



# Outline

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



# Introduction

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



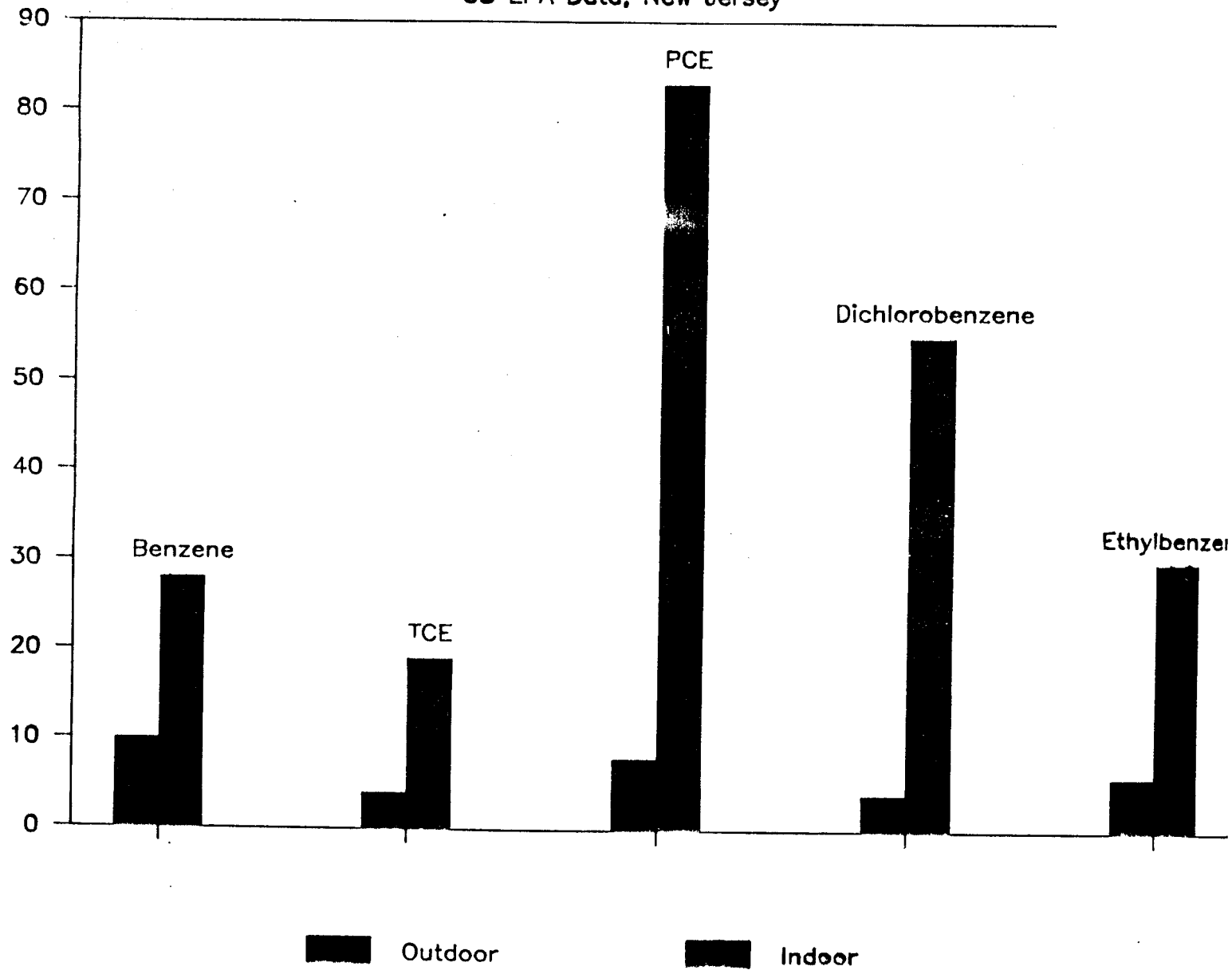
# Introduction

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- 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

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- 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

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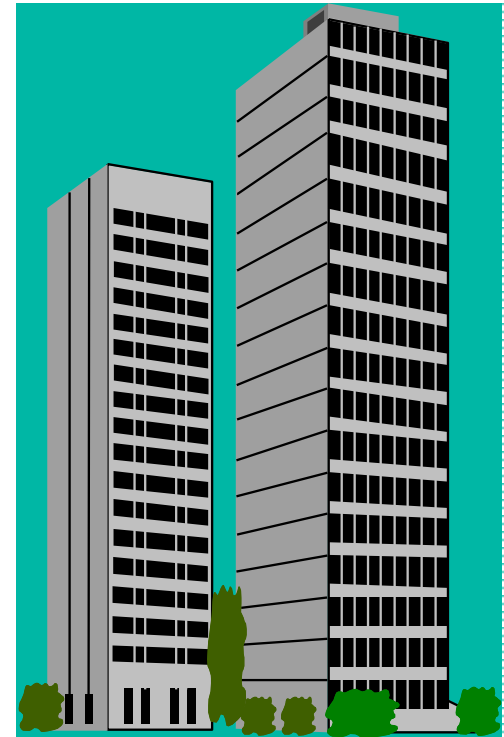
- Standards/Guidelines
  - OSHA proposed an IAQ standard in 1994 - put on the shelf
  - ASHRAE has guidelines for ventilation specs
  - EPA/NIOSH has Building Air Quality Action Plan
  - EPA has developed report “Healthy Building - Healthy People”



