Forest Fires:
Impacts on Air Quality and Health

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BC Centre for Disease Control
An Agency of the Provincial Health Services Authority

Outline

- Air quality
- Health
- Public health’s role
- Questions and discussion

Forest fires

- Natural phenomena but have many negative consequences:
  - physical safety
  - economic costs of damaged land and homes, evacuation, and fighting fires
  - air quality
  - health

Forest fires

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  - physical safety
  - economic costs of damaged land and homes, evacuation, and fighting fires
  - **air quality**
  - **health**

Air quality




Fires in Russia (2010)

Photo credit: BBC In Pictures

Forest fires

- Deteriorate air quality through smoke emissions
  - release pollutants
  - reduce visibility

- Fire smoke contains[1]:
  - particulate matter ($PM_{2.5}$,PM_{10})
  - nitrogen oxides (NO_X)
  - carbon monoxide
  - volatile organic compounds
  - plus others

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Pollution

- Elevated PM levels measured during fires
  - 2003 fires
  - BC[2]: 24-hr $PM_{2.5}$ peaks of 200 μg/m^3
  - California[3]: 1-hr PM_{10} peaks of 1000 μg/m^3

- For comparison, Canada Wide Standard for $PM_{2.5}$ (24-hr) is 30 μg/m^3

Smoke emissions

- Levels can be high
  - size
  - proximity
  - meteorology
  - topography

- May remain elevated for days to weeks
- Impact local, regional and global air quality

Downtown Calgary

Photo credit: Calgary Herald

Fires may continue to increase

Natural Resources Canada, 2010

Health

Exposure assessment

	Developing countries	Firefighters	Communities
Affected population	Women & children exposed to cooking smoke	Healthy individuals	All ages, health levels
Health impacts	✓	✓	✓

Respiratory effects

- Increased hospital visits for:[4,5,6,7,8]
  - asthma
  - COPD
  - upper respiratory infections
  - general respiratory problems
  - eye irritation
  - smoke inhalation

Vulnerable groups

- Greater health impacts for[3, 6, 9,10]:
  - children
  - elderly
  - individuals with pre-existing respiratory or cardiovascular disease

Cardiovascular effects

- Exposure to $PM_{2.5}$ has been linked with cardiovascular effects, including increased:
  - cardiovascular mortality
  - risk of development of cardiovascular disease
  - risk of myocardial infarction

But no studies have found evidence for increased cardiovascular-related hospital visits during forest fires

Gaps

- Nature of forest fires make them difficult to study

- Studies have only looked at short – term exposure impacts on health

Role of public health




Public health

- Inform the public
  - deteriorated air quality
  - potential health impacts
  - exposure reduction measures

- Determine need for evacuation
  - due to fire
  - due to smoke exposure

Recommendations

- Stay indoors
- Keep windows and doors closed
- Run air cleaner
- Run air conditioner
- Limit indoor sources
- Keep cool

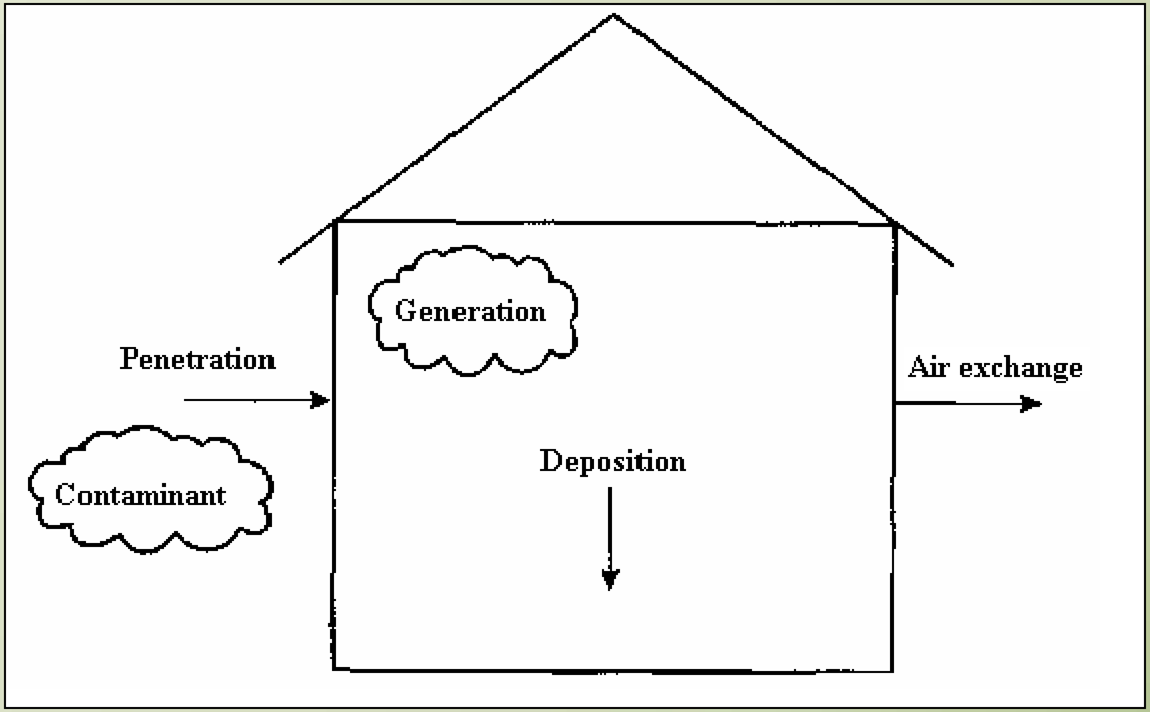
What’s the evidence?

Staying indoors

- Are levels lower indoors versus outdoors?
- Is closing windows and doors enough?

Infiltration

Fraction of outdoor pollutants that penetrate indoors and remain suspended



Modified from Thatcher and Layton (1995)[11]

Infiltration (cont.)

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

F_{inf} = infiltration efficiency

P = penetration

a = air exchange

k = deposition

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

Reducing infiltration

- Staying indoors is protective but varies between buildings

- Lower F_{inf} values associated with:
  - Winter season
  - Closing windows
  - Newer homes
  - Air conditioning
  - Air cleaner use

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Lower air exchange rates (AER)

Air exchange rates

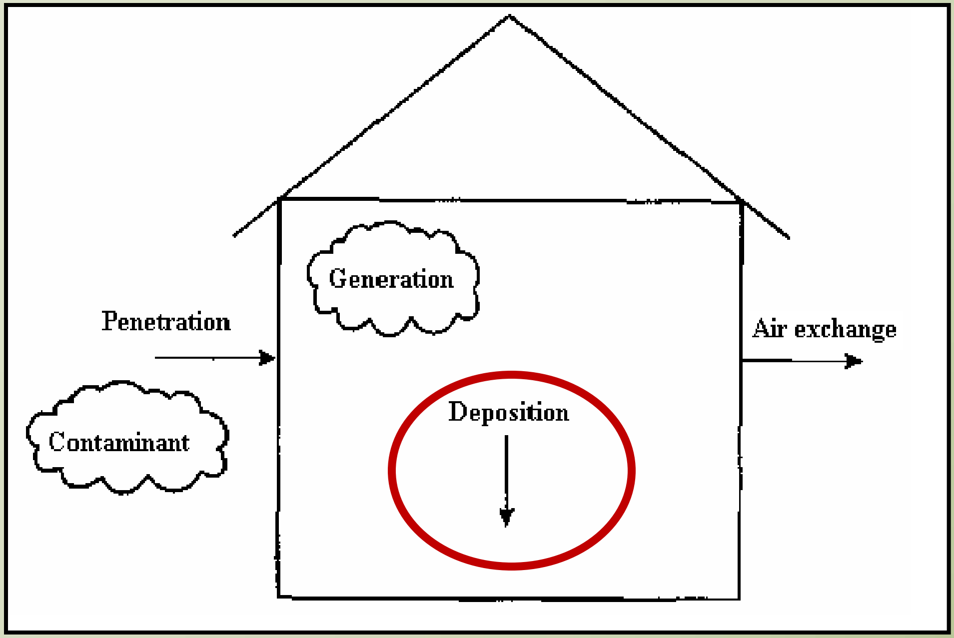
- Lower AER means less of what is outside is getting indoors
- Important to ensure that levels of indoor pollutants aren’t building up
- Reduce indoor sources

Do air cleaners provide protection?

