

Indoor Air Quality

Colleen Thornton, MPH, CIH
colleen@hlevn.com
(650) 996-5028

Topics of Discussion

- Background
- Health Effects
- Symptoms and Complaints
- The Building Environment
- Pollutants and Sources
- Diagnosing IAQ Problems
- Performing IAQ Sampling
- Consensus Standards
- Case Studies / Table Top Exercises



Background

Background

- Indoor air quality (IAQ) is highly impacted by individual sensitivity/comfort, pollutants/contaminants, and the proper functioning of the HVAC system.
- If the HVAC system is out of balance, an individual is uncomfortable, or pollutants/contaminants are present, then it is possible that an IAQ complaint would arise.

Background (cont.)

- Because individuals have varying sensitivities, one individual may react to a particular IAQ problem while surrounding occupants have no ill effects.
- A single indoor air pollutant or problem can trigger different reactions in different people.
- Odors often associated with perception of poor air quality

Background (cont.)

- IAQ complaints typically involve chemical, physical, biological, and/or psychological factors
 - Some factors can be present concurrently
 - Environmental stressors (lighting, noise, job stress, etc.) can produce symptoms similar to those associated with poor air quality
- You might never know precisely why the IAQ problem occurred and why it disappeared after your investigation.

Health Effects

- ### Building-related Diseases
- Hypersensitivity Diseases
 - Most cases are caused by proteins or glycoproteins
 - Infections
 - Contagious diseases, including flu, cold, and TB
 - Legionnaires' disease
 - Spread from environmental reservoirs
 - Toxicoses
 - Most caused by exposures to combustion chemicals or activities/materials used in the environment (VOCs)
 - Exposures to biological toxins in levels sufficient to cause disease is rare in nonindustrial indoor environments

- ### Building-related Diseases (cont.)
- Nonspecific Building-Related Symptoms
 - Complex of symptoms including nasal irritation, sinus congestion, eye irritation, non-productive cough, headaches, fatigue or lethargy, dry skin, dizziness, and nausea
 - Subjective
 - Typically present in some occupants of all buildings at some times.
 - Symptom commonality, clear temporal association?

Building-related Diseases (cont.)

- Psychosomatic illness
 - Created by suggestion
 - Result of on-the-job or other stress
 - Symptoms mimic those of the nonspecific building-related symptoms

Nonbiological Agents

- CO₂ – Asphyxiant; cause headaches, loss of judgment, dizziness, drowsiness, and rapid breathing
- CO – Asphyxiant; attaches to hemoglobin, decreasing O₂ to tissues; fatigue, SOB, headache, nausea, and death (at high levels)
- NO₂ – Acute pulmonary edema and death at high concentrations (200 ppm)
- SO₂ – Irritant; causes bronchoconstriction in asthmatics

Nonbiological Agents (cont.)

- Formaldehyde – Ubiquitous in modern environment; mucous membrane irritation (>1-3ppm), a human carcinogen
- Other VOCs – some are carcinogens (extrapolated from high-level exposures in industrial environments – benzene, carbon tetrachloride, chloroform)
 - Effects of low level VOC exposures over long periods are unknown
- Radon – noble gas, emits alpha particles w/ 1/2-life of 3.8 days; major risks include lung cancer, some nasal cancers, and stomach cancer (ingesting radon-containing water)

IAQ Symptoms and Complaints

- ### Symptoms and Complaints
- Headache
 - Fatigue
 - Shortness of Breath
 - Sinus Congestion
 - Coughing
 - Sneezing
 - Eye, Nose, and Throat Irritation
 - Skin Irritation
 - Dizziness
 - Nausea

- ### Symptoms Patterns and Groups?
- Headache, lethargy, dizziness, drowsiness
 - Combustion sources (CO, CO₂)
 - Congestion, swelling, irritation, and such
 - Allergy (if a few people)
 - Irrational or Viral (if many people)
 - Chemical irritant
 - Cough, SOB, fever, chills, fatigue on return to building
 - Hypersensitivity pneumonitis
 - Pneumonia, death, diagnosed disease
 - Legionnaire's Disease
 - Histoplasmosis

Patterns in Timing?

- Symptoms worse at start of the day at work
 - HVAC cycles
- Symptoms worsen over the work day
 - HVAC inadequate
 - Building contamination
 - Construction
- Symptoms relieved on leaving building
- Intermittent symptoms or patterns?

The Building Environment

The Building Environment

- The building environment varies depending on the kind of building:
 - Residential buildings
 - Nonindustrial workplaces (office buildings, schools, and other “clean” environments)
 - Industrial workplaces
 - Health care facilities
- For our discussion, we will focus on the nonindustrial workplaces.

