• Indoor Air Quality
  – Introduction
  – HVAC
  – Source of IAQ Problems
  – Contaminants & Health Effects
  – 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 a relatively new field
• energy conservation efforts in 70’s play a role in IAQ problems
• approximately 90% of time spent indoors
• IAQ investigations often find no specific cause

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”
Sources of information

Building Managers Guide to IAQ
  http://www.epa.gov/iaq/largeblnds/baq_page.htm
IAQ Building Education and Assessment Model (I-BEAM) Computer Software
  http://www.epa.gov/iaq/largeblnds/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

Introduction

• Terminology
  – sick-building syndrome
  – tight-building syndrome
  – building-related disease
Introduction

• Sick or Tight-building syndrome
  – a series of acute complaints for which there is no obvious cause and where medical tests reveal no particular abnormalities
  – symptoms generally subside after leaving building

• Building-related illness
  – identifiable illness traceable to building conditions
  – includes:
    • hypersensitivity pneumonitis
    • Legionnaire’s disease
    • humidifier fever
Introduction

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

Introduction

• Psychogenic illness
  – controversial
  – symptoms resulting from psychological or psychosocial origin
    • stressors
    • suggestions from co-workers
Introduction

• 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

Introduction

• 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”
## Introduction

- **Multiple chemical sensitivity**
  - Vague symptoms: depression, irritability, mood swings, fatigue, drowsiness, respiratory symptoms, etc.
  - Possible triggers: organics, perfumes, building materials, paints, exhaust, smoke, etc.
  - Most physicians who diagnose this ailment are “clinical ecologists”

- **Opponents to MCS**
  - No scientifically plausible mechanism
  - No diagnostic tests have been substantiated
  - MCS has not been clearly defined
    - No ICD-9 code
HVAC System

• 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
HVAC System

- Thermal comfort
  - factors:
    - relative humidity
    - air movement
    - activity level
    - clothing
    - physiology
HVAC System
ASHRAE standard 55-1981

<table>
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<tr>
<th>RH</th>
<th>Winter Temp (°F)</th>
<th>Summer Temp (°F)</th>
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<td>30%</td>
<td>68.5 – 76.0</td>
<td>74.0 – 80.0</td>
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<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>
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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

OVERHEADS….
Sources of IAQ Problems

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

• Equipment
  – HVAC system
    • dust or dirt in ductwork & other components
    • microbial growth in drip pans, humidifiers, coils & water spray systems
    • refrigerant leakage
Sources of IAQ Problems

• Equipment
  – Non-HVAC equipment
    • office equipment
      – VOCs
      – ozone from copier
    • supplies (solvents, toner, cleaners)
    • emissions from shops, labs, cleaning processes

Sources of IAQ Problems

• Building materials
  – chemicals released from materials
    • formaldehyde from adhesives, particle board
    • other VOCs from carpeting & adhesives
Sources of IAQ Problems

– 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
    • OLF unit
### Source of IAQ Problems

- Miscellaneous
  - chemical spills
  - flooding
  - fire damage
  - redecorating & remodeling activities

### Classes of Contaminants

- Combustion products
- VOCs
- Bioaerosols
- Particulates (non-viable)
- Radon
- Environmental tobacco smoke
IAQ Problems

- 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
Contaminants

- 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 pneumophilia*
  - 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

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

T = \frac{T_{\text{return air}} - T_{\text{mixed air}}}{T_{\text{mixed air}} - T_{\text{outdoor air}}} \times 100 \quad \text{T = temperature in °F}

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

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

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

- Converting %OA to CFM/person

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

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

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

• 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
References


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