The Impact of the Outdoor Environment on Natural and Mechanical Ventilation Performance

ASHRAE Ireland Chapter – COVID-19 Technical Mini-Series – Part 5
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ASHRAE Ireland Chapter Sponsors
THE GREATEST THREAT?

OUTDOOR OR INDOOR POLLUTION
THE newest threat!
SARS-CoV-2 (COVID-19)
AIRBORNE TRANSMISSION OF PARTICLES (AEROSOLS)

Source: WHO, 2020
VENTILATION DURING COVID PANDEMIC

Source: Morawska et al., 2020
OVERVIEW

MY CONTEXT

PARTICLE/AEROSOL POLLUTION MITIGATION

OUTDOOR AND INDOOR EXPOSURE

STEPS TOWARDS CLEANER AIR

INNOVATIVE IN MV & NV DESIGN

RETURN TO MY CONTEXT

OVERVIEW

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RETURN TO MY CONTEXT

CONCLUSION
MY CONTEXT – OUTDOOR, INDOOR, INTERFACE

OUTDOOR

INDOOR/OUTDOOR INTERFACE

INDOOR

OVERVIEW  MY CONTEXT  PARTICLE/AEROSOL POLLUTION MITIGATION  STEPS TOWARDS CLEANER AIR  INNOVATION IN MV & NV DESIGN  RETURN TO MY CONTEXT  CONCLUSION
MY CONTEXT – MEASURE, MODEL, MITIGATE

MEASURE

MODEL

Indoor

Outdoor

MITIGATE

OVERVIEW

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CONCLUSION
Reduce exposure to particles/aerosols in the built environment

An office building with a mechanical ventilation system

A pedestrian sidewalk in an urban street canyon environment

Natural ventilation openings in residential or commercial building

My Context – Footwalk, Rooftop and Openings
Account for the life cycle in every research question.

Effectively capture the boundary conditions of your problem.

Analyse for sensitivity and uncertainty.

Consider the consequences of change.
PARTICLES/AEROSOLS AND OUTDOOR EXPOSURE

PHYSICAL OBJECTS AFFECT DISPERSION AND DEPOSITION

Abhijith et al., 2017; Abhijith & Kumar, 2019
Urban morphology creates a complex environment for effective ventilation design.

Jeanjean et al., 2017
TEMPERATURE PROFILES AND SHAPE AND FORM OF INDOOR SPACE AFFECT EXPOSURE

PARTICLES/AEROSOLS AND INDOOR EXPOSURE
OVERVIEW

PARTICLES/AEROSOLS AND INDOOR EXPOSURE

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**STEPS IN ASSESSMENT TO REDUCE PARTICLE/AEROSOL EXPOSURE**

1) **Define indicators to be measured** that can encapsulate the outdoor and/or indoor environments with regards to ventilation and exposure.

2) **Characterise and parameterise factors to be considered in modelling** investigations of ventilation systems which allow a thorough examination of exposure.

3) **Be informed of the scientific knowledge** that governs particle/aerosol transport in outdoor and indoor environments, to support the development of **mitigation** solutions.
1) Indicators for Assessment - Measurement

Net escape velocity (NEV)
Pollutant exchange velocity ($U_{poll}$)
Air delay ($\tau_a$)

Purging flow rate (PFR)
Age of air ($\tau_v$)

Residential time (TP)
Revised roof air exchange rate (R-ACH$_{rel}$)

Visitation frequency (VF)

Air exchange rate (ACH$_{hol}$)
Air exchange velocity ($U_a$)

Roof air exchange rate (ACH$_{rel}$)

Volumetric flow rate (Q)
Pollutant exchange rate (PCH)

Indices employed for urban outdoor ventilation assessment

Higher value means better
Lower value means better

Source: Peng et al., 2019
2) Factors to Inform Design - Modelling

Characterisation and Parameterisation

Which factors impact upon the performance of natural or mechanical ventilation systems?

Which factors impact upon the performance of natural and mechanical ventilation systems?

