Indoor Air Quality Testing during Home Inspections

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InspectionWorld 2015

PRISM
Analytical Technologies

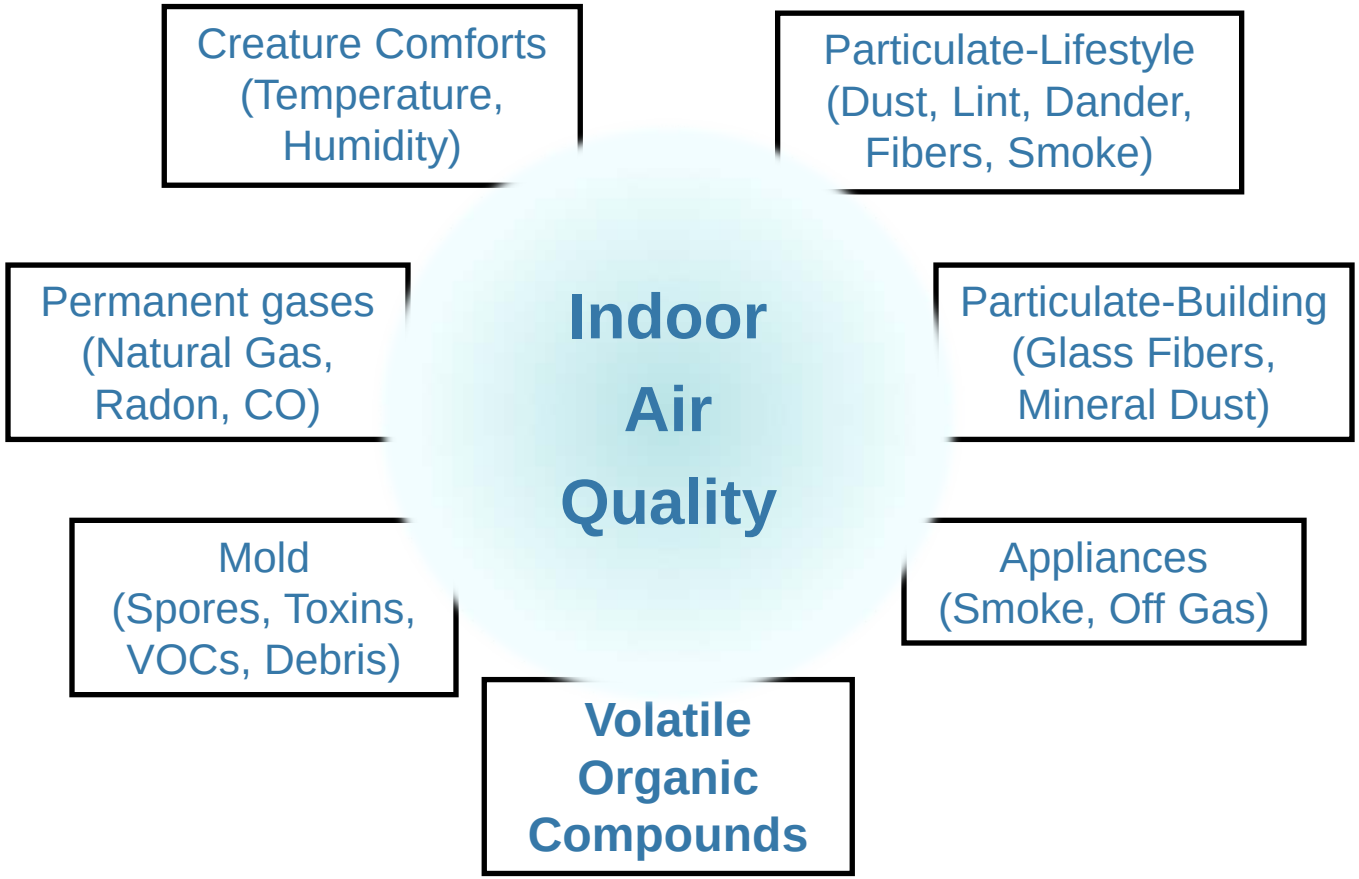
Course Goals

1. **Learn about Indoor Air Quality**
2. **Learn about technologies to monitor Indoor Air Quality**
3. **Learn how to deploy Indoor Air Quality technology**

Situations with IAQ Concerns

- **Buying new home**
- **Health**
- **Odor**
- **Mold**
- **Change in situation**
  - New baby
  - New product (e.g., furniture)
  - Renovation
  - Event (e.g., structural fire)

What is Indoor Air Quality?

