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Indoor Air Quality

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Problem:

- Contacted by a school with teachers complaining about sickness they associated with poor indoor air quality at work.

What do we do?

Introduction

- School is required by law in the US
- Pre-school and child care aren't required, but are common
- There is a huge gap in identifying, tracking, and remediating environmental health threats in school, pre-school, and day care[1]

[1]Paulson and Barnett (2016)

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Indoor Air Quality

- Attributes of indoor air affecting a person's wellbeing
  - ❖Pollutant level
  - ❖Air temperature
  - ❖Humidity
  - ❖Air velocity
  - ❖Odors
  - ❖Etc.

Indoor Air Quality (IAQ) Concerns

- Non-industrial buildings pose a major IAQ health concern[2]
- Schools are subject to relatively unique pollutant exposure, health, and comfort concerns[2]
  - ❖mechanically ventilated
  - ❖high occupant densities[2]

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Nonresidential Pollutant Exposures

1. Elevated bioeffluent levels associated with high occupant densities and inadequate ventilation
2. Emissions from office equipment
3. Cross-contamination from contaminant-generating areas
4. Entrainment of contaminants generated outdoors
5. Reentry of building exhaust gases

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Nonresidential Pollutant Exposures

6. Contamination of air-handling units by organisms and biological by-products
7. Transmission of contagious diseases such as flu, colds, and tuberculosis
8. Exposure to re-suspended surface dusts
9. Exposure to ETS where smoking is not restricted

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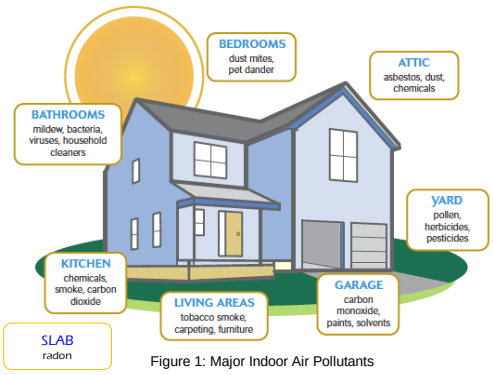

Figure 1: Major Indoor Air Pollutants

What about schools?

Asbestos

- A collective term for a number of fibrous mineral silicates
- Fire and heat-resistant, with high tensile strength
- Accounted for more than 90% of the fibrous mass used in various asbestos-containing products[2]
- Recognized as a major IAQ concern in the late 1970s[2]

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ACM Example

Figure 2: ACM Example

Asbestos

- **1973**: Regulated as a hazardous air pollutant[2]
- **1979**: Asbestos-in-Schools program[2]
- **1986**: Asbestos Hazard Emergency Response Act (AHERA)
- **Late 1980s**: Scientific and regulatory communities agreed that exposure risk to the general school population was very small

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Radon

- Radioactive gas/decay of radium-226
- Common minerals: granite, schist, limestone, etc.[2]
- As Rn decays, it releases alpha and beta particles and gamma rays
- RDPs readily attach to particles, producing radioactive aerosols

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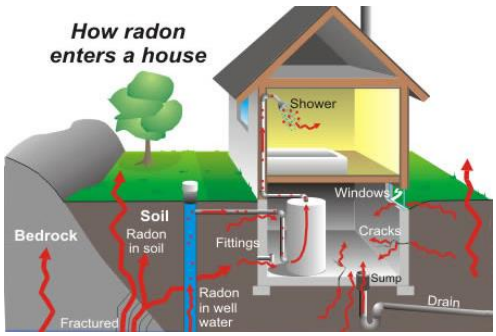

Figure 3: How radon enters a house[3]

Radon Health Risks

- Lung cancer
- 13,000 – 16,000 lung cancer deaths a year
- **1998**: U.S. EPA issued a public health advisory recommending all homes be tested and remediation be undertaken[2]
- **Action level**: 4 pCi/L

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Carbon Monoxide (CO)

- Colorless, odorless, tasteless gas[2]
- Anthropogenic and natural sources
  - ❖Burning of carbon-based materials
  - ❖Combustion, industry, biomass burning
- Direct anthropogenic emissions account for approximately 25% to 30% of CO emissions in the northern hemisphere[2]

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CO Health Effects

- Long-term exposure can lead to increased risk of heart disease[4]

Percent CO in Blood	Typical Symptoms
<10	None
10-20	Slight headache
21-30	Headache, slight increase in respirations, drowsiness
31-40	Headache, impaired judgment, shortness of breath, increasing drowsiness, blurring of vision
41-50	Pounding headache, confusion, marked shortness of breath, marked drowsiness, increasing blurred vision
>51	Unconsciousness, eventual death if victim is not removed from source of CO

Figure 4: CO health symptoms

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Carbon Dioxide (CO_2)

- Relatively abundant
- Aerobic biological processes, combustion, and weathering of carbonates in rock and soil[2]
- Anthropogenic sources
  - ❖Fossil fuel combustion
  - ❖Land use conversion
- Airborne concentrations >10% may cause convulsions, coma, and death[2]

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Table 1. CO2 PPM and Health Problems

PPM	Health Problems
1000-2000	Drowsiness and poor air
2000-5000	Headaches, sleepiness, and stagnant, stale, stuffy air. Poor concentration, loss of attention, increased heart rate, and nausea
5000	Oxygen deprivation could occur