Relative Humidity (RH)

- RH: Amount of moisture maintained in the mix of air within an environment
- Eye irritation, throat irritation, and cough are often blamed on low RH
- $RH < 30\%$ → Sensation of air being too dry and may cause drying of the mucus membranes and discomfort.
- $RH > 60\%$ → Increases the potential for indoor microbial growth.

Thermal Comfort

- “Condition of mind which expresses satisfaction with the thermal environment” (ASHRAE)
- Perception of thermal comfort associated with:
 - Metabolic heat production
 - Transfer of metabolic heat to environment
 - Resulting body temperature
- Increasing air movement causes the temperature to feel lower
- Minimal air movement can lead to complaints of stuffiness and poor air quality

Odors and IAQ

- Odors most often associated with poor air quality
- Most problematic: odors unexpected in the environment
 - Cooking odors can cause anxiety or irritation in office environment
 - Tobacco smoke causes concerns in many nonsmokers
- Odor threshold

Building Ventilation

- Most nonindustrial buildings are mechanically ventilated, air-conditioned
- Amount or distribution of outdoor (fresh) air supplied can affect IAQ
- Role of Heating, Ventilating, and Air-Conditioning (HVAC) systems
 - Provide outdoor air
 - Filter air
 - Mix air
 - Distribute outdoor & indoor air
 - Provide temperature and humidity control

Problems with HVAC Designs

- Insufficient provision for outdoor air
- Inefficient filtration
- Inadequate cooling
- Improperly designed drip pans
- Use of porous insulation near water sources
- Inadequate provision for access to HVAC components needing maintenance
- Use of materials that release inappropriate amounts of VOCs or fibers

HVAC Maintenance Problems

- Inoperable fans
- Clogged filters
- Microbial contamination on filters
- Microbial contamination in condensate pans
- Microbial contamination in ductwork

Pollutants and Sources

Sources of IAQ Concerns

- Occupants
- Building components
- Contamination of building components
- Outdoor air
- Ventilation System Problems
- Other factors

Source: Occupants

- Contagious diseases: Flu/cold viruses
- Carriage of allergens: Pet owners
- Other agents on clothing: Personal care products, tobacco smoke
- Noxious odors
 - spoiled food (esp. citrus fruits)
 - bathroom odors (esp. odor-masking fragrances)
- Carbon dioxide (CO₂) – primary sources are human respiration and tobacco smoke

Source: Building Components

- Off-gassing from building materials: Volatile Organic Compounds (VOCs)
 - Drywall from China emitting sulfur gasses
 - New paint
- Office Equipment Chemicals
 - Copiers (highly variable, manufacturer-specific)
 - Blueprint machines
- Cleaning Products (esp. odorants and carpet cleaners)
- Noxious odors from dry drain traps

Source: Contamination of Bldg. Components

- Microbial agents
 - Molds (fungi) (water damage, mold smells)
 - Bacteria (Legionella)
 - Viruses
- Other allergens
 - Insects, Dust Mites
 - Furred and Feathered Animals
- Pesticides

Outdoor Air

- chemical air pollutants, microorganisms, other allergens
- Food smells (i.e., coffee smell)
- Environmental Tobacco Smoke – Produces CO, NO_x, CO₂, HCN, formaldehyde, VOCs, etc.
- Vehicle/Diesel exhaust – combustion byproducts (CO, NO_x, SO_x)
- Pollen/flowers/nature/Spring!

Ventilation System Problems

- No fresh air supply (build-up of CO₂)
- Stagnant water
- Air too dry, too moist, or too hot
- Office layout blocks air circulation
- Fan off when not heating or cooling
- Insufficient quantity of outside air
- Mold in coils or drip pans
- Contaminant carried to space by shared ventilation system
- Louvers and dampers inoperable or improperly set

Other Factors

- Lighting
- Noise
- Ergonomics
- Psychological Factors
 - Anxiety
 - Labor Relations
 - Office Culture
 - Frustration
 - Hysteria
- Vapor Intrusion

Diagnosing IAQ Problems

Data Collection

- Phone call complaint?
 - 5W's
- Conduct initial walkthrough
 - Explanation found?
 - Yes - control the source/explanation
 - No - conduct further investigation
- Administer questionnaires
- Conduct Interviews
- Develop and test hypotheses

❖ Team effort amongst occupants, Facilities, Maintenance, and Health and Safety Department

Initial Walkthrough

- Look at physical environment (lighting, ventilation, windows, plants)
 - Any obvious sources of air contamination inside? (food, furnishings, cleaning supplies, copy machines, etc.)
 - Any obvious sources outside? (idling delivery trucks, construction/renovation, shared ventilation systems)
 - Water damage evident?

