Indoor Air and Air Cleaners: An Inside Look

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An Agency of the Provincial Health Services Authority

Outline

- Indoor air quality
- Air cleaners
- Questions and discussion

Indoor Air Quality




Indoor Air Quality

- We spend most of our time indoors (~85%)[1]
- Indoor air contains a mixture of contaminants from both indoor and outdoor sources
- Can be biological, radiological, and **chemical** – we will focus on chemical contaminants

Common indoor contaminants

Contaminant	Description	Sources
$PM_{2.5}$	Liquid or solid particles smaller than 2.5 µm	environmental tobacco smoke (ETS), cooking, cleaning, wood stoves; wood burning, traffic, forest fires, industrial processes
NO_2	Gas; odorous, brown, highly corrosive.	kerosene heaters, un-vented gas and wood stoves, ETS; traffic, industrial processes
CO	Gas; odorless, tasteless	unvented (or improperly vented) kerosene & gas space heaters, gas water heaters, wood stoves, fireplaces; traffic, industrial processes
Ozone	Gas; highly reactive	Ozone generators, office equipment; traffic, industrial processes
VOCs	Gases; highly volatile	Off-gassing from paint, furniture, building materials, cleaning supplies, pesticides, office equipment, chemical manufacturing

Health Canada guidelines

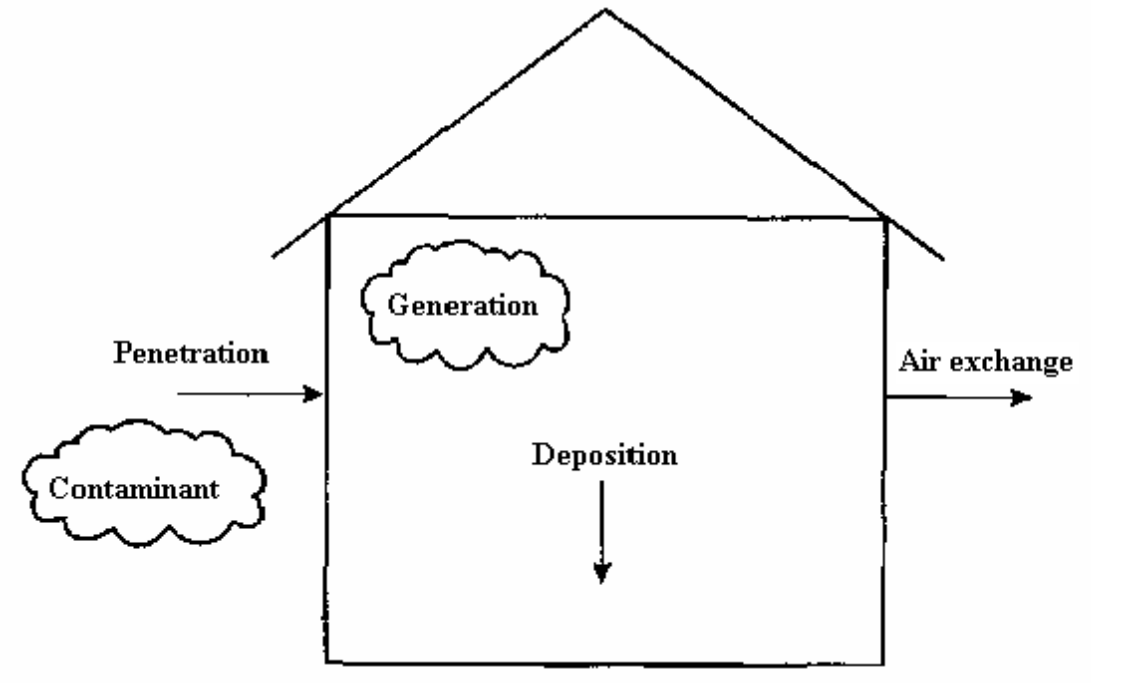
Contaminant (Year)	Guideline values
$PM_{2.5}$ (1987)	- 40µg/m^3 for 24 hr* - 100 µg/m^3 for 1 hr
NO_2 (1987)	-100 µg/m^3 (0.05 ppm) for 24 hr - 480 µg/m^3 (0.25 ppm) for 1 hr
CO (2010)	-11.5 mg/m^3 (10 ppm) for 24 hr - 28.6 mg/m^3 (25 ppm) for 1 hr
Ozone (2010)	- 40 µg/m^3 (20 ppb) for 8 hr
Formaldehyde (2006)	- 50 µg/m^3 (40 ppb) for 8 hr - 123 µgm^3 (100 ppb) for 1 hr exposure

*Major revision underway on these guideline values; revised document will be posted to the Canada Gazette by summer 2011

Adapted from Dales et al. 2008[2]

Outdoor sources

- Outdoor air also impacts indoor air quality
- The fraction of contaminants that move indoors and remain in the air can be quantified: **infiltration**



Modified from Thatcher and Layton (1995)[3]

Infiltration

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

F_{inf} = infiltration efficiency

P = penetration

a = air exchange

k = deposition

Infiltration of contaminants

Ozone:

