• Indoor Air Quality
  – 1. Introduction & Health Effects
  – 2. HVAC
  – 3. Source of IAQ Problems & Contaminants
  – 4. Evaluation & Control
Introduction

• Indoor air quality (IAQ) refers to the quality of air in:
  – offices
  – schools
  – homes
  – health care settings
  – settings other than industrial
Introduction

- EPA ranks indoor air pollution in the top 5 environmental risks to public health
- EPA studies indicate that indoor air levels of many pollutants may be 2-5 times, and occasionally, more than 100 times higher than outdoor levels
Introduction

- IAQ is an ongoing concern for urban workforce
- approximately 90% of time spent indoors
- energy conservation efforts in 70’s play a role in IAQ problems
- IAQ investigations often find no specific cause
- Distinguish Sick building syndrome from indoor related illness
Introduction

- Standards/Guidelines
  - OSHA proposed an IAQ standard in 1994 - put on the shelf
  - ASHRAE has guidelines for ventilation specs
  - EPA/NIOSH has Building Air Quality Action Plan
  - EPA has developed report “Healthy Building - Healthy People”
HEALTH EFFECTS

SICK BUILDING SYNDROME (SBS) VS BUILDING RELATED ILLNESS (BRI)
HEALTH EFFECTS

• SICK BUILDING SYNDROME
  – A PERSISTENT SET OF SYMPTOMS IN > 20%
  – CAUSE(S) NOT USUALLY RECOGNIZABLE
  – COMPLAINTS/SYMPTOMS RELIEVED AFTER EXITING BUILDING
HEALTH EFFECTS

• SICK BUILDING SYNDROME (SBS)
  – EYE, NOSE, OR THROAT IRRITATION
  – HEADACHES
  – FATIGUE
  – REDUCED MENTATION
  – IRRITABILITY
HEALTH EFFECTS

• SICK BUILDING SYNDROME (SBS)
  - DRY SKIN
  - NASAL CONGESTION
  - DIFFICULTY BREATHING
  - NOSE BLEEDS
  - NAUSEA
HEALTH EFFECTS

• BUILDING RELATED ILLNESS
  – CLINICALLY RECOGNIZED DISEASE(S)
  – EXPOSURE TO INDOOR AIR POLLUTANTS
  – RECOGNIZABLE CAUSES
HEALTH EFFECTS

• BUILDING RELATED ILLNESS (BRI)
  – PONTIAC FEVER - LEGIONELLA spp.
  – LEGIONNAIRE’S DISEASE
  – HYPERSENSITIVITY PNEUMONITIS
  – HUMIDIFIER FEVER
HEALTH EFFECTS

• BUILDING RELATED ILLNESS (BRI)
  – ASTHMA
  – ALLERGY
  – RESPIRATORY DISEASE
    • CHRONIC OBSTRUCTIVE PULMONARY DISEASE (COPD)
HEALTH EFFECTS

• IAQ can be a complex issue:
  – numerous sources
  – often there is no point source as in industrial settings
  – psychogenic components
HEALTH EFFECTS

• Psychogenic illness
  – controversial
  – symptoms resulting from psychological or psychosocial origin
  • stressors
  • suggestions from co-workers
• Mass psychogenic illness components
  – Poor work environments
  – Labor/management problems
  – Persistence of complaints following removal of “offending components”
  – Excessive work loads
  – Boring and repetitive work
  – Gender-specific complaint rates
HEALTH EFFECTS

• Multiple chemical sensitivity
  – Even more controversial!
  – Other names for the syndrome:
    • Environmental illness, ecologic illness, allergic toxemia, cerebral allergy
  – Assertions:
    • failure to adapt to low-dose exposure to man-made chemicals resulted in sensitivity to these chemicals
    • Immune system becomes “overloaded”
HEALTH EFFECTS

• Multiple chemical sensitivity
  – Vague symptoms: depression, irritability, mood swings, fatigue, drowsiness, respiratory symptoms, etc.
  – Possible triggers: organics, perfumes, building materials, paints, exhaust, smoke, etc.