# HEALTH EFFECTS

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## SICK BUILDING SYNDROME (SBS) VS BUILDING RELATED ILLNESS (BRI)





## HEALTH EFFECTS

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





## HEALTH EFFECTS

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- SICK BUILDING SYNDROME (SBS)
  - EYE, NOSE, OR THROAT IRRITATION
  - HEADACHES
  - FATIGUE
  - REDUCED MENTATION
  - IRRITABILITY



# HEALTH EFFECTS

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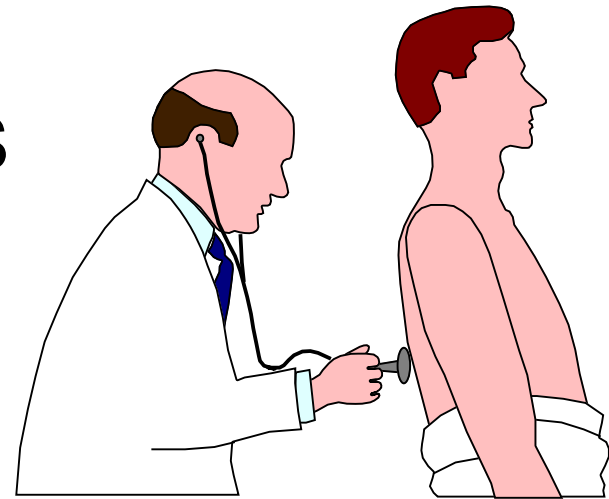
- SICK BUILDING SYNDROME (SBS)
  - DRY SKIN
  - NASAL CONGESTION
  - DIFFICULTY BREATHING
  - NOSE BLEEDS
  - NAUSEA



# HEALTH EFFECTS

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- **BUILDING RELATED ILLNESS**
  - CLINICALLY RECOGNIZED DISEASE(S)
  - EXPOSURE TO INDOOR AIR POLLUTANTS
  - RECOGNIZABLE CAUSES





## HEALTH EFFECTS

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- BUILDING RELATED ILLNESS (BRI)
  - PONTIAC FEVER - LEGIONELLA spp.
  - LEGIONNAIRE' S DISEASE
  - HYPERSENSITIVITY PNEUMONITIS
  - HUMIDIFIER FEVER



# HEALTH EFFECTS

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- BUILDING RELATED ILLNESS (BRI)
  - ASTHMA
  - ALLERGY
  - RESPIRATORY DISEASE
    - CHRONIC OBSTRUCTIVE PULMONARY DISEASE (COPD)



# HEALTH EFFECTS

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



# HEALTH EFFECTS

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



# HEALTH EFFECTS

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- 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

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- 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

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- 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



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# Section 2

Sources & contaminants



# Sources of IAQ Problems

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



# Sources of IAQ Problems

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- 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

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- 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

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



# Classes of Contaminants

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





# IAQ Problems

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- NIOSH Study found:
  - 52% - poor ventilation
  - 17% - indoor pollutants
  - Unknown – 12%
  - Outside Pollutants – 11%
  - Microbiological – 5%
  - Furnishings – 3%



# Contaminants

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



# Contaminants

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- 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

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



# Contaminants

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



# Contaminants

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- VOCs
  - types:
    - aliphatic hydrocarbons
    - halogenated hydrocarbons
    - aromatics
    - alcohols
    - ketones & esters
  - can be a problem in new buildings or renovated areas



# Contaminants

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- 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

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





# Contaminants

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- **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

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- Basic concepts of bioaerosol exposure
  - reservoir
  - amplification
  - dissemination
- no applicable regs for bioaerosol exposures



# Guidelines, etc.

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- 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

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- 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

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- 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

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- 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

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- Non-viable particulates
  - particulates from combustion sources
  - fibers such as asbestos



# Contaminants

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- 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

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- 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

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



# Contaminants

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- Reducing levels:
  - sealing points of entry
  - basement ventilation
  - sub-slab depressurization



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# Section 3

## HVAC & Building Systems



# HVAC Systems

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

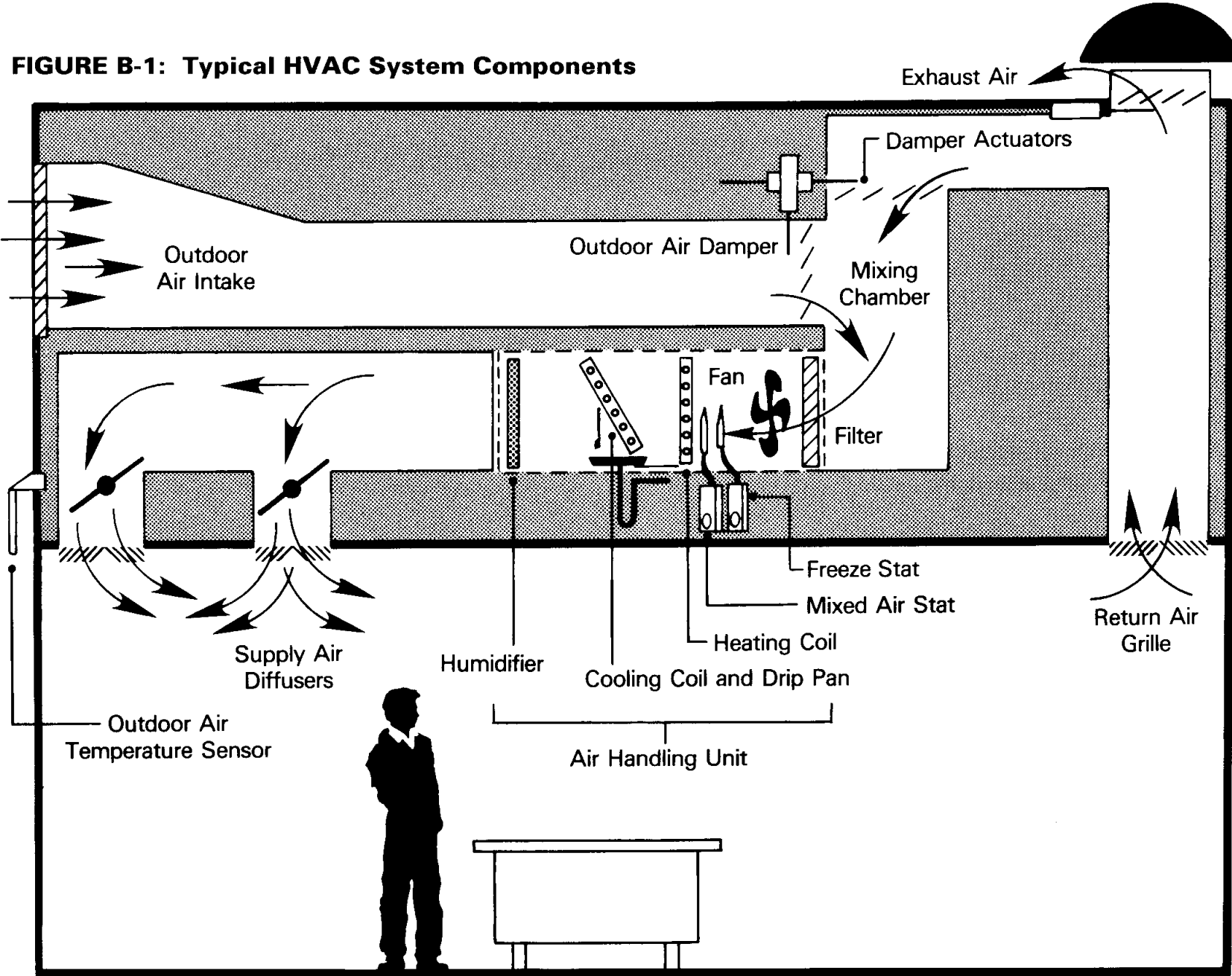


# HVAC System

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

**FIGURE B-1: Typical HVAC System Components**





# HVAC System

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





# HVAC System

ASHRAE standard 55-1981

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



# HVAC System

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- 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

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- 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

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- 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

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- 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



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# Section 4

## Evaluation and control



# IAQ Evaluation

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



# Initial Walkthrough/Inspection

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- 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

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- Check the following elements:
  - Temperature
  - Humidity levels
  - Odors
  - Carbon dioxide levels
  - HVAC initial inspection
  - other



# Worker Interview

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



# Further Evaluation

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- Collect additional info:
  - Worker surveys
  - HVAC system (s)
  - Pollutant pathways & sources



# Evaluation

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- Worker survey
  - description of symptoms
  - temporality of symptoms
  - work activities & materials
  - description & temporality of any odors



# Evaluation

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- 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

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- 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

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- Converting %OA to CFM/person

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



# Example

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## 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

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Answer:

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

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



# Evaluation

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- Indirect methods for contaminants
  - carbon dioxide levels
    - CO<sub>2</sub> 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

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- Total hydrocarbons:
  - levels exceeding 5 mg/m<sup>3</sup> tend to be associated with IAQ complaints
- Levels of bioaerosols
  - sample, identify & quantify biological agents
  - No widespread standards exist



# Evaluation

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



# Control

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- 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

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Building Managers Guide to IAQ

[http://www.epa.gov/iaq/largebldgs/baq\\_page.htm](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](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

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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>*



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