Infiltration of air pollutants and effectiveness of air cleaners

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Outline

• Infiltration of pollutants to indoors
  – $O_3$, NO$_2$, PM$_{2.5}$

• PM$_{2.5}$ and air cleaner use
  – exposure reduction
Infiltration

Fraction of outdoor pollutants that penetrate indoors and remain suspended

Modified from Thatcher and Layton (1995)
Infiltration cont.

\[ F_{\text{inf}} = \frac{P \cdot a}{a + k} \]

- \( F_{\text{inf}} \) = infiltration efficiency
- \( P \) = penetration
- \( a \) = air exchange
- \( k \) = deposition
Measuring infiltration

• Compare indoor - outdoor levels when no sources are present
  – Tracer
  – Time period (e.g. night time)

• Take continuous of measurements of indoors – outdoor levels
  – remove indoor-generated portion
Ozone

• Typically indoor levels are low
  – few indoor sources; major source is outdoor ozone

• Penetration of ozone to indoors is low
  – reacts with building materials as it moves indoors
  – moves through open windows in summer

• Once indoors, ozone is quickly removed
  – half-life is 7-10 minutes
Nitrogen dioxide

- Indoor sources: kerosene heaters, un-vented gas and wood stoves, ETS
- Outdoor sources: Vehicle and ship traffic, industrial processes
- Indoor levels vary across homes and seasons:
  - Indoor > outdoor during winter in homes with sources
  - Indoor < outdoor generally for homes without sources
  - 50-70 % of NO₂ infiltrates from outdoors
Particulate matter

- Indoor sources: ETS, cooking, cleaning, wood stoves

- Outdoor sources: wood burning, traffic, forest fires, industrial processes

- $F_{\inf}$ typically higher for smaller particles
  - Penetration is particle size dependent
Particle penetration

PM < 2.5 µm
PM 2.5 - 10 µm
PM > 10 µm

Penetration efficiency

0 %
100 %
Improving indoor air quality

1. Reduce indoor-generated pollution

2. Modify air exchange rate (AER)
   – Depends on pollutant source

3. Filter indoor air
Air cleaner use as a public health intervention

- Air cleaners can increase deposition of particles
  - Can decrease exposure
  - Decreased exposure can potentially lead to some health benefits: Particles are known to trigger underlying mechanisms leading to disease processes, including asthma
Types of Air Cleaners

• Set – up
  – in-duct: part of HVAC system, designed to clean air from whole house
  – portable: clean air from a single room

• Operation
  – mechanical filter: filter particles, eg. High Efficiency Particulate Air (HEPA)
  – electronic precipitators & ion generators: charge particles in the air
Ozone and air cleaning

- Ozone generators produce ozone to clean air while some electrostatic precipitators produce it as a by-product
  - ozone is a respiratory irritant
  - exposure poses a health concern

- Health Canada has issued a warning against the use of ozone generators

- Residential ozone generators are no longer approved by Canadian Standards Association
HEPA filters and exposure reduction

• Particulate pollutants
  – Indoor sources: ETS, fungal spores, dust, allergens
  – Outdoor sources: Traffic, wood smoke, forest fire smoke

• Studies find substantial decreases in pollutant concentrations with air cleaner use
  – 90 % decrease in baseline dog allergen concentrations in a room within 24 hours$^2$
  – 80 % decrease in baseline fungal spore concentrations in a room within 24 hours$^3$
  – 30-70 % reductions in baseline ETS particles in a home after a 2 month period$^4$

• Effectiveness varies among studies due to study design
  – Number of devices, time period, AER, air cleaner placement
Air cleaner effectiveness

Depends on both:

• Efficiency of device (filter) at removing the pollutant
  – MERV (in duct) or CADR (portable) ratings

• Amount of air “cleaned” by device (filter)
  – AER, room size, time
Increasing ACE

AER is an important factor for both indoor air quality and ACE

– if indoor sources are dominant, an increase in AER can improve IAQ
– if outdoor sources are dominant, a decrease in AER can improve IAQ and improve ACE
# Outdoor AQ and air cleaners in homes

<table>
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<td>Brauner et al. 2008&lt;sup&gt;5&lt;/sup&gt;</td>
<td>Traffic</td>
<td>Portable HEPA</td>
<td>+ filter: 48hr, - filter: 48 hr</td>
<td>Lower PM&lt;sub&gt;2.5&lt;/sub&gt; levels during + filter period (GM: 4.7 ± 0.8 µg/m&lt;sup&gt;3&lt;/sup&gt;) vs. - filter period (GM: 12.6 ± 1.4 µg/m&lt;sup&gt;3&lt;/sup&gt;) across homes (n= 21)</td>
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<td>Allen et al. 2009&lt;sup&gt;6&lt;/sup&gt;</td>
<td>Wood smoke</td>
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<td>Lower PM&lt;sub&gt;2.5&lt;/sub&gt; F&lt;sub&gt;inf&lt;/sub&gt; during + filter period (0.20 ± 0.17) vs. - filter period (0.34 ± 0.17) across homes (n=25)</td>
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<td>Barn et al. 2008&lt;sup&gt;7&lt;/sup&gt;</td>
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<td>Henderson et al. 2005&lt;sup&gt;8&lt;/sup&gt;</td>
<td>Fire smoke</td>
<td>Portable ESP</td>
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<td>Indoor PM&lt;sub&gt;2.5&lt;/sub&gt; levels 63-88 % lower in treatment vs. matched control homes (n= 4 pairs) ; mean 24 hr indoor PM&lt;sub&gt;2.5&lt;/sub&gt; ≤ 3 µg/m&lt;sup&gt;3&lt;/sup&gt; in treatment homes vs. 5.2 – 21.8 µg/m&lt;sup&gt;3&lt;/sup&gt; in control homes</td>
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In-duct filters

• Few studies have evaluated in-duct filters outside of chamber tests

• Comparison of in-duct vs. portable units showed higher particle removal rates for in-duct vs. portable units⁹
  – Portable units may not effectively draw air from other rooms, hallways

• PM₂.₅ removal rates⁹:
  – baseline: 0.5 hr⁻¹
  – portable HEPA: 2.4 hr⁻¹
  – in-duct media filter: 4.6 hr⁻¹
  – in-duct high efficiency electrostatic: 7.5 hr⁻¹

• Removal rates higher for same home when unoccupied
Key Points

• Levels of indoor pollutants will differ depending on their infiltration efficiencies and the presence of indoor sources

• HEPA filter air cleaners can lower indoor particle levels and thereby reduce exposure
  – AER and room size are important determinants
  – In-duct filters may be more effective at lowering PM$_{2.5}$ levels in the whole house

• Air cleaners can be particularly useful when outdoor AQ is poor
Thank You

Questions?
Comments?

www.ncceh.ca | www.ccnse.ca
References


Other references used: