Environmental Health & Respiratory Disease: Indoor Air Quality

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Disclosure

- Rosalyn Singleton, AJ Salkoski, and Tom Kovesi have no relevant financial relationships with the manufacturer(s) of commercial services discussed in this CME activity.

- The authors do not intend to discuss any unapproved/investigational uses of any commercial products in this presentation.
Global estimates of severe RSV:
Rate of Severe or Hospitalized RSV/1000 infants/yr

Banerji. PIDJ Cost of hospitalization for RSV in Canadian Inuit Pediatr Infect Dis 2009;28:.
Pneumonia and influenza-associated child death rate by race and age group, 1999-2009

Bronchiolitis Hospitalizations/1000/yr
Alaska Native infants by region, 2009-2011

Northern and Western AK: 141
Manilaq: 97
B: 74
A: 72
C: 50
ANCH: 28
D: 25
US: 26

Unpublished data, Singleton RJ, AIP-CDC, from IHS NIPRS data
LRTI in Indigenous Canadian Children

- Newfoundland & Labrador
  - Hospitalization was 11.6 vs 3/1000 in the Innu/Inuit communities
  - Infants 93.4/1000
    *Alaghehbanda (2007); Int J Infect Dis 11:23-8*

- Northern Ontario (Sioux Lookout Zone)
  - LRTI 3x more frequent than in the rest of Ontario
  - Hospitalization 44/1000 infants (up to 111/1000 some communities)
    *McCuskee (2014); Pediatr Infect Dis J 33:1023-6*

- Nunavik (Northern Quebec)
  - LRTI 10x more frequent than in the rest of Canada
  - Hospitalization 198/1000 infants, 119/1000 toddlers
    *Dallaire (2006); Canadian J Public Health 97:362-369*

- Canadian Arctic
  - LRTI rates varied: 39/1000 NW Territories to 456/1000 Nunavik
  - LRTI rates in Nunavik/Nunavut are some of the highest worldwide
    *Banerji A. CMAJ Open. 2016. DOI:10.9778/cmajo.20150051*
Asthma & Cough in Alaska Kids

- American Indian/Alaska Native children have asthma prevalence similar to other U.S. children.

- Alaska Native children have a high prevalence of asthma or asthma-like symptoms or chronic cough

Lewis et al – Interviewed 377 middle school children in Southwest Alaska
  - 40% reported one category of chronic respiratory disease:
    - 7.4% - physician-diagnosed asthma,
    - 11.4% - asthma-like symptoms without asthma diagnosis,
    - 21.5% chronic productive cough without asthma diagnosis,

Long Term Effects of Pneumonia

- **Chronic Suppurative Lung Disease/Bronchiectasis**
  - Airway damage leads to loss of elasticity (“ectasia”) of bronchi
  - Chronic Wet Cough ↔ CSLD ↔ Bronchiectasis
  - 1:63 Y.K. children w/ bronchiectasis vs. 1:2,000 U.S. children w/ CF

- **Decreased lung function and COPD in Adulthood**
  - Adults with childhood pneumonia have decreased lung function
Respiratory Infection: Environmental Risk Factors

- Household crowding
  - Persons/ room, # children in house
- Daycare attendance
- Smoke exposure
  - Tobacco exposure
  - Wood/coal fuels for heat, cooking
- Indoor Air Quality
  - PM2.5 (particulates)
  - Volatile Organic Compounds (VOCs)
- Lack of in-home running water
- Socioeconomic factors
  - Parental education; poverty
Indigenous Canadians: Housing

- 67% people report their houses are in need of repair
- 18% have no phone
- 3.5% have no flush toilets
- 3.7% have no hot running water
- 118 First Nations communities in Canada need to boil their water

Alaska Rural vs U.S. homes: Healthy Homes Study homes compared with general U.S. homes

<table>
<thead>
<tr>
<th>Housing</th>
<th>Study houses</th>
<th>US houses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean # occupants</td>
<td>7.3</td>
<td>2.6</td>
</tr>
<tr>
<td>Median sq. feet</td>
<td>920</td>
<td>2,465</td>
</tr>
<tr>
<td>% &gt;1 person/room</td>
<td>73%</td>
<td>3%</td>
</tr>
<tr>
<td>% with woodstove primary heat</td>
<td>16%</td>
<td>2%</td>
</tr>
<tr>
<td>% w/ smokers</td>
<td>49%</td>
<td>26%</td>
</tr>
<tr>
<td>% no running water</td>
<td>60%</td>
<td>0.5%</td>
</tr>
</tbody>
</table>

U.S. data from 2008-2012 Census, American Community Survey
Household Crowding in the U.S. 2000 Census Data

Alaska Native Villages

American Indian Reservations

Indoor Air Pollution: Navajo and Alaska Native Children

- Any wood burning stove in the home increased odds of childhood lower respiratory tract infection (LRTI) by 4.9 times in Navajo children.

- Household particulate matter concentration >65 μg/m³ resulted in an increase of odds of LRTI by 7 times in Navajo children.