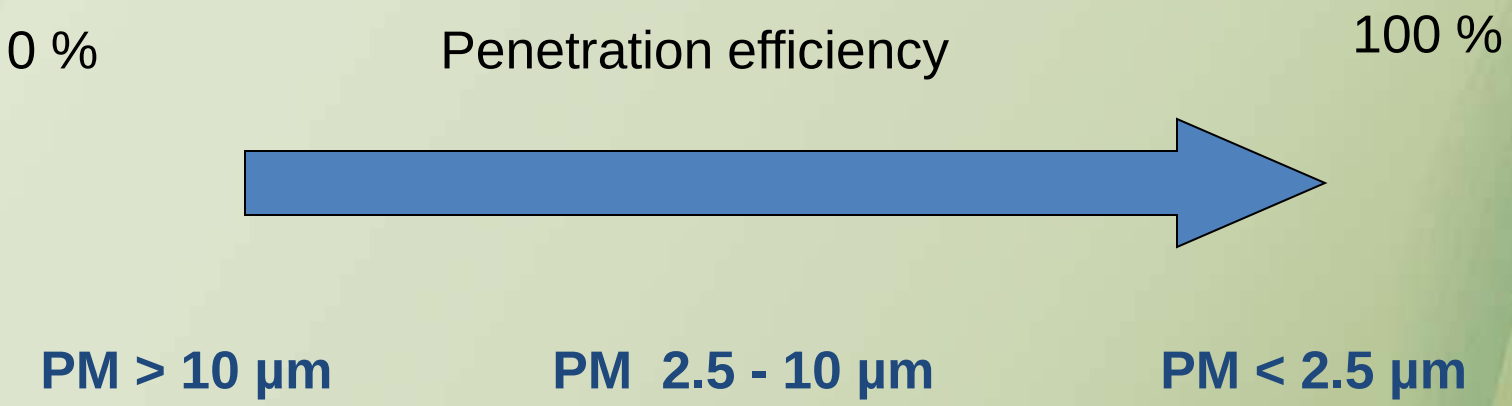
- penetration of ozone to indoors is low
- reacts with building materials as it moves indoors
- primarily moves through open windows in summer
- once indoors, ozone is quickly removed (half-life is 7-10 minutes)[4]

NO_2

- ~ 50-70 % of NO_2 infiltrates from outdoors
- Indoor sources are dominant for NO_2 in homes

Infiltration: Particulate matter

- F_{inf} is influenced by several factors, including particle size



Estimates of Residential Fine PM F_{inf}

Mean F_{inf}	Season	Study Location	Reference
Non-A.C. = 0.86 A.C. = 0.69	Summer	Uniontown, PA	Suh et al., 1992
0.74	Summer	Virginia & Connecticut	Leaderer et al., 1999
0.74	Spring-Summer & Fall-Winter	Boston, MA	Long et al., 2001
0.70	Fall	Riverside, CA	Ozkaynak et al., 1996 (PTEAM)
0.66	Summer & Winter	Birmingham, AL	Lachenmeyer and Hidy, 2000
0.65	Annual	Seattle, WA	Allen et al., 2003
0.62	Annual	Victoria, BC	Hystad et al., 2009
0.59	Annual	RTP, NC	Wallace and Williams, 2005
0.50	Winter	Boise, ID	Lewis, 1991
0.48	Annual	Los Angeles, CA	Sarnat S. et al., 2006
0.30	Winter	Smithers, BC	Allen et al., in preparation
0.61 0.27	Summer Winter	Prince George, BC	Barn et al., 2008

Courtesy of Ryan Allen, 2009

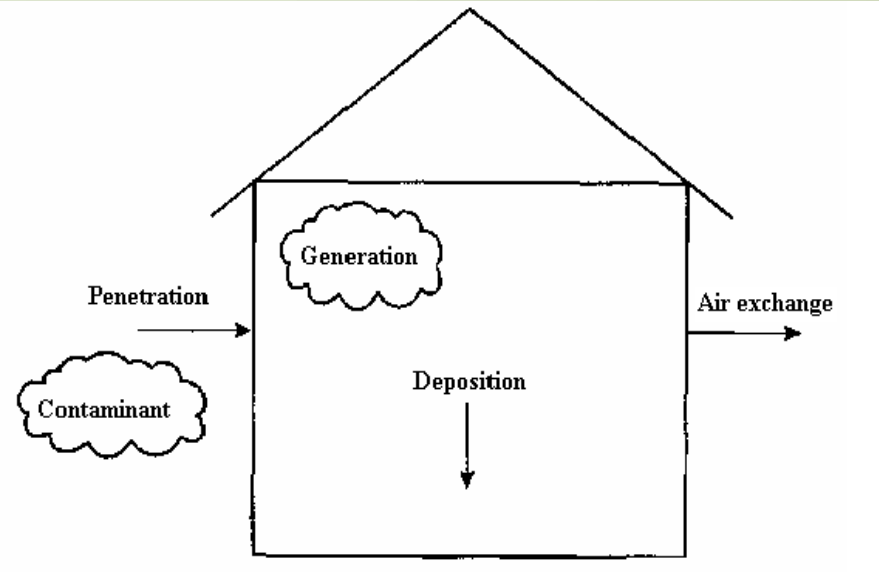
Improving indoor air quality

1. Reduce indoor-generated pollution
2. Modify air exchange rate (AER)
3. Filter indoor air

Air Cleaners




Air cleaner use as a public health intervention



Air cleaners can increase deposition of particles leading to a reduction in exposure

