Improved Ventilation System for Reduction of Airborne Disease Transmission in the Library of University of Regina

Changyan Chen, Gangwei Dong, Songsong Wang, Zhenlin Zhou

University of Regina

Background

Infectious diseases such as the SARS virus which spreads through air and aerosols threaten the safety and health of human beings. From 2019 to 2021, the outbreak of COVID-19 and its transmission rates are very high in indoor facilities. Poor ventilation and inefficient disinfection are two main reasons that the COVID-19 virus transmits so rapidly indoors. Nowadays, all existing buildings (with the exception of hospitals) are not designed with infectious diseases in mind.

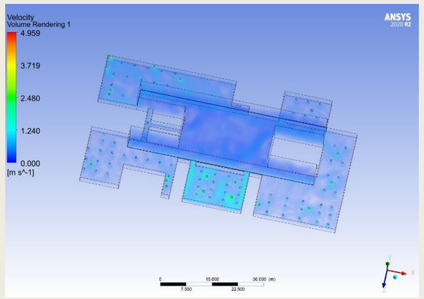
This project focused on providing some design strategies to improve ventilation system in the library of University of Regina based on the CFD simulation results and ASHRAE guideline.

CFD Boundary Condition

CFD Model Selection	
Steady/Transient	Transient
Dimension	3-D
Turbulence Model	SST K-omega
Discrete Phase model	Water-Liquid (Five Injections)
Boundary Conditions	
Outlet	Pressure Outlet; Escape (DPM)
Mouth	Velocity Inlet: Escape (DPM); Inject Using Face Normal Direction
Inlet	Velocity Inlet
Wall	Wall (Standard Wall)； Trap (DPM)
Initial Condition of Environment	
Temperature	20℃

Initial Conditions of Injections/Coughing	
Particle Diameter	3.1e-7 m
Particles per Coughing	200,000
Temperature of Droplets	37℃
Duration of Coughing	0.5 s
Coughing Velocity	10 m/s
Total Flow Rate	9.9e-12 kg/s
Initial Conditions of Inlets	
Velocity of Inlet (Group 1)	2.33 m/s
Velocity of Inlet (Group 2)	2.98 m/s
Velocity of Inlet (Group 3)	2.25m/s
Velocity of Inlet (Group 4)	2.6 m/s
Velocity of Inlet (Group 5)	2.18m/s
Velocity of Inlet (Group 6)	1.9 m/s

Airflow Simulation Result



Airflow Pattern Simulation

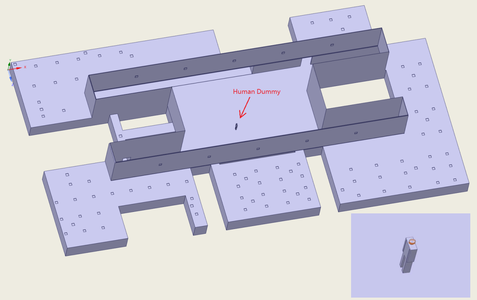
- The central vaulted ceiling area is low flow rate area due to darker blue color presented.
- Studying room area is high flow rate area due to lighter blue color presented.

In summary, the ventilation performance in the central vaulted ceiling area is determined as poor. The poor performance of the air flow pattern is caused by the lack of outlets and inlets.

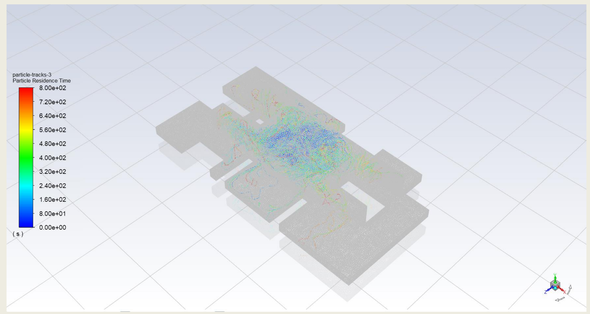
Bioaerosol Dispersion Simulation Result

- In the first simulation of the central vaulted ceiling area, the particles has spread into other areas and the residence time is long. After 800 s simulation, about 32% particles are still remained.
- The simulation of the study room area and bookshelves area both indicates that the particles did not spread into other areas and the residence time is short. After 150s, there are almost no residual particles exist.