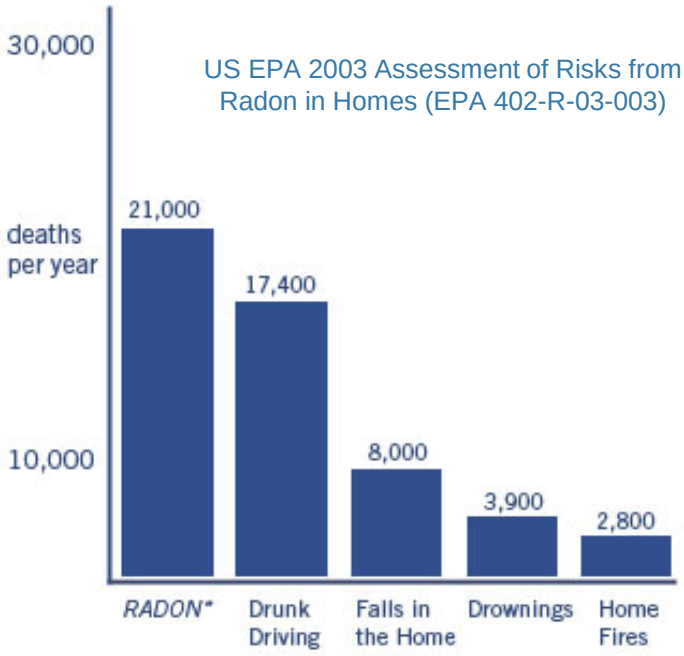


What is Indoor Air Quality?

- **Chemicals**
  - Radon – Radioactive element that is cancer causing
  - Volatile Organic Compounds (VOCs)
  - Permanent gases (methane, CO, CO_2)
- **Mold**
  - Spores, Mycotoxins, MVOCs
- **Allergens**
  - Animals or pets, pet dander, cockroach, dust mites, pollen
- **Particulate/Dust**
  - Fibers (glass, cellulose, asbestos), biological (skin cells, pollen), mineral
  - Tobacco, structural, or wild fire
- **Comfort factors**
  - Temperature, humidity

Radon – What is the Concern?

- **Radon – Leading cause of lung cancer among non-smokers**
  - Causes 21,000 deaths per year
- **Natural breakdown of uranium in soil, rock, and water**
  - ^{222}Rn has half-life of 3.82 days
- **Variable depending on topography**
- **Typical levels**
  - Average 1.3 pCi/L
  - Outdoor 0.4 pCi/L
  - Action 4.0 pCi/L



Radon Testing

- **Action Level: 4 pCi/L**
  - No known safe level
- **Charcoal canisters, alpha track, electret ion chamber, continuous monitors, charcoal liquid scintillation**
- **Passive**
  - Short term: 2-90 days
  - Long term: > 90 days
- **Active**
  - Continuous monitors

VOLATILE ORGANIC COMPOUNDS (VOCS)

VOCs – What is the Concern?

VOCs: chemicals that easily vaporize at room temperature

- **Many chemical categories**
  - Hydrocarbons, aromatics, aldehydes, ketones, esters, furans, acids, amines, amides, halogenates, sulfurous
- **Different sources**
  - Products
  - Activities
  - Conditions
- **Different effects**
  - Health
  - Odors

Most occupants are unaware of VOCs

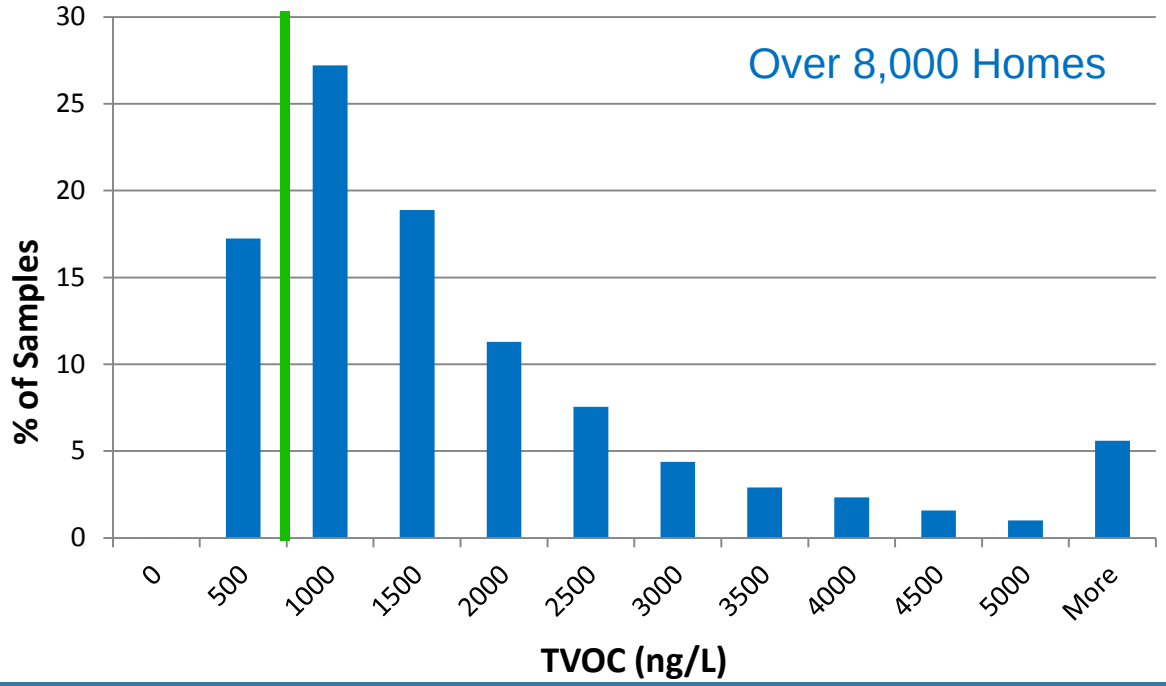
VOCs – What is the Concern?