- Exposure reduction?
- Health benefits?

Air cleaners

Theoretically, cleaners reduce F_{inf} by increasing deposition



Air cleaners cont.

- Many types and models
- Indoor air is mixture of pollutants
  - indoor and outdoor sources
  - types and concentrations
- No air cleaner can remove all pollutants

Air cleaning technologies

Design	Pollutants targeted
Mechanical filters (e.g. HEPA)	Particles
Electronic precipitators	Particles
Ion generators	Particles
Activated carbon filters	Gases
Ozone generators	Gases

Air cleaner use and outdoor-generated PM

Study	Exposure	Air cleaner	Study Period	Findings
Brauner et al. 2008[15]	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[16]	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[17]	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[18]	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

Air cleaner effectiveness

- Effectiveness varies among studies
  - study design: number of devices, time period, AER, air cleaner placement
- Depends on both:
  - efficiency of device at removing the pollutant
  - amount of air “cleaned” by device

Health benefits

- Only 1 study has looked at health benefits of air cleaners during forest fires
- Use of portable HEPA filters was associated with decreased odds of reporting respiratory symptoms (both **frequency** and **duration**)[10]
  - fire near Hoopa Valley, California (1999)
  - other interventions not as effective
  - lack of exposure measurements

Interventions

Intervention	Effectiveness
HEPA filter air cleaners (n= 98)	Length of use inversely related to symptom reporting
Public Service Announcements (n=238)	Those able to recall PSAs less likely to report symptoms
Mask use (n=100)	Not effective; use positively correlated with outdoor exposure
Evacuation (n=140)	Not effective

Health benefits in general

- Results are mixed
- Use of cleaners has been associated with:
  - reductions in some **asthma and allergy-related symptoms**[19]
- Greater benefits when used with other interventions, including[20]:
  - removal of sources, removal of carpets, use of impermeable bed coverings, and reduced AER

Air conditioners

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Air conditioners (ACs)

- Use has not been evaluated during forest fires
- ACs reduce AER
  - Some models may also have filters
- Linked to some health benefits but not well established
  - reduced risk of cardiovascular-related hospitalizations found in communities where AC use is prevalent[21]
  - not clear if effect due to other factors (regional , socioeconomic)[22]

Recommendations

- Staying indoors and using air cleaners is protective but effectiveness varies
- Less evidence for air conditioner use for exposure reduction, but important in keeping cool

Other community impacts

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Smoke intrusion to hospitals

- Local example where rural hospital was experiencing infiltration of fire smoke
  - led to patient complaints
  - visible smoke (no measurements)

- Hospital responded by turning off HVAC system
  - Led to increase in CO_2

→ Best approach for hospital to take?

Important questions

- How long will conditions persist?
- What is the exposure?
- What are the health impacts? For whom?
- What can be done?

Short-term responses

Options	Considerations
Keep HVAC **on**	Hope conditions (weather, wind) change. How long is an appropriate time to wait?
Turn HVAC **off**	For how long? What about indoor-generated pollutants? What about air flow in different departments?
Turn HVAC **off** and use **air cleaners**	In all rooms or in rooms of vulnerable patients? Which type of air cleaners and how many? Purchase, maintenance, storage costs?
Evacuate	What is “trigger” for evacuation? Everyone or only vulnerable patients? To where (i.e. are beds available elsewhere)? Costs?

Long-term response

- Work with ventilation experts to design system
  - High efficiency filtering in “emergency” situations
  - Lower efficiency filtering in “normal” situations
  - Maintain necessary air flow in all departments: labs, patient rooms, surgery rooms, food prep areas

Key Points

- Forest fire are important sources of many pollutants, including PM

- Exposure to smoke is linked to respiratory health impacts; gaps exist for long-term health impacts

- Public health can inform the public about poor AQ, health impacts, and exposure reduction measures

- Current recommendations to stay indoors, and use air cleaners or air conditioners can reduce exposure to pollution and heat indoors

Thank You

Questions?
Comments?

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