\boldsymbol{u}}$ = Velocity field vector (m/s)

$\vec{\boldsymbol{u}}_p$ = Particle velocity field vector (m/s)

t = Time (s)

$u_x;\ u_y;\ u_z$ = Velocity components in x, y, z directions (m/s)

$u'_x;\ u'_y;\ u'_z$ = Fluctuating velocity components in x, y, z directions (m/s)

$\bar{u}_x;\ \bar{u}_y;\ \bar{u}_z$ = Time averaged velocity components in x, y, z directions (m/s)

V = Volume (m^3)

$\dot{V}_{pol}$ = Contaminant generation rate (kg/s)

$x;\ y;\ z$ = Cartesian coordinates (m)

Greek Symbols

β = Kurtosis of sample

σ = Stefan-Boltzmann constant (W/m^2K^4); Standard Deviation of sample

μ = Dynamic viscosity (Pa.s)

ξ = Gaussian random number (-)

π = Constant equal to 3.1415 (-)

ρ = Density of air (kg/m^3)

ρ_p = Density of particle (kg/m^3)