

Infiltration of air pollutants and effectiveness of air cleaners

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Santé et environnement: enjeux, rôles et interventions

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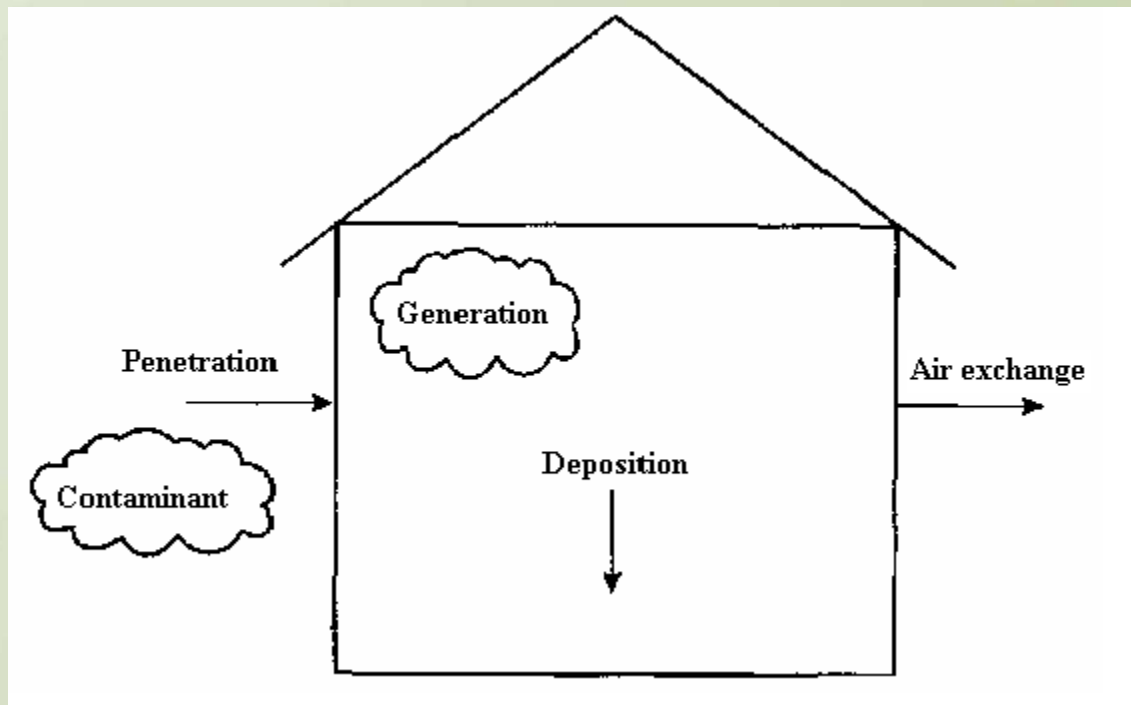
BC Centre for Disease Control
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Outline

- 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)¹

Infiltration cont.

$$F_{\text{inf}} = \frac{P a}{a + k}$$

F_{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

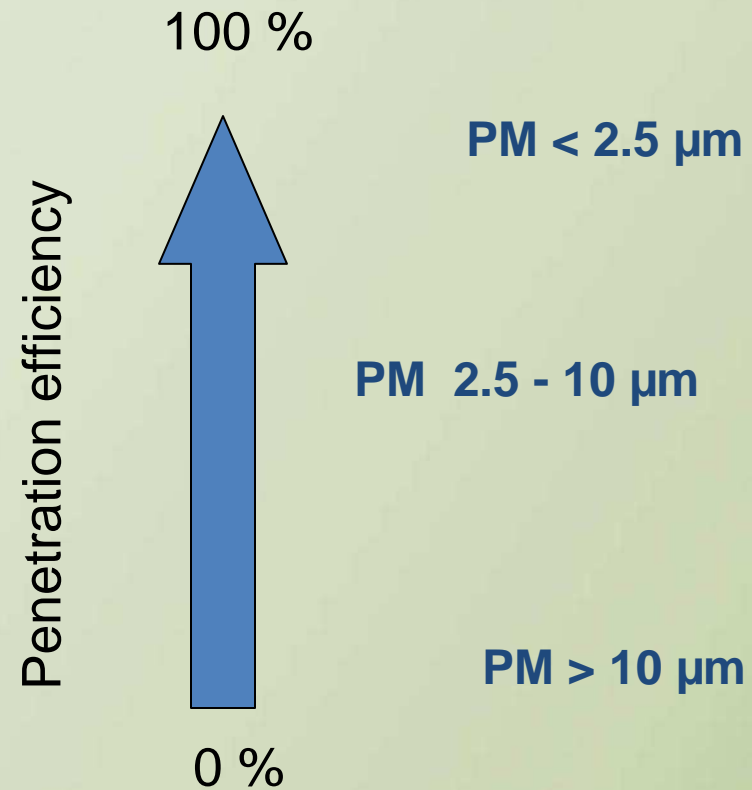
Nitrogen dioxide

- 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

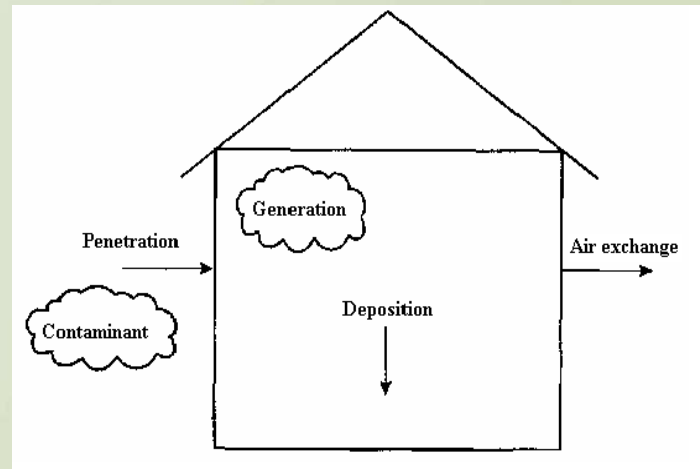
Particle penetration



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 hours²
 - 80 % decrease in baseline fungal spore concentrations in a room within 24 hours³
 - 30-70 % reductions in baseline ETS particles in a home after a 2 month period⁴
- 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

Study	Exposure	Air cleaner	Study Period	Findings
Brauner et al. 2008 ⁵	Traffic	Portable HEPA	+ filter: 48hr - filter: 48 hr	Lower PM _{2.5} levels during + filter period (GM: 4.7 ± 0.8 µg/m³) vs. - filter period (GM: 12.6 ± 1.4 µg/m³) across homes (n= 21)
Allen et al. 2009 ⁶	Wood smoke	Portable HEPA	+ filter: 7d - filter: 7d	Lower PM _{2.5} F _{inf} during + filter period (0.20 ± 0.17) vs. - filter period (0.34 ± 0.17) across homes (n=25)
Barn et al. 2008 ⁷	Forest fire & wood smoke	Portable HEPA	+ filter: 24hr - filter: 24hr	Lower PM _{2.5} F _{inf} on + filter days (0.13 ± 0.14) vs. - filter days (0.42 ± 0.27) across homes (n= 29)
Henderson et al. 2005 ⁸	Fire smoke	Portable ESP	24 - 48hr	Indoor PM _{2.5} levels 63-88 % lower in treatment vs. matched control homes (n= 4 pairs) ; mean 24 hr indoor PM _{2.5} ≤ 3 µg/m³ in treatment homes vs. 5.2 – 21.8 µg/m³ in control homes

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
- PM_{2.5} 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?

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