Air cleaner set up

- In-duct:
  - part of HVAC system
  - designed to clean air from whole house

Photo credit: BanksPhotos; licensed by iStockphoto

- Portable:
  - clean air from a single room

Operating technologies

Design	Pollutants targeted	How they work
Mechanical filters	Particles	Particles move across filter and are removed based on particle size. Filters can be flat, pleated or high efficiency particulate air (HEPA).
Electrostatic precipitators	Particles	Charge an incoming stream of particles and collect them within the device on an oppositely charged plate.
Ion generators	Particles	Charge particles in the air to increase their deposition onto room surfaces.
Activated carbon filters	Gases	Gases move across the filter and adsorb onto the filter.
Ozone generators	Gases	Release ozone into the air to react with indoor pollutants. Use is associated with health concerns in residential settings.

Adapted from Barn, 2010[5]

Air cleaner effectiveness

- Exposure reduction
  - gases
  - particles
- Health impacts
  - particles

Exposure reduction - gases

- Very limited data from chamber studies
- Effectiveness depends on: filter density, flow rate of air through the filter, filter material[5]
- Activated carbon filters effective at removing some gases
  - Denser gases removed more effectively versus “lighter” gases

Exposure reduction – particles

- Handful of studies on electronic precipitators and ion generators[5]
- Most studies have investigated use of portable HEPA filters

HEPA filters and exposure reduction

- Particulate pollutants
  - Indoor sources: ETS, fungal spores, dust, allergens
  - Outdoor sources: Traffic, wood smoke, forest fire smoke
- In homes, studies have found substantial decreases in particle levels, with use[5]
  - 90 % decrease in baseline dog allergen concentrations in a room within 24 hours[6]
  - 80 % decrease in baseline fungal spore concentrations in a room within 24 hours[7]
  - 30-70 % reductions in baseline ETS particles in a home after a 2 month period[8]
- Effectiveness varies among studies
  - Number of devices, time period, AER, air cleaner placement

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[11]
  - Portable units may not effectively draw air from other rooms, hallways
- Electrostatic in-duct filters more effective than HEPA in-duct filters

Air cleaner effectiveness

Depends on both:

- Efficiency of device (filter) at removing pollutant
  - Some industry developed standards for particles; MERV (in duct) or CADR (portable) ratings
  - None availablefor gases
- Amount of air “cleaned” by device (filter)
  - AER, room size, time

Are air cleaners useful under certain conditions?

- AQ advisory days?
- Wood heating season?
- Forest fire season?

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Air cleaner use and outdoor PM

Study	Exposure	Air cleaner	Study Period	Findings
Brauner et al. 2008[12]	Traffic	Portable HEPA	+ filter: 48 hr - filter: 48 hr	Lower $PM_{2.5}$ levels during + filter period (GM: 4.7 ± 0.8 µg/m^3) vs. - filter period (GM: 12.6 ± 1.4 µg/m^3) across homes (n= 21)
Allen et al. 2011[11]	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[12]	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[13]	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/m^3 in treatment homes vs. 5.2 – 21.8 µg/m^3 in control homes

Health benefits




Health - respiratory effects

- Results are mixed
- Some reduction of **asthma and allergy-related symptoms** with HEPA filter use[5]
- Greater benefits when used with other interventions, including removal of sources, removal of carpets, use of impermeable bed coverings, and reduced AER[14]

Health - cardiovascular effects

Study	Exposure	Study Period	Study Population	Health outcomes
Brauner et al. 2008[10]	Traffic	+ HEPA filter: 48 hr - HEPA filter: 48 hr	21 non – smoking elderly couples (60-75 yrs)	**Blood vessel health**: 8.1% (95% confidence interval, 0.4–16.3%) improvement in microvascular function
Allen et al. 2011[11]	Wood smoke	+ HEPA filter: 7d - HEPA filter: 7d	45 healthy adults	**Blood vessel health**: 9.4 % (95% CI, 0.9-18%) increase in reactive hyperemiaindex **Inflammation**: decrease in C-reactive protein by 32.6 % (95 % CI, 4.4-60.9%)

Key Points

- Indoor air a complex mixture of indoor and outdoor sources
- Reducing sources and modifying AER can help to improve indoor air quality
- Use of air cleaners is useful but benefits are limited
- HEPA filter air cleaners can lower indoor particle levels and thereby reduce exposure
  - AER and room size are important determinants
  - Linked with some respiratory and cardiovascular health benefits
- Air cleaners can be particularly useful when outdoor AQ is poor

Thank You

Questions?
Comments?

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