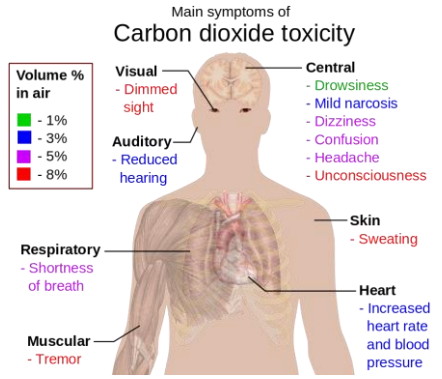

Figure 5: Symptoms of CO2 Toxicity

Aldehydes

- Organic substances that belong to a class of compounds called carbonyls[2]
- Most are sensory (mucous membrane) irritants and skin sensitizers
  - ❖Some may be human carcinogens
- Aldehydes known to cause serious IAQ contamination or health effects:
  - ❖HCHO (formaldehyde)
  - ❖Acrolein
  - ❖Glutaraldehyde

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Formaldehyde (HCHO)

- Widely used industrial and commercial chemical
  - Found in pressed wood materials[2]
- Potent mucous membrane irritant
- Potent dermal irritant
- Chronic exposure may cause neurological symptoms

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Volatile Organic Compounds (VOCs)

- Emitted from a variety of sources:
  - ❖Building materials and furnishings
  - ❖consumer products
  - ❖building maintenance materials
  - ❖Humans
  - ❖office equipment
  - ❖tobacco smoke
- Sensory irritation and possibly neurological symptoms[2]

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Mold (Mycotoxins)

- Large molecules produced by many fungal species
- *Aspergillus flavus* produces aflatoxins
- *S. chartarum* is widely found in building environments
  - ❖face paper of gypsum board
  - ❖ceiling tiles
  - ❖processed wood fiber materials

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EPA Guidance on School IAQ

Figure 6: Framework for Effective School Indoor Air Quality Management[5]

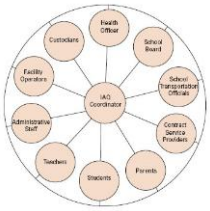

Figure 7: Forming an IAQ Team[6]

Research Findings on Contaminants in Schools

- In Portugal: CO_2, PM, and formaldehyde above reference levels in Portuguese and WHO guidelines[7]
- In Canada: 11 out of 65 schools studied had at least one radon measurement above Canadian Federal guideline[8]
- In Italy: high concentrations of terpenes[9]
- In US (Michigan)[10] and Serbia[11]: high concentrations of CO_2
- In Portugal: culturable bacteria above guidelines[12]

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Research into mold and submicron fungus

- In 8 schools in South Korea:
  - ❖Researchers looked at airborne mold and smaller fungal particles
  - ❖Study found that airborne mold/bacteria and submicron fungal fragments went down by 35% - 55% after the rainy season[13]
- Demonstrates that good IAQ is a moving target and methods to handle it must be adjusted seasonally

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Research into Effects of Poor IAQ

- Correlated with asthma and other respiratory illnesses[14]
- Associated with school-related stress and poor teacher-student relationship (N = 26946)[15]
- Good student perception of IAQ associated with decreased teacher sick leave (N=1678)[16]
- Schools with larger maintenance backlogs and smaller janitorial staff showed lower academic performance[17]

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Addressing risks from IAQ

- One study laid out five ways to address air quality:
  - Type I: Raise Awareness
  - Type II: Change Behavior
  - Type III: Change products/materials and places of activities
  - Type IV: Make technical and technological changes
  - Type V: Make structural changes[7]

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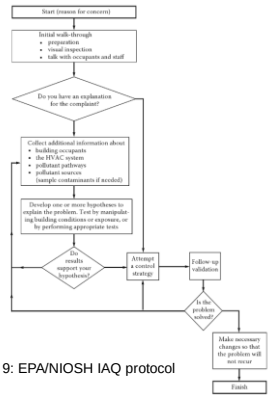

Figure 9: EPA/NIOSH IAQ protocol

- Investigating IAQ Issues

Air Quality Guidelines

Parameter	Limit/Range	Reference
Temperature	Summer 74 to 82°F (23 to 28°C) Winter 68 to 78°F (20 to 25.5°C)	ASHRAE Standard 55-2010 ISO 7730
Relative Humidity	30% to 65%	ASHRAE Standard 55-2010 ISO 7730
Air Movement	0.8 ft/s or 0.25 m/s	WHO ISO 7730
Ventilation (fresh air)	15 to 60 cfm/person minimum depending on type of space	ASHRAE Standard 62.1-2010
Ventilation (CO_2)	About 700 ppm over outdoor ambient	ASHRAE Standard 62.1-2010

Figure 10: Air Quality Guidelines

Measurement of Indoor Contaminants

- Conducted in most IAQ investigations
- Surface Dust Sampling
- Airborne concentrations of
  - ❖Gases
  - ❖Vapors
  - ❖Biological Contaminants

IAQ Management

- Exclusion
  - ❖Avoid use of contaminant emitting products (e.g. HCHO-free)
  - ❖Low-emitting products (e.g. Low levels of HCHO)
- Source Removal
- Source Treatment
  - ❖Treated or modified to reduce contaminant emissions
    - ❖ Encapsulate furniture containing HCHO
- Ventilation
  - ❖Infiltration and exfiltration
  - ❖Natural (e.g. open doors and windows)
  - ❖Mechanical (e.g. general dilution and local exhaust ventilation)

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