Formaldehyde – A known cancer causing chemical

- **Present in many construction materials**
  - Engineered hardwood and bamboo laminate flooring
  - Cabinetry (urea formaldehyde resins – can off-gas significantly)
  - Plywood and OSB (phenol formaldehyde resins – tend to off-gas less)
  - Insulation (glass and foam – both urea and phenol formaldehyde types used)
- **Produced by combustion sources**
  - Methane (natural gas) converts to formaldehyde due to incomplete combustion
  - Furnace, unventilated combustion sources, fireplace, tobacco smoke
- **Significant levels found in new or newly renovated homes**
  - Causes numerous respiratory issues
  - New or newly renovated homes should be tested for this known air toxic

VOCs – What is the Concern?

- **VOCs can add up to significant levels**
- **U.S. Green Building Council recommends less than 500 ng/L**
  - Average 1,900 ng/L
  - Median 1,100 ng/L



VOCs from Building Materials

- **Flooring**
  - Formaldehyde, solvents
- **Vinyl Flooring**
  - Tetradecane
- **Cabinetry**
  - Formaldehyde, toluene, xylenes
- **Drywall**
  - Sulfur species
- **Paint**
  - Texanols, butyl cellusolve, HCs
- **Carpeting**
  - Caprolactam
- **PVC Cement**
  - Tetrahydrofuran, methylethylketone
- **Plastic Materials**
  - Phthalate esters
- **HVAC**
  - Freons™
- **Fiberglass**
  - Phenol/formaldehyde
- **Spray Foam Insulation**
  - Freons™, isobutane, butane, HCs
  - Pentafluoropropane
  - Trans 1,2-dichloroethene
- **Rigid Insulation Polystyrene**
  - Styrene
- **Adhesives**
  - Toluene, Xylenes

VOCs from Home Contamination

Some materials remain in home for long periods, even if located and removed

- **Moth Balls or Moth Crystals**
  - Napthalene based
  - para-Dichlorobenzene based
- **Coatings and Paints**
- **Kerosene / Diesel / Fuel Oil**
- **Heavier Solvents / Turpentine**
- **Chlorinated Solvents**
  - Cleaning solvents
  - Dry cleaning solvents
- **Toluene and Xylenes**
  - Used in many adhesives and caulks

VOCs from Home Contents

Occupant chemicals are significantly reduced when current owner or tenant vacates

- **Alcohol Products**
  - Ethanol, Isopropyl Alcohol
  - Very common
- **Personal Care Products**
  - Acetone, alcohols, esters
  - Very common
- **Gasoline**
  - Benzene, toluene, xylenes, C5-C8 HCs
  - Very common
- **Odorants or Fragrance Products**
  - Limonene, a-Pinene