- Risk Factors for LRTI hospitalizations in rural Alaska included household crowding and woodstove use.

What Works?
Evidence-based Interventions

- **Wood-stoves:** HEPA filters, changeout wood stove, best burn practice
- **Ventilation:** install or fix vents, install range exhausts and bathroom fans, Heat recovery ventilators, air exchange
- **Dust and Dust mite:** impermeable pillow/mattress covers, wash bedding, remove carpet, cleaning/vacuuming
- **Pets:** remove pets, keep pets out of bedroom
- **Mold:** address moisture, ventilation, remove carpet
- **Irritants:** HEPA filters, increase ventilation

Strong evidence for home-based multi-trigger, multi-component interventions in reducing symptoms and missed school in children with asthma

CDC Task Force Findings Interventions for Children and Adolescents with Asthma
http://www.thecommunityguide.org/asthma/rrchildren.html
Partnering with:
ANTHC Div. Environmental Health & Engineering
ANTHC Community Health and Environment
The Healthy Homes Study

Background
- Alaska Native children have high rates of pneumonia and bronchiolitis hospitalizations and chronic lung disease

Partners
- Alaska Native Tribal Health Consortium (lead)
- Yukon Kuskokwim Health Corporation
- Bristol Bay Area Health Corporation
- Arctic Investigations Program - CDC

Goal
- Evaluate whether simple home renovations can reduce indoor air pollutants and improve respiratory health in children with lung disease

Methods
- Identify homes of children with lung problems
- Assess homes for indoor air quality concerns
- Simple home renovations and education
- Measure indoor air quality (PM2.5, VOC, CO2, humidity), respiratory visits and symptoms before and after interventions
New and/or Improved Vents

Ventilation intake plugged with a rag

New ventilation intake
Woodstove Replacement

Old woodstove

New EPA-certified, low-emission woodstove
Cooking Stove Exhaust

Cooking stove with no range exhaust

New range exhaust
### Indoor Air Measures: Study Homes at Baseline

<table>
<thead>
<tr>
<th>Measure</th>
<th>Cut-off</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM 2.5 (ug/m³)</td>
<td>51% over the cutoff</td>
</tr>
<tr>
<td>CO₂ (ppm)</td>
<td>70% over the cutoff</td>
</tr>
<tr>
<td>Ave. Rel Humidity (%)</td>
<td>&lt;30 over half of time (30%)</td>
</tr>
<tr>
<td></td>
<td>&gt;60 over 1% of time (18%)</td>
</tr>
<tr>
<td>Temperature (°F)</td>
<td>Average 74, Max 84</td>
</tr>
<tr>
<td>Volatile Organic Compounds</td>
<td></td>
</tr>
<tr>
<td>Benzene</td>
<td></td>
</tr>
<tr>
<td>m,p Xylene</td>
<td>23% over the cutoff*</td>
</tr>
<tr>
<td></td>
<td>8% over the cutoff</td>
</tr>
</tbody>
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* ATSDR MRL Agency for Toxic Substances and Disease Registry minimum risk levels
Healthy Homes Study: Baseline findings

• **Indoor Air Quality**
  - High Volatile Organic Compounds (VOCs) and Particulates (PM2.5)

• **Respiratory symptoms in study household children**
  - high rates of cough between colds, hospitalization for lung infections, history of pneumonia, and wheezing.

• **Household factors and child symptoms**
  - VOCs
  - Primary wood heat  Related to  • Cough between colds
  - PM2.5  Related to  • Wheeze between colds
  - VOCs  Related to  • Asthma diagnosis
Summary: Alaska

- Houses in rural Alaska are much smaller and crowded that average U.S. houses.
- Some indoor pollutants like PM2.5 and VOCs occur at high levels in homes.
- Indoor air pollutants contribute to respiratory symptoms in children with lung problems and their siblings.
- We are analyzing the results of the Healthy Homes interventions on pollutants and child respiratory health.
Next Step: Environmental Health Hospital Consultation Study

Year: 2016-2019
Organizations: ANTHC, SCF, YKHC, other THOs
Objectives: Pilot project to determine the feasibility of a hospital-based environmental consultation program at ANMC.
Methods: Environmental Health staff provide consult to caregivers, equip them with techniques/tools to improve indoor air quality, make referrals to village housing if needed.
Evaluate: Home modification completion, changes in household behaviors, child resp. visits and hospitalizations.
Other Interventions to Reduce PM2.5

- **University of Montana**
  - Initial community-wide wood stove changeout program resulted in reduced wintertime ambient PM2.5 and childhood wheeze and respiratory infections.
  - However, team observed variable and uncertain effects on PM2.5 following the introduction of new wood stoves.
  - In randomized intervention trial of asthmatic children living in wood stove homes, HEPA air filtration units were less costly and more consistent in reducing PM2.5 (~60%) than wood stove changeout (no significant change)
  - Current study is evaluating whether home-based education is as effective and less costly than HEPA filter in reducing indoor PM2.5 and lung infections.

