



Outline

- Indoor Air Quality
 - Introduction
 - Health Effects
 - HVAC
 - Source of IAQ Problems
 - Contaminants
 - Evaluation & Control



Introduction

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

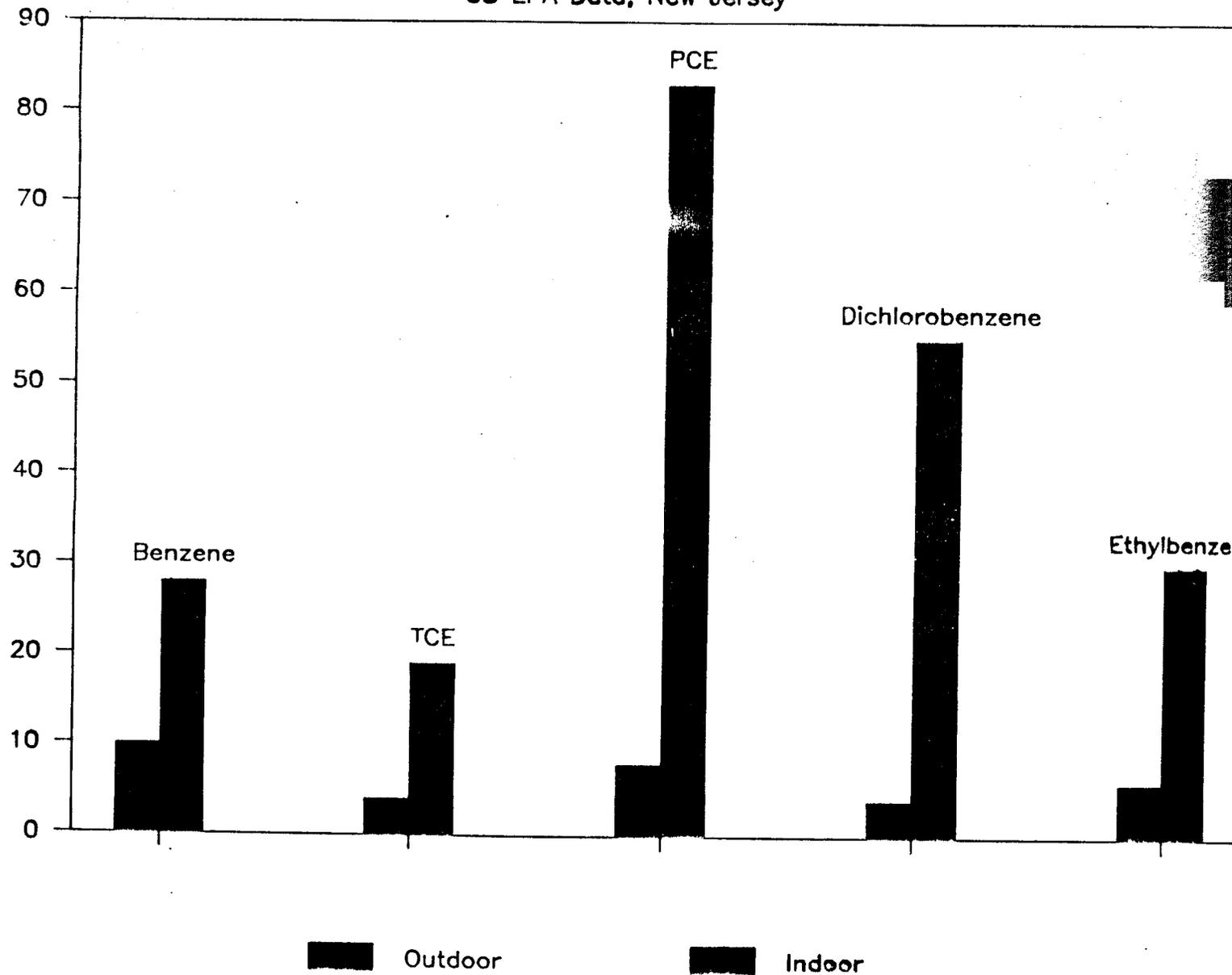


Introduction

- 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

INDOOR/OUTDOOR ORGANICS

US EPA Data, New Jersey





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



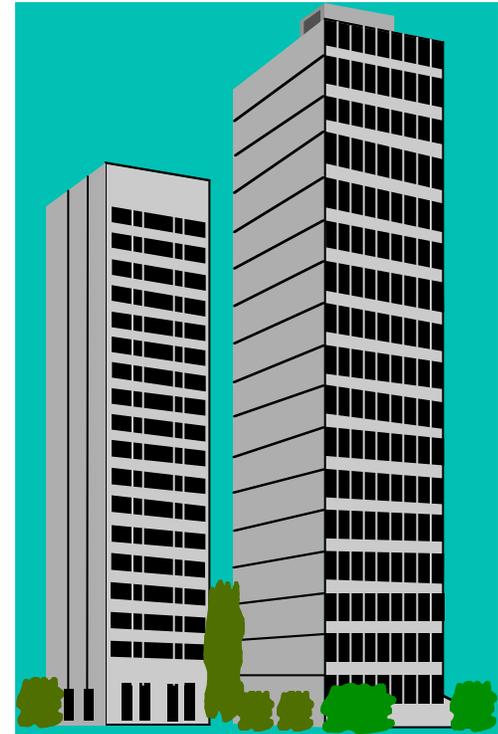
Introduction

- 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



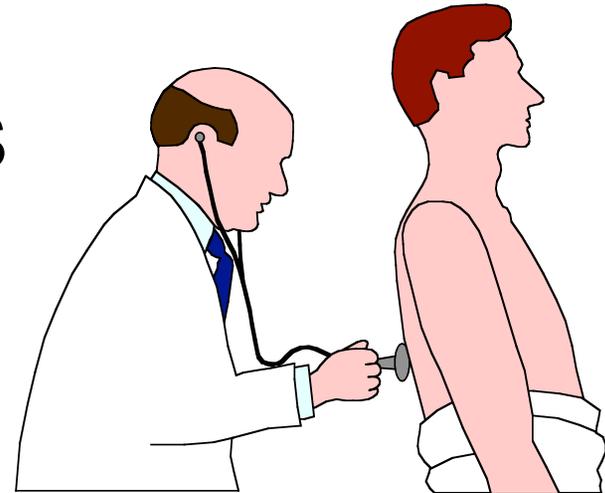
HEALTH EFFECTS

- 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



HEALTH EFFECTS

- 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-9 code



HVAC System

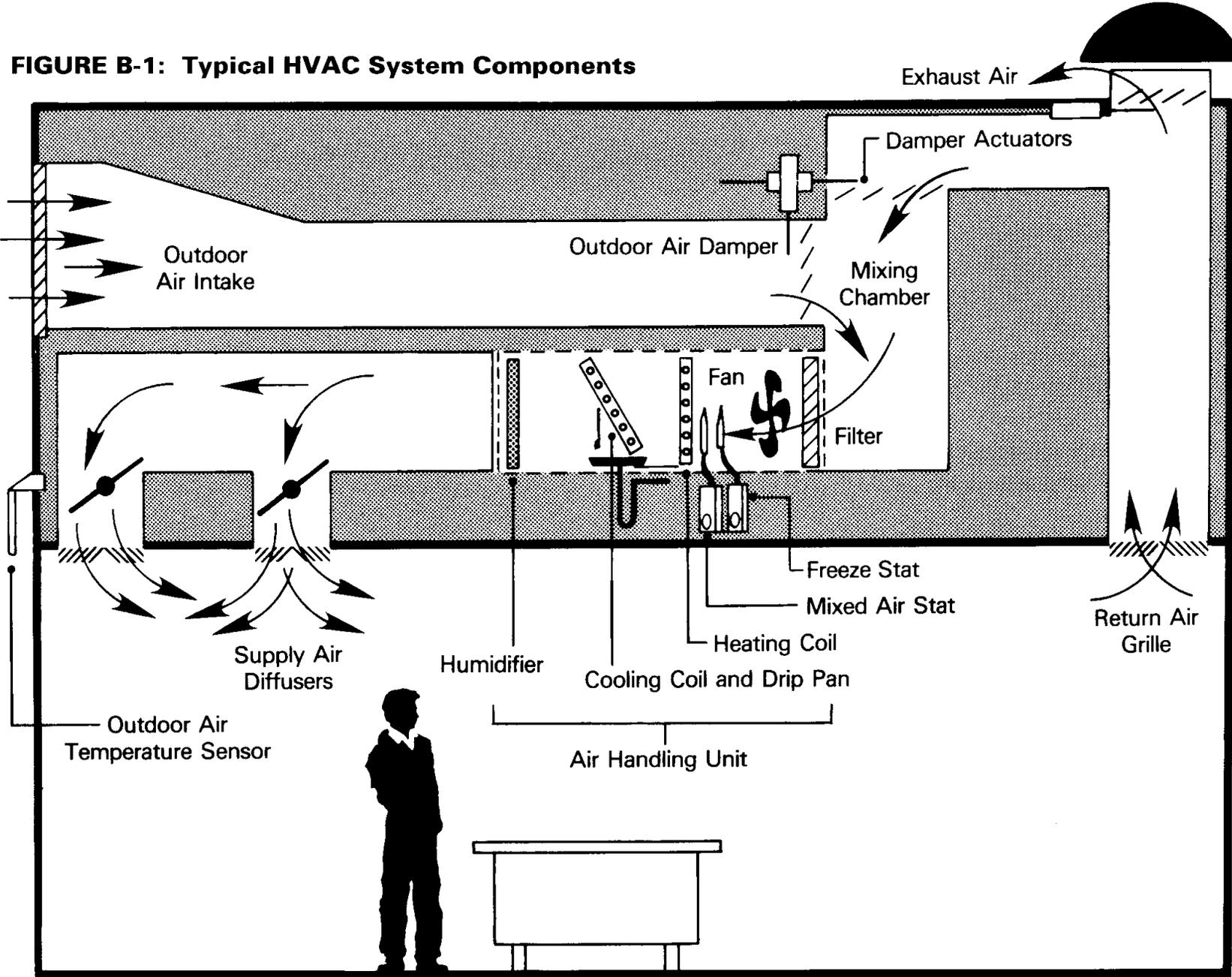
- Purpose:
 - thermal comfort
 - mix and distribute adequate amounts of outdoor air