Chemical Air Sample Collection and Analysis

Chemical Sampling Media

Canisters

Bags

Thermal Desorption Tubes

Chemical Sampling Media Comparison

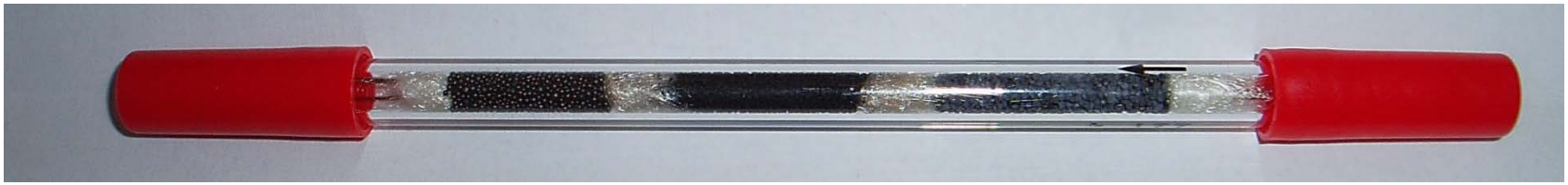
	TDT	Canister	Bag
Good for VOCs	✓	✓	
Good for SVOCs	✓		
Good for Permanent Gases		✓	~
Requires pump	✓		~
Whole air sample		✓	✓
Large sample volume (>10 L)	✓		
Fast sample collection		~	✓
Coordination with lab not required	✓		
Long hold time	✓		
Inexpensive to purchase	✓		✓
Inexpensive to ship	✓		~
Long shelf life	✓		✓
Can be reconditioned and reused	✓	✓	

✓ Media applicable to this feature

~ Media may be applicable to this feature in some situations

Thermal Desorption Tubes

Broad Spectrum Sampling Tube



Tri-matrix tube collects large range of chemicals

Must be inserted with Arrow pointing towards sample pump

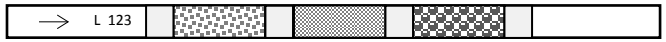
Sample Collection & Analysis

Key Elements

Sample Collection

20-40 L of Air + Contaminants

Thermal Desorption tube

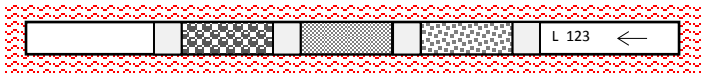


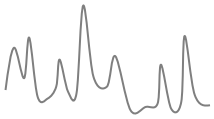
Clean Air

Sample Sent To Lab

Sample Analysis

Carrier Gas





Analysis

No chemicals used and tube reused

"Green Process"

Thermal Desorption Tube (TDT) Sample Collection

- **TDT VOC Sample Collection**
  - Remove sample media from sealed tube
  - Place sample media on sample pump
    - Sample flow direction important
    - Sample flow rate important
    - Sampling time is important
      - VOC 1 to 4 hours
      - Formaldehyde 20 to 30 min
  - Return sample media to transport tube
  - Submit sample to lab with COC
- **Sample Pump**
  - Fixed or variable flow rate available
  - Different atmospheric pressure is okay
  - Flow recertification every 6 months - recommended

VOC Sampler Home Setup

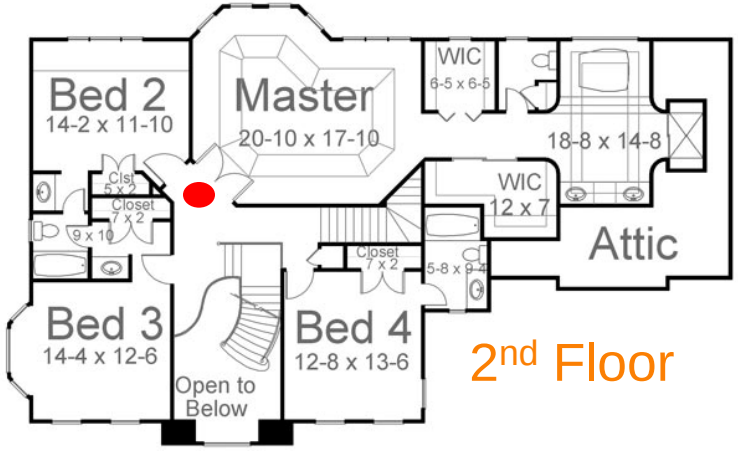
VOC Sampling Strategy

Purpose of testing

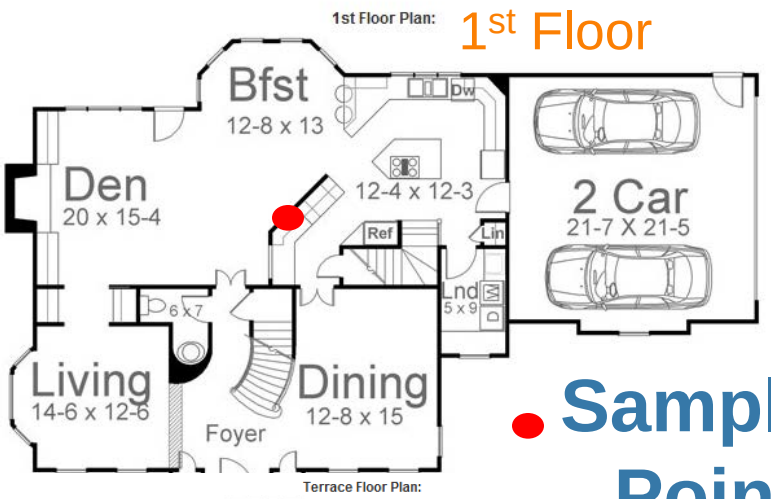
- **General IAQ**
  - Approximate normal parameters; avoid specific activities
  - Place in central area near breathing zone (3-5 feet)
  - Place near air return
- **Problem Area**
  - Concentrate air by closing problem area up for 24 hours
  - Collect air sample in non-problem area

VOC Sampling in a Home

3 Level 3,000 sq. ft.

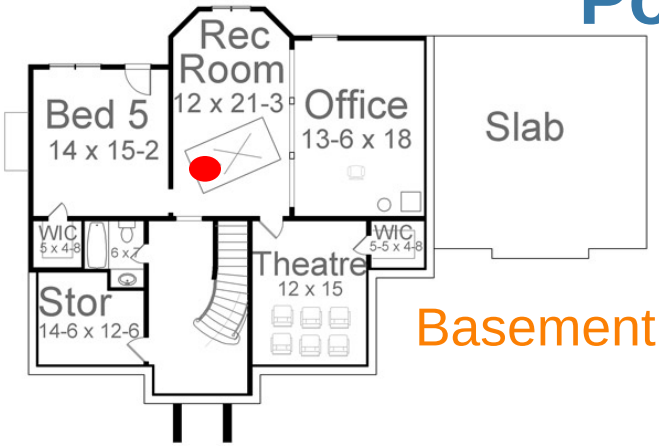


2nd Floor



1st Floor

Sampling Points

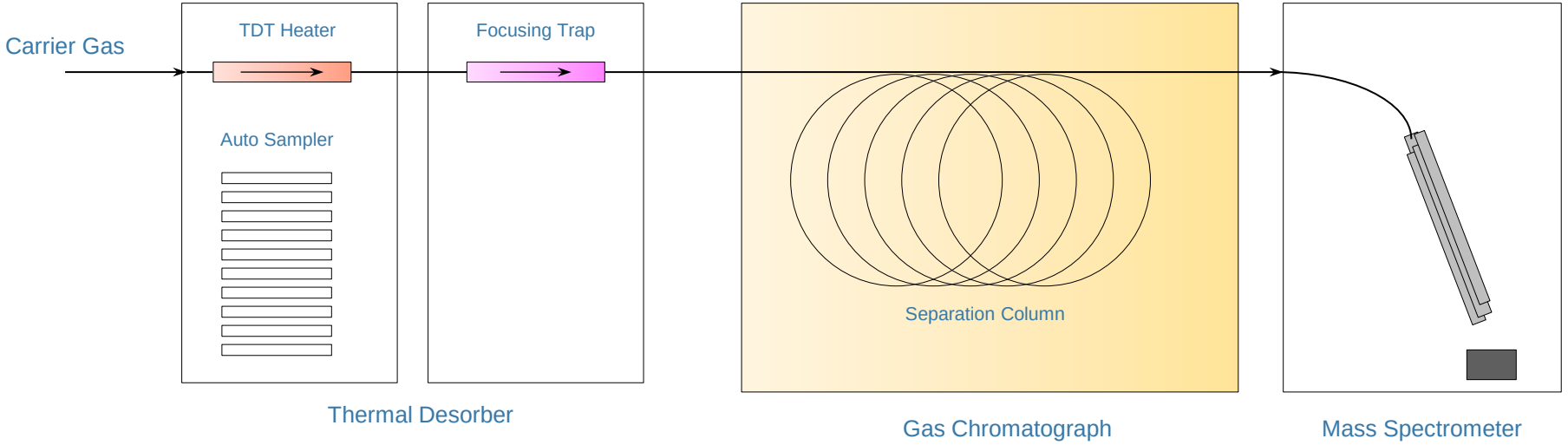


Basement

Chemical Analysis For VOC Testing

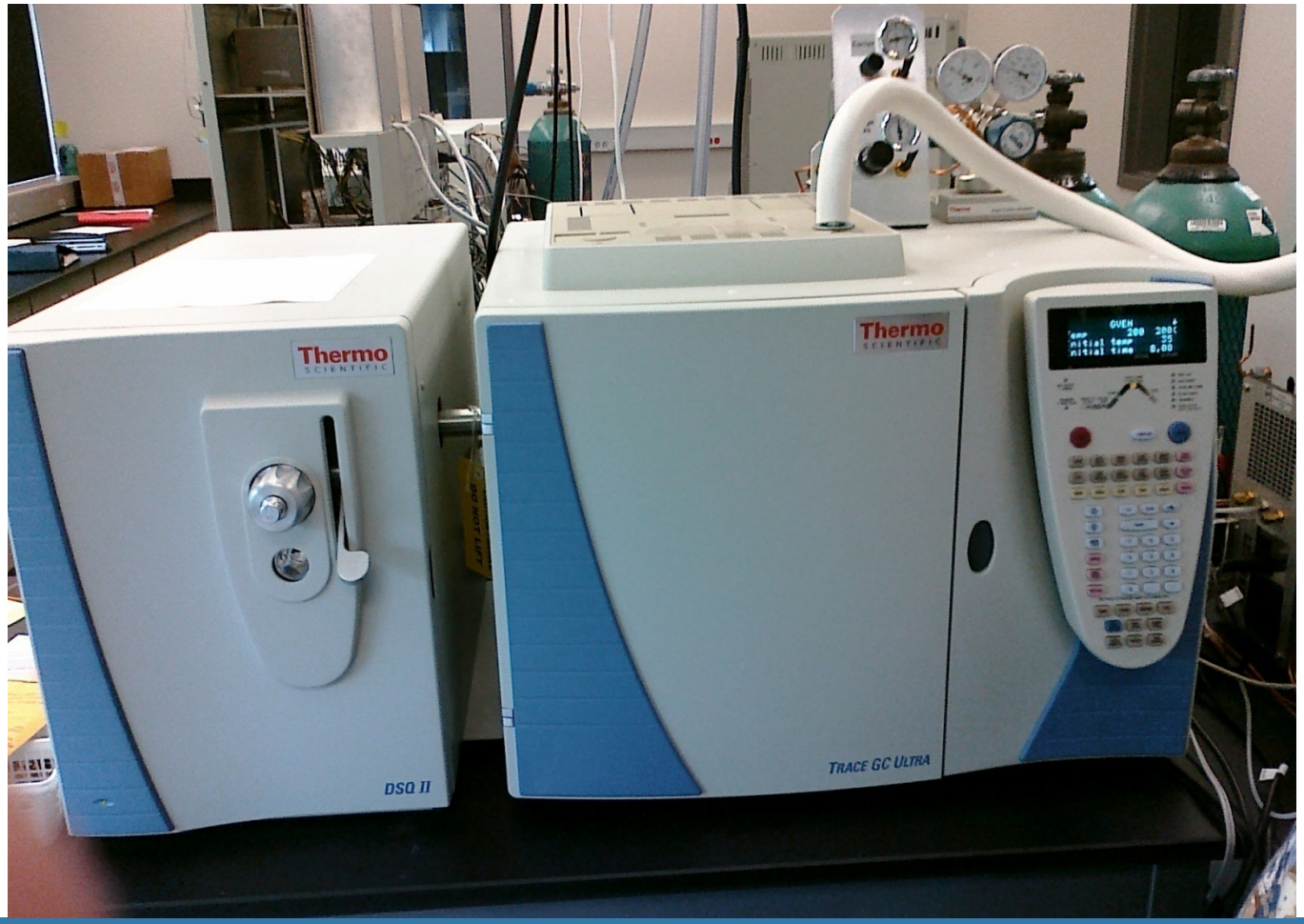
TD GC-MS System

- Thermal Desorption Gas Chromatography-Mass Spectrometry (TD GC-MS)
  - Sample tube heated to drive off captured VOCs
  - GC separates VOCs by volatility and chemical class
  - MS identifies individual VOCs by fragmenting molecules into characteristic pieces