Ward TJ. Results of a residential indoor PM2.5 sampling program before/after a woodstove... Indoor Air 2008;18(5):408-15.
Indoor Air studies and Interventions in Nunavut

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Faculty/Presenter Disclosure

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• Canada’s newest territory
• Population: 32,000
  - 84% Inuit
  - 33% aged 0 - 14 years
• 3 regions:
  - Qikiqtaaluk
    - 14 communities, all accessible only by boat (summer) or plane
  - Kitikmeot
  - Kivalliq
• Capital: Iqaluit; also has regional hospital
• Highest rates TB, bronchiectasis, bronchiolitis hospitalization, suicide in Canada
• 49% houses crowded; 26% in need of major repairs, 12% both
  - 53% use living room as a place to sleep
Indoor Air Quality (IAQ) Studies (Nunavut)

Pond Inlet

Pangnirtung

Clyde River

Iqaluit

Cape Dorset
Indoor Air Quality (IAQ) Studies (Nunavut)

- Comprehensive assessment 20 homes Inuit infants & children < 2 years of age in Cape Dorset, Nunavut (Kovesi, Indoor Air 2006)
- Houses single-story, raised above ground (due to permafrost) & small (Mean indoor volume was 233 m³)
  - Median occupancy 6 (range 2-12)/house
  - Homes heated with low-sulphur arctic diesel, no evidence leakage from furnaces; Median NO₂ concentration: 3.7 ppb, max. 14.7 ppb (< 50 ppb)
  - Settled dust, dust mite levels extremely low; settled dust Endotoxin & 1,3-b-D-glucan were modestly elevated
  - Airborne nicotine 95% houses
  - Most houses had reduced air change, elevated indoor CO₂
Multi-community study 96 Inuit homes (49 with children < 6 years of age) (Kovesi, CMAJ 2007): Ventilation

- **Mean air flow rate:** 5.6 L/s/person
  - Recommended: > 7.5 L/s/person (ASHRAE standard)

- **Mean CO2 1358 ppm**
- **CO2 < 1000 ppm** often used as indicator of adequate ventilation (Enmet Canada)
Risk of Lower Respiratory Tract Infections

Indoor CO₂

Crowding

Indoor CO₂

Crowding

Pneumonia

Pneumonia
Intervention Study: Randomized Trial of Heat Recovery Ventilators (HRV) in Nunavut

- HRVs improve ventilation while maintaining energy efficiency (bringing in fresh air, transferring heat to the fresh air, and exhausting stale air outdoors)
- Active HRV: give 25-30 L/s ventilation for 15 minutes every hour (triggered by furnace) (*Kovesi, Indoor Air 2009*)
- Placebo units circulated air inside, don’t provide fresh air from outside (ventilation)
  - Converted to active HRVs after study

- 51 HRV’s successfully installed in homes of Inuit children 5 years & less in 4 communities
Intervention Study: Findings

- HRV’s significantly reduced indoor CO₂ (33%)
  - Mean CO₂ 1385 ppb placebo units
  - Mean CO₂ 924 ppb active units
- Also significantly reduced relative humidity (25.6 vs 30.9%) & tended to reduce indoor temperature
- Children: mean age 26.8 months; Mean occupancy 5.5 persons/house; 86.3% lived with smoker(s)
- No children hospitalized in study; no differences in Health Center visits
  - Subjects significantly more likely to be admitted or visit Health Center in 1st 2 years of life (before study)
HRV Effects

- Progressive fall in risk of reported wheeze
  - After ~5 months, Odds Ratio 0.14 (p < 0.00001).
- Significant reduction in risk of reported rhinitis (not associated with cold air exposure) (p = 0.0044)
First Nations Housing

- We know very little about IAQ in First Nations Housing, and it likely varies a lot across Canada
- > ½ reported to be in need of major repairs (CMHC, 2001)

- Weichenthal (*Indoor Air* 2013):
  - 20 homes in a southern Manitoba First Nations Reserve: PM$_{10}$ 49 mcg/m$^3$; PM$_{2.5}$ 42 mcg/m$^3$; NO$_2$ 2.8 ppb, CO$_2$ 1230 ppm
  - Use of electrostatic filter (3M Filtrete) significantly reduced PM$_{2.5}$ but it remained 5X > outdoor due to smoking; no major effects on lung function, BP in adults
Next Steps

• We wish to examine IAQ in Sioux Lookout Zone, where there is wood stove use, likely high levels of mold & endotoxins, and correlate IAQ measures (including ventilation) with health center visits by children for:
  - LRTI
  - Asthma
Conclusion

- Northern Indigenous peoples face many health challenges (cardiovascular, mental health among others); respiratory illness particularly in young children & elders is under-appreciated.
- Inadequate housing has important impacts on mental well-being & respiratory health.
- Improving indoor environmental quality, by structural & behavioral modifications and by reducing overcrowding by building more housing, can be expected to improve the long-term respiratory health and well-being of indigenous children and adults.