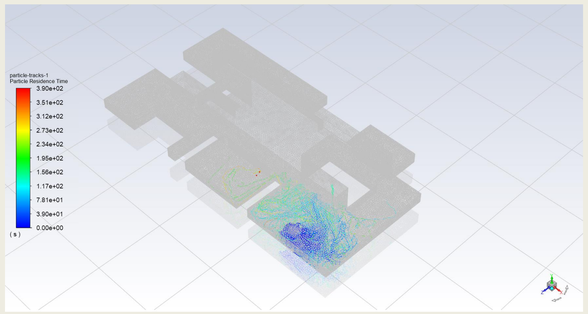
As a result, only the central vaulted ceiling area is required to improve the performance of air flow pattern.



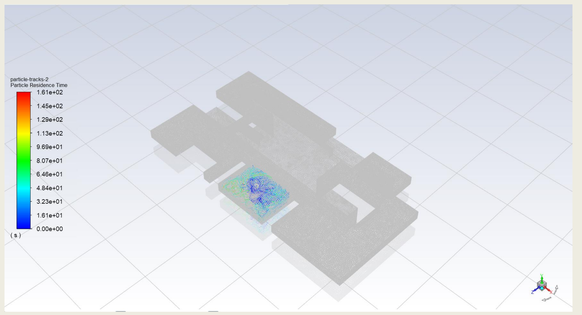
Library 3-D Model with Human Dummy



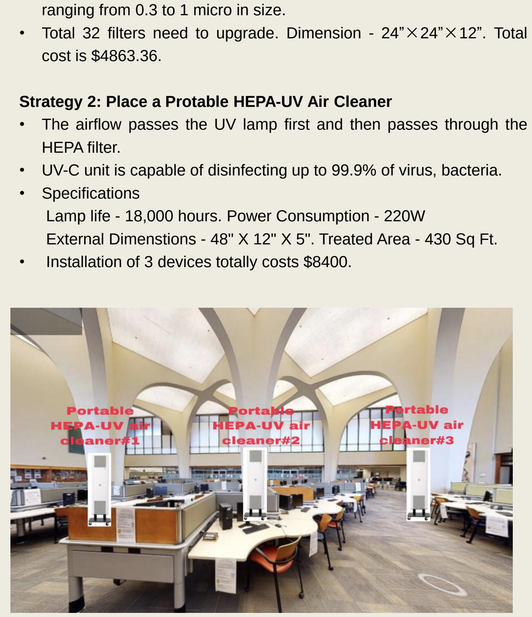
1st Simulation
(Scenario 1-Emission from Central Vaulted Ceiling Area)



2nd Simulation
(Scenario 2- Emission from Bookshelves Area)



3rd Simulation
(Scenario 3- Emission from Studying Room Area)



MERV 14 Filter

Ultimate Design Strategies

Strategy 1:Upgrade Return Air Filter from MERV 13 to MERV 14

- Filtration efficiency can increase from 66.3% to 81.4% for particle ranging from 0.3 to 1 micro in size.
- Total 32 filters need to upgrade. Dimension - 24”×24”×12”. Total cost is $4863.36.

Strategy 2: Place a Protable HEPA-UV Air Cleaner

- The airflow passes the UV lamp first and then passes through the HEPA filter.
- UV-C unit is capable of disinfecting up to 99.9% of virus, bacteria.
- Specifications
  Lamp life - 18,000 hours. Power Consumption - 220W
  External Dimenstions - 48" X 12" X 5". Treated Area - 430 Sq Ft.
- Installation of 3 devices totally costs $8400.

3 Portable HEPA-UV Air Cleaners Placed in the Library

Conclusion

- Central vaulted-ceiling area has poor ventilation performance due to lack of fresh air outlet grids.
- CFD bioaersol simulation results show that higher particles escaped time occurs when the bioaerosol emission source located in the central vaulted-ceiling area.
- The upgrade of return air filter and placement of HEPA-UV are proposed as the final design strategies; total cost is $13236.26.

Acknowledgments

- **Amy Veawab**
Faculty Supervisor
- **Tom Atkins**
Mechanical Engineer
and Vice President
in Stantec's Buildings group
- **Rob Kleisinger**
University of Regina
Facilities Management
Manager of Mechanical Services