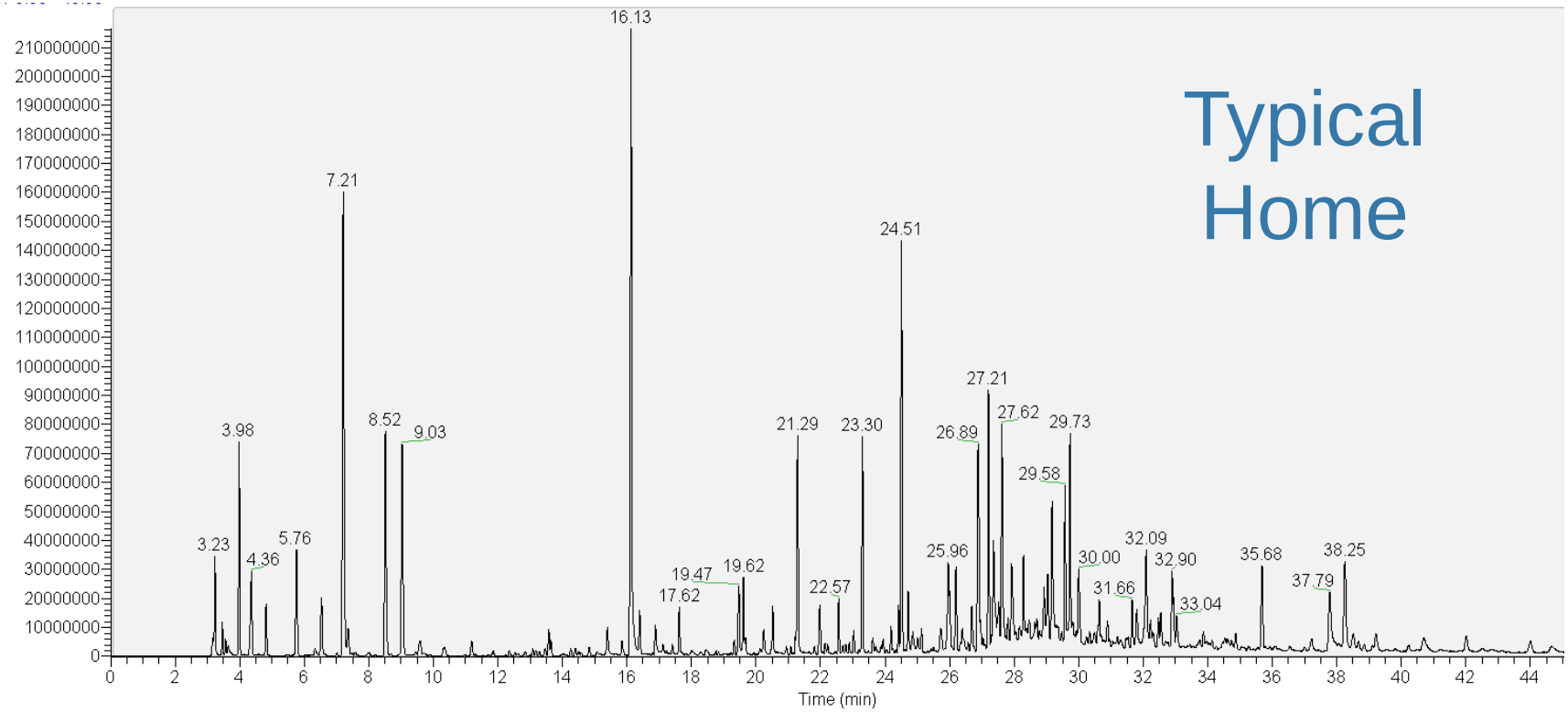
Thermal Desorption System

GC-MS Instrument



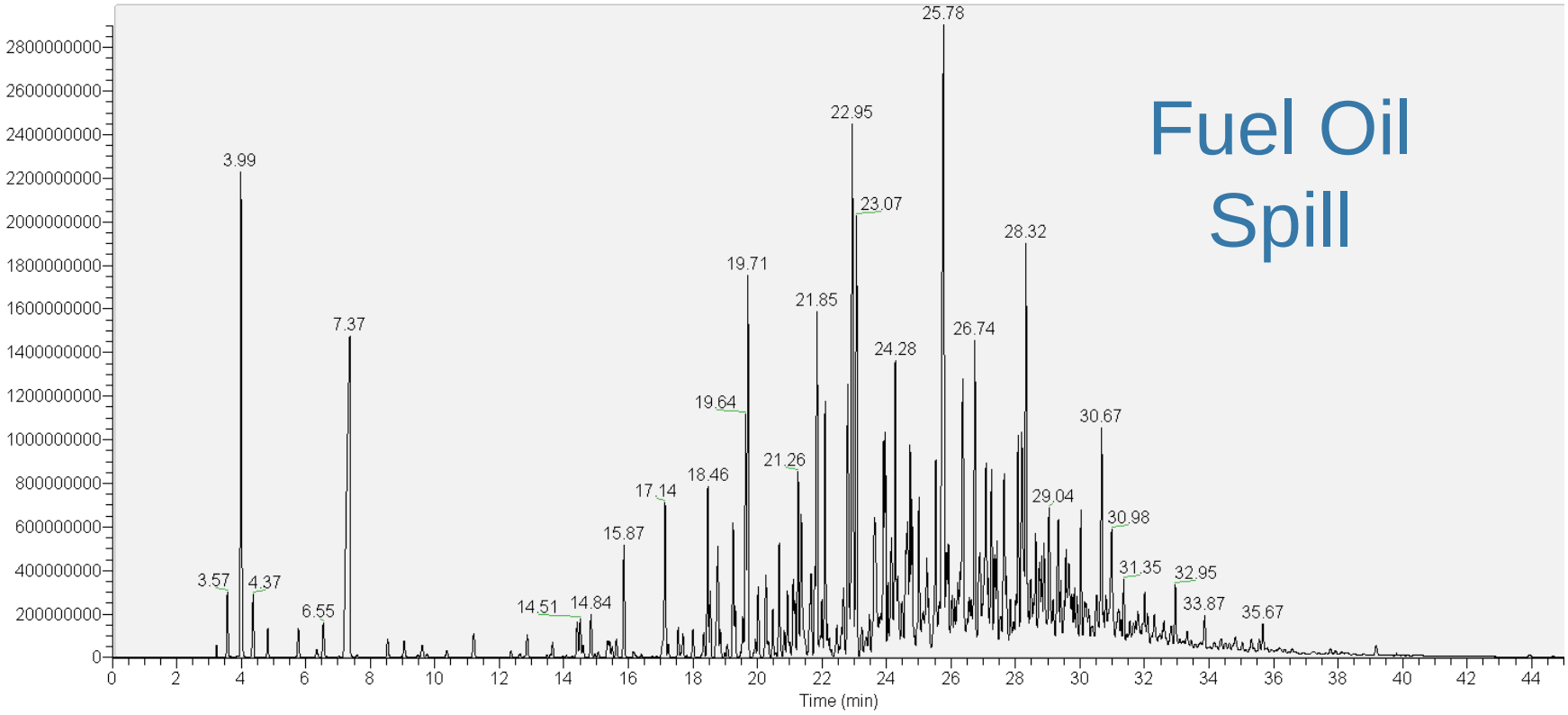
GC-MS Data of Home Sample

1,100 ng/L TVOC



GC-MS Data of Home Sample

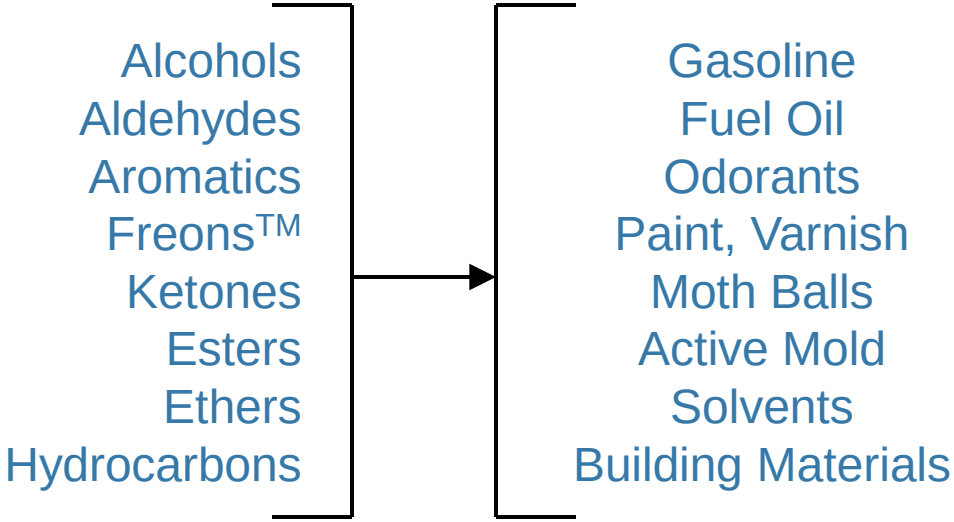
25,000 ng/L TVOC



Chemical Source Prediction

Volatile Organic Compounds

VOCs



Chemicals **Sources**

VOCs – Source Prediction

Building Sources

- **Coatings**
  - Paints, finishes, sealants, waxes
- **Wood products**
  - OSB, MDF
- **PVC Cement**
- **Adhesives, mastics**
- **Blowing agents and refrigerants**
  - Freons™, light hydrocarbons

VOCs – Source Prediction

Occupant/Lifestyle Sources

- **Personal Care and Cleaning Products**
  - Soap, lotions, hair and nail products
- **Odorants and Fragrance Products**
  - Air fresheners, scented candles
- **Dry Cleaning**
- **Medicinal Products**
- **Gasoline and Fuel Oil**

Significant VOCs

Some VOCs are more indicative of products and activities or increased health risks

Ethanol
Isopropanol
Acetone
Ethylacetate
Methacrylate
Methylethylketone

Carbon disulfide
Carbonyl sulfide
Dimethyl sulfide
Acetonitrile
Acrylonitrile

Butane
Isobutane
Hexane
Tetradecane
Cyclohexane
Methylhexanes

Methylene chloride
Tetrahydrofuran
Chloroform
Dichlorobenzene
Freon™ 142
Pentafluoropropane