• Opponents to MCS
  – No scientifically plausible mechanism
  – No diagnostic tests have been substantiated
  – MCS has not been clearly defined
    • No ICD code
Section 2

Sources & contaminants
Sources of IAQ Problems

• Outside Building
  – contaminated outdoor air
  – emissions from nearby sources
  – moisture or standing water
  – Soil gas
Sources of IAQ Problems

• Equipment
  – HVAC system
    • dust or dirt in ductwork & other components
    • microbial growth in drip pans, humidifiers, coils & water spray systems
    • refrigerant leaks
  – Non-HVAC equipment
    • office equipment
      – VOC’s (solvents, toner, cleaners)
      – ozone from copier
    • emissions from shops, labs, cleaning processes
Sources of IAQ Problems

- Building materials / indoor sources
  - chemicals released from materials
    - formaldehyde from adhesives, particle board
    - other VOCs from carpeting & adhesives
  - microbial contamination
    - Water-damaged carpeting, ceiling tile, furniture, etc.
  - dust or fibers
    - friable asbestos
    - old or deteriorated furnishings
Source of IAQ Problems

- **Human activities**
  - Housekeeping
  - Maintenance
  - Smoking
  - Too many people
- **Miscellaneous**
  - chemical spills
  - flooding
  - fire damage
  - redecorating & remodeling activities
Classes of Contaminants

- Combustion products
- VOCs
- Bioaerosols
- Particulates (non-viable)
- Radon
- Environmental tobacco smoke
• NIOSH Study found:
  – 52% - poor ventilation
  – 17% - indoor pollutants
  – Unknown – 12%
  – Outside Pollutants – 11%
  – Microbiological – 5%
  – Furnishings – 3%
Contaminants

• Combustion products
  – Types
    • carbon monoxide
    • nitrogen oxide
    • sulfur dioxide
  – Sources:
    • boilers
    • kerosene space heaters
    • generators
    • trucks & cars (re-entrainment)
Contaminants

• Carbon monoxide
  – health effects
    • asphyxiant which converts hemoglobin to carboxyhemoglobin
    • symptoms:
      – fatigue, SOB, headache, nausea, death at high levels
  • standard: TLV-TWA = 25 ppm
Contaminants

- Oxides of nitrogen
  - Respiratory irritant (lower tract)
    - Low water solubility
  - in susceptible individuals
    - decreased lung function
    - exacerbation of asthma
Contaminants

- Sulfur dioxide
  - Eye & upper respiratory tract irritant
    - higher water solubility
  - in susceptible individuals
    - decreased lung function
    - exacerbation of asthma
Contaminants

• VOCs
  – types:
    • aliphatic hydrocarbons
    • halogenated hydrocarbons
    • aromatics
    • alcohols
    • ketones & esters
  – can be a problem in new buildings or renovated areas
• Formaldehyde
  – used in numerous building materials
    • bonding/laminating agents
    • adhesives
    • paper/textiles
    • foam insulation (urea foam)
  – off-gassing of new materials can produce significant levels
Contaminants

- Formaldehyde
  - health effects
    - > 1-3ppm mucous membrane irritation, respiratory symptoms
    - chronic exposures may increase risk of cancer
Contaminants

• Bioaerosols
  • airborne particles that are living organisms or once living organisms
  • fungi
  • bacteria
  • virus
  • endotoxins (outer membrane of gram-)
  • protozoa
  • mites
  • pollen, spores, mycotoxins, etc.
Contaminants

• Basic concepts of bioaerosol exposure
  – reservoir
  – amplification
  – dissemination

• no applicable regs for bioaerosol exposures
Guidelines, etc.