Questionnaires

- See example questionnaire

Interviews

- Have occupants fill out questionnaires
- Avoid leading questions
 - Instead of asking: do you experience headaches, drowsiness, "stuffiness", etc.?
 - Ask: Do you have any complaints or experienced any symptoms?
- Conduct individual interviews (no group interviews!)

Visual Inspection

- Most of the IAQ survey involves your eyes rather than sophisticated measuring equipment
- Inspect:
 - The occupied area of interest
 - Outdoor environment surrounding area of interest
 - Inspect the HVAC system, if possible

HVAC Inspection

- Work with Facilities/Maintenance to inspect HVAC equipment and maintenance records
- Note general state of cleanliness and repair
- Look for slime in drip pans and chiller coils, dust buildup, and lack of maintenance
- When does the fan turn on/off?
- Does fan only operate when heating/cooling is required?
- Where is the air supply intake?*

Generate Hypotheses

- Develop one or more hypotheses to explain the problem
- Test hypotheses by manipulating building conditions or exposure, or by performing appropriate tests
- Do the results support your hypothesis?
 - Yes – attempt a control strategy
 - No – collect additional info.
- After control strategy, conduct follow-up validation

Special Considerations

- Any trigger events (i.e., floors/walls were polished/painted overnight; fire in a building)
- Sensitive individuals? (immunocompromised?)

Performing IAQ Sampling

Before Sampling

- Building occupants often want sampling of air contaminants
- Need to determine purpose of sampling and what to do with results
 - risk communication
 - Exposure standards
 - ASHRAE standards
- “Shotgun” sampling may raise anxiety level of occupants
- Only sample for what you have reason to sample for!

Sources for Sampling

- Building parameters
 - CO₂/CO levels, temperature, relative humidity
- VOCs (often emitted from building products and furnishings)
 - Sampling not always useful
 - May be useful if sampling for specific emission of interest
 - Can be expensive
- Formaldehyde
 - Low levels normally present in both outside and inside air

Sources for Sampling (cont.)

- Microbial Contaminants
 - Productive when water/excessive moisture is present

Building Parameters Sampling

- Sample CO₂/CO levels, temperature, relative humidity
 - Instantaneous measurements or 24-hour measurements
- Objective: Determine “comfort” levels and whether HVAC is functioning well
- Equipment: TSI Q-Trak Indoor Air Quality Monitor



Spore Trap Air Sampling

- Collect air samples of non-viable mold spores and particulates indoors + 1 outdoor control sample
- Mold spores include penicillium/Aspergillus, Ascospores, Basidiospores, etc.
- Particles include hyphae fragments, algal spores, fern spores, pollen, skin cell fragments, fiberglass, cellulosic fibers, opaque particles, and insect parts
- Compare spore counts of indoor samples with that of outdoor samples

Spore Trap Air Sampling (cont.)

- Objective: Determine whether indoor mold spores greatly exceed that of outdoors, which may indicate indoor mold growth
- Collect samples for 10 minutes
- Sampling equipment: Zefon Air-O-Cell Spore Traps + 15 LPM pump



Surface Sampling

- Tape, swab, or bulk
- Objective: Determine and identify molds actually growing on the surface sampled, as opposed to the mere presence of mold spores
- Surface sampling for direct microscopic examinations usually requires no special equipment

Andersen Air Sampling

- Collect air samples of spores that are then cultured on petri dishes
- Objective: Capture and quantify the different culturable fungal spores present in the air.
- Equipment: Andersen sampler + agar-filled petri dishes
 - Can also use BioCassette™ and sampling pump



Vapor Intrusion Sampling

- Collect air samples of VOCs
- Typically collected over 8-hour period
- Objective: Quantify low levels of VOCs
- Equipment: Summa Canisters
- Use GC/MS analytical methods



Reporting Investigation Results

- Often involves the art of risk communication
- Before reporting to building occupants:
 - Document and correct any immediate problems found
 - Detail actions required of others
 - Make sure those with action items understand what they need to do and why
- Inform occupants of what was found, at it means, and what corrective actions will be taken
- ❖ Occupants should not be led to believe that everyone will be symptom-free all the time

Consensus Standards

ASHRAE Standards

- The American Society of Heating, Refrigerating, and Air-Conditioning Engineers
 - ASHRAE 55-2004: *Thermal Environmental Conditions for Human Occupancy*
 - ASHRAE 62-2001: *Ventilation for Acceptable Indoor Air Quality*

ASHRAE Standards*

Temperature (° F)	RH (%)	CO (ppm)	CO ₂ (ppm)
73-79 (summer)	30-60	<9	<1000
68-75 (winter)			

* ASHRAE 62-2001; ASHRAE 5-2004

Case Studies / Table Top Exercises