 - isolate & remove odors and contaminants through pressure control, filtration & exhaust fans



HVAC System

- Components:
 - furnaces & boilers
 - chillers
 - cooling towers
 - air handling units
 - exhaust fans
 - ductwork
 - filters

FIGURE B-1: Typical HVAC System Components





HVAC System

- Thermal comfort
 - factors:
 - relative humidity
 - air movement
 - activity level
 - clothing
 - physiology



HVAC System

ASHRAE standard 55-1981

RH	Winter Temp (°F)	Summer Temp (°F)
30%	68.5 – 76.0	74.0 – 80.0
40%	68.5 – 75.5	73.5 – 79.5
50%	68.5 – 74.5	73.0 – 79.0
60%	68.0 – 74.0	72.5 – 78.0



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



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



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
 - <http://www.aiha.org/GovernmentAffairs-PR/html/prmoldsources.htm>
- Legislation
 - Toxic Mold Safety & Protection Act (6/02)
 - <http://www.house.gov/conyers/mold.htm>



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



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

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

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

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

C = 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

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



Example

Thermal Mass Balance Approach:

- $T_{OA} = 53^{\circ}\text{F}$
- $T_{MA} = 65^{\circ}\text{F}$
- $T_{RA} = 77^{\circ}\text{F}$
- 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



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

EPA (1994). *Indoor Air Pollution: A guide for Health Professionals*

EPA (1991). *Building Air Quality: A Guide for Building Owners and Facility Managers*

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