- Resources/Guidelines

- Legislation
  - Toxic Mold Safety & Protection Act (6/02)
Contaminants

• Legionnaire’s disease
  • caused by *Legionella pneumophila*
  • mild to severe pneumonia exposure to water contaminated with bacterium
    – Elderly & immunosuppressed most susceptible
  • symptoms:
    – fever, cough, SOB
    – fatigue, headache
    – chest pain
Contaminants

• Hypersensitivity pneumonitis
  – allergic reaction from exposure to airborne antigens
  – Often traced to contaminated humidifiers and AC systems
  – symptoms include:
    • acute & recurrent pneumonia
    • cough, SOB, fatigue, fever
Contaminants

• Humidifier fever (self-limiting)
  – respiratory illness caused by exposure to endotoxins from microorganisms found in humidifiers and air conditioners.
  – symptoms:
    • fever, chills, muscle aches and malaise
    • chest tightness/breathlessness on exertion.
Contaminants

• Non-viable particulates
  – particulates from combustion sources
  – fibers such as asbestos
Contaminants

- Radon
  - natural breakdown product from radioactive decay of uranium-238
  - EPA estimates approximately 5-20,000 people die annually of lung cancer from radon exposure
  - found in rocks & soils with granite, shale, phosphate & pitchblend
Contaminants

• Radon
  – EPA guidelines:
    • acceptable: <4 pCi/L
    • above avg: 4 - 20 pCi/L
    • greatly above avg: 20 - 200 pCi/L
    • grave level: > 200 pCi/L
Contaminants

• Radon
  – source of entry into homes
    • soil gas
      – cracks in foundation
      – cracks in basement flooring
      – loose-fitting pipes
    • building materials - granite
    • water
Contaminants

• Reducing levels:
  – sealing points of entry
  – basement ventilation
  – sub-slab depressurization
Section 3

HVAC & Building Systems
HVAC Systems

• Purpose:
  – thermal comfort
  – mix and distribute adequate amounts of outdoor air
  – isolate & remove odors and contaminants through pressure control, filtration & exhaust fans
HVAC System

• Components:
  – furnaces & boilers
  – chillers
  – cooling towers
  – air handling units
  – exhaust fans
  – ductwork
  – filters
FIGURE B-1: Typical HVAC System Components

- Outdoor Air Intake
- Outdoor Air Temperature Sensor
- Supply Air Diffusers
- Outdoor Air Damper
- Mixing Chamber
- Fan
- Filter
- Freeze Stat
- Mixed Air Stat
- Heating Coil
- Cooling Coil and Drip Pan
- Humidifier
- Air Handling Unit
- Exhaust Air
- Damper Actuators
- Return Air Grille
HVAC System

• Thermal comfort
  – factors:
    • relative humidity
    • air movement
    • Physical activity levels
    • clothing
    • physiology
## HVAC System

### ASHRAE standard 55-1981

<table>
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<th>RH</th>
<th>Winter Temp (°F)</th>
<th>Summer Temp (°F)</th>
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<tbody>
<tr>
<td>30%</td>
<td>68.5 – 76.0</td>
<td>74.0 – 80.0</td>
</tr>
<tr>
<td>40%</td>
<td>68.5 – 75.5</td>
<td>73.5 – 79.5</td>
</tr>
<tr>
<td>50%</td>
<td>68.5 – 74.5</td>
<td>73.0 – 79.0</td>
</tr>
<tr>
<td>60%</td>
<td>68.0 – 74.0</td>
<td>72.5 – 78.0</td>
</tr>
</tbody>
</table>
HVAC System

- Ventilation to meet occupant needs
  - most air handling units distribute a blend of outdoor air with recirculated indoor air
  - conditioned air is a blend that is heated or cooled, filtered and sometimes humidified
HVAC System

• ASHRAE std. 62-1999
  – For a typical office space
    • 15-20 cubic feet per minute (cfm) of outside air per occupant
      – 15 CFM for reception areas
      – 20 CFM for office space & conference rooms
      – 60 CFM for smoking rooms
HVAC Systems

• Control of odors & contaminants
  – in office buildings - dilution
  – ventilation efficiency
    • the ability of the ventilation system to distribute
      supply air and remove odors and pollutants
  – local exhaust ventilation
    • isolate and remove contaminant at the source
      – fume hoods
      – kitchen range hood exhaust
HVAC

• Control of odors & contaminants
  – isolation - controlling pressure relationships between rooms
    • positive pressure
      – more air is supplied than is exhausted
    • negative pressure
      – less air supplied than is exhausted
  – used in “mixed use” buildings
Section 4

Evaluation and control
IAQ Evaluation

- Initial walkthrough
- Workplace inspection
- Worker Interview
- Estimating Outdoor Air Quantities
  - Thermal balance
  - Carbon dioxide balance
- Measuring airborne contaminants
  - indirect
  - direct
Initial Walkthrough/Inspection

- contact building manager
- identify types, affected workers & areas of complaints
- Identify HVAC zones, maintenance schedules
- Identify recent renovations/design changes
- identify potential sources of contaminants
Inspection

• Check the following elements:
  – Temperature
  – Humidity levels
  – Odors
  – Carbon dioxide levels
  – HVAC initial inspection
  – other
Worker Interview

- Worker interview(s)
  - description & temporality of symptoms
  - description & temporality of any odors
  - work activities & materials
  - possible causes?
  - Any other employees with symptoms?
Further Evaluation

• Collect additional info:
  – Worker surveys
  – HVAC system(s)
  – Pollutant pathways & sources
Evaluation

• Worker survey
  – description of symptoms
  – temporality of symptoms
  – work activities & materials
  – description & temporality of any odors
Evaluation

• Thermal mass balance

\[
\% \ OA = \frac{T_{\text{return air}} - T_{\text{mixed air}}}{T_{\text{return air}} - T_{\text{outdoor air}}} \times 100
\]

\( T \) = temperature in °F

return air - in return air system before the mixing chamber
mixed air - upstream of heating/cooling unit - before the fan
outdoor air - local outdoor temperature near air handling intake
Evaluation

- Carbon dioxide measurements

\[
\% \ OA = \frac{C_{\text{supply air}} - C_{\text{return air}}}{C_{\text{outdoor air}} - C_{\text{return air}}} \times 100
\]

\(C = \text{carbon dioxide in ppm}\)

- supply air - in room or in air handler
- return air - in return air system before the mixing chamber
- outdoor air - outdoor air
Evaluation

• Converting %OA to CFM/person

\[
\text{OA (cfm)/person} = \frac{\text{Outdoor air (\%) x total airflow (cfm)}}{\# \text{ of building occupants}}
\]
Example

Thermal Mass Balance Approach:

- $T_{OA} = 53^\circ F$
- $T_{MA} = 65^\circ F$
- $T_{RA} = 77^\circ F$
- 250 occupants in building
- HVAC CFM = 10,000
Example

Answer:

\[ %OA = \frac{77 - 65}{77 - 53} \times 100\% = 50\% \]

\[ CFM \ OA/\text{person} = \frac{10,000 \times 0.5}{250} = 20 \]
Evaluation

• Indirect methods for contaminants
  – carbon dioxide levels
    • CO₂ is an indicator of adequate/inadequate ventilation
    • levels exceeding 800 ppm are often associated with occupant complaints
    • can be measured with:
      – colorimetric detector tubes
      – electrochemical detectors
      – IR
Evaluation

• Total hydrocarbons:
  – levels exceeding 5 mg/m³ tend to be associated with IAQ complaints

• Levels of bioaerosols
  – sample, identify & quantify biological agents
  – No widespread standards exist
Evaluation

- Perform air sampling only if you know what you are looking for
  - direct-reading instruments
  - air sampling & collection
Control

- HVAC maintenance & operation
- maintenance of equipment and building materials
- remove materials that become damp
- remove or remediate contaminant source
- follow-up on worker complaints
Sources of information

Building Managers Guide to IAQ
http://www.epa.gov/iaq/largebldgs/baq_page.htm

IAQ Building Education and Assessment Model (I-BEAM) Computer Software
http://www.epa.gov/iaq/largebldgs/ibeam_page.htm

EPA Indoor Air Quality: Tools for Schools.
http://www.epa.gov/iaq/schools/index.html

IAQ Clearinghouse
http://www.epa.gov/iaq/iaqinfo.html
References


Available at: http://www.cdc.gov/niosh/pdfs/iaq.pdf