<table>
<thead>
<tr>
<th>Characterisation and Parameterisation</th>
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</thead>
<tbody>
<tr>
<td><strong>Physical</strong></td>
</tr>
<tr>
<td>Outdoor</td>
</tr>
<tr>
<td>Surrounding Buildings</td>
</tr>
<tr>
<td>Building shape and form</td>
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<tr>
<td>Indoor</td>
</tr>
<tr>
<td>Internal layout</td>
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<tr>
<td>NV Opening</td>
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<tr>
<td>Size and shape</td>
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<tr>
<td>Position on building face</td>
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<tr>
<td>Materials</td>
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<tr>
<td>Facades</td>
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<tr>
<td>Existing System</td>
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<tr>
<td>Heating</td>
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<tr>
<td>Cooling</td>
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<tr>
<td>Ventilation</td>
</tr>
<tr>
<td><strong>Environmental</strong></td>
</tr>
<tr>
<td>Wind</td>
</tr>
<tr>
<td>Speed</td>
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<tr>
<td>Direction</td>
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<tr>
<td>Temperature</td>
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<tr>
<td>Outdoor spatial and temporal variations</td>
</tr>
<tr>
<td>Differential between I/O</td>
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<tr>
<td>Pollution</td>
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<tr>
<td>Ambient air quality</td>
</tr>
<tr>
<td>Location of sources</td>
</tr>
<tr>
<td>Type of pollutant</td>
</tr>
</tbody>
</table>
3) Apply scientific knowledge to improve design - mitigation

**Design-driven**

- Human vs Mechanical sampling
- Particle characteristics
- Speed of ambient air flow
- Gravitational settling
- Angle of ambient wind to the plane of the inlet
- Inlet design/geometry
- Speed of sampling/breathing rate
- Electrostatic effects
- Aspiration efficiency

**Human vs Mechanical sampling**
### Location and setting

<table>
<thead>
<tr>
<th>Location</th>
<th>Type</th>
<th>Total PM (μg/m³)</th>
<th>PM reduction (μg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dublin, Ireland</td>
<td>(low pollution, small coastal European city)</td>
<td>10-25</td>
<td>2-4</td>
</tr>
<tr>
<td>Maastricht, Netherlands</td>
<td>(moderate pollution, central Europe city)</td>
<td>25-40</td>
<td>4-7</td>
</tr>
<tr>
<td>London, UK</td>
<td>(high pollution, industrial European and US cities)</td>
<td>50-70</td>
<td>9-12</td>
</tr>
<tr>
<td>Delhi, India</td>
<td>(very high pollution, Asia and Middle East)</td>
<td>100-300</td>
<td>17-51</td>
</tr>
</tbody>
</table>

34% REDUCTION IN TOTAL MASS CONCENTRATION OF PM
**Innovation in Mechanical Ventilation Design**

**Better Indoor Air Quality = Improved Filtration**

**Improved Filtration = Better Filters (ISO16890)**

**Better Filters = Increased Pressure Drop**

**Increasing Pressure Drop = Additional Energy Demands**

**Shorter Lifespans**

**More Filters Required**

**Additional Costs and Waste**

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**Overview**

**My Context**

Particle/Aerosol Pollution Mitigation

Steps Towards Cleaner Air

Innovation in MV & NV Design

Return to My Context

Conclusion
INNOVATIONS IN NATURAL VENTILATION DESIGN

VARIATION IN AQ BETWEEN AND ACROSS NV OPENINGS IN BUILDING
INNOVATIONS IN NATURAL VENTILATION DESIGN

Variation in AQ due to external physical features outside NV opening

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Conclusion
Modern Buildings with Advanced HVAC Systems
RETURN TO MY CONTEXT

HISTORICAL BUILDINGS

WITH

RETROFITTED VENTILATION SOLUTIONS

OVERVIEW  MY CONTEXT  PARTICLE/AEROSOL POLLUTION MITIGATION  STEPS TOWARDS CLEANER AIR  INNOVATION IN MV & NV DESIGN  RETURN TO MY CONTEXT  CONCLUSION
Some natural ventilation

Distinct lecture theatres

Some mechanical ventilation

Return to my context
CONCLUSION

COVID IS AN IMMEDIATE CONCERN FOR PROVIDING ADEQUATE VENTILATION, BUT LONG-TERM INDOOR AIR QUALITY CHALLENGES STILL NEED TO BE ADDRESSED.

WE DON’T UNDERSTAND THE IMPACT OF OUTDOOR ENVIRONMENTAL CONDITIONS SUFFICIENTLY WHEN DESIGNING AND OPERATING NATURAL AND MECHANICAL VENTILATION SYSTEMS..

ENSURING ADEQUATE VENTILATION IN THIS COVID WORLD IS A CHALLENGE IN OLDER BUILDINGS.
THANK YOU!

QUESTIONS?

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