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Indoor Air Quality

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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 care¹

¹Paulson and Barnett (2016)



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 concern²
- Schools are subject to relatively unique pollutant exposure, health, and comfort concerns²
 - ❖ mechanically ventilated
 - ❖ high occupant densities²



Nonresidential Pollutant Exposures

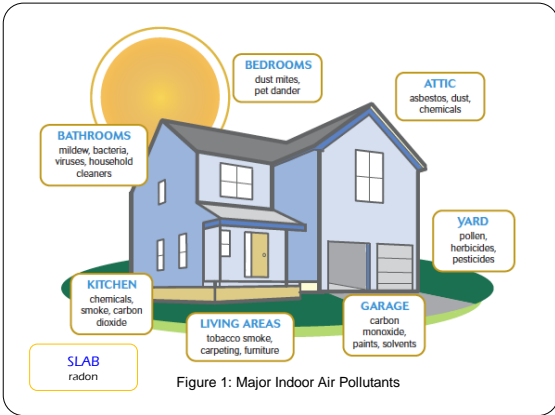
1. Elevated bioeffluent levels associated with high occupant densities and inadequate ventilation
2. Emissions from office equipment
3. Cross-contamination from contaminant-generating areas
4. Entrainment of contaminants generated outdoors
5. Reentry of building exhaust gases



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





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 products²
- Recognized as a major IAQ concern in the late **1970s²**



ACM Example



Figure 2: ACM Example

Asbestos

- **1973**: Regulated as a **hazardous air pollutant²**
- **1979**: **Asbestos-in-Schools program²**
- **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



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



How radon enters a house

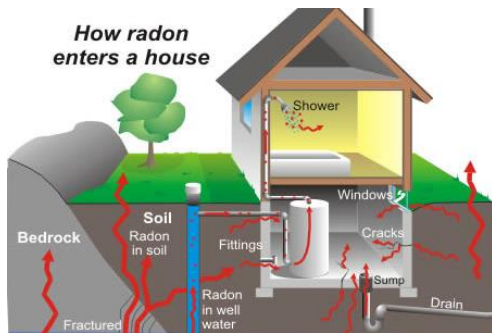


Figure 3: How radon enters a house³

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 undertaken²
- Action level: 4 pCi/L



Carbon Monoxide (CO)

- Colorless, odorless, tasteless gas²
- **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 hemisphere²**



CO Health Effects

- Long-term exposure can lead to **increased risk of heart disease⁴**

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



Carbon Dioxide (CO₂)

- Relatively abundant
- **Aerobic biological processes, combustion, and weathering of carbonates in rock and soil²**
- Anthropogenic sources
 - ❖ Fossil fuel combustion
 - ❖ Land use conversion
- **Airborne concentrations >10% may cause convulsions, coma, and death²**



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

Main symptoms of Carbon dioxide toxicity

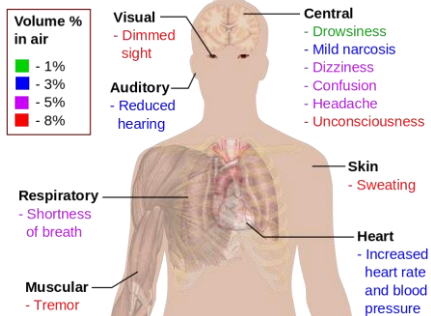


Figure 5: Symptoms of CO2 Toxicity

Aldehydes

- Organic substances that belong to a class of compounds called carbonyls²
- 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



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**



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



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



EPA Guidance on School IAQ



Figure 6: Framework for Effective School Indoor Air Quality Management⁶

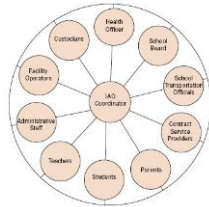


Figure 7: Forming an IAQ Team⁶

Research Findings on Contaminants in Schools

- In Portugal: **CO₂, PM, and formaldehyde** above reference levels in Portuguese and WHO guidelines⁷
- In Canada: **11 out of 65** schools studied had at least **one radon** measurement above Canadian Federal guideline⁸
- In Italy: **high concentrations of terpenes**⁹
- In US (Michigan)¹⁰ and Serbia¹¹: **high concentrations of CO₂**
- In Portugal: **culturable bacteria** above guidelines¹²



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



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



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 changes⁷



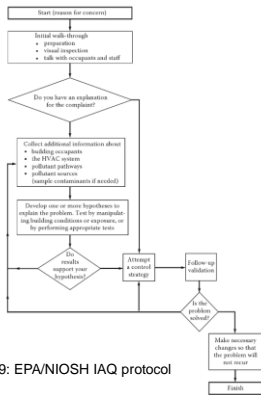


Figure 9: EPA/NIOSH IAQ protocol

- 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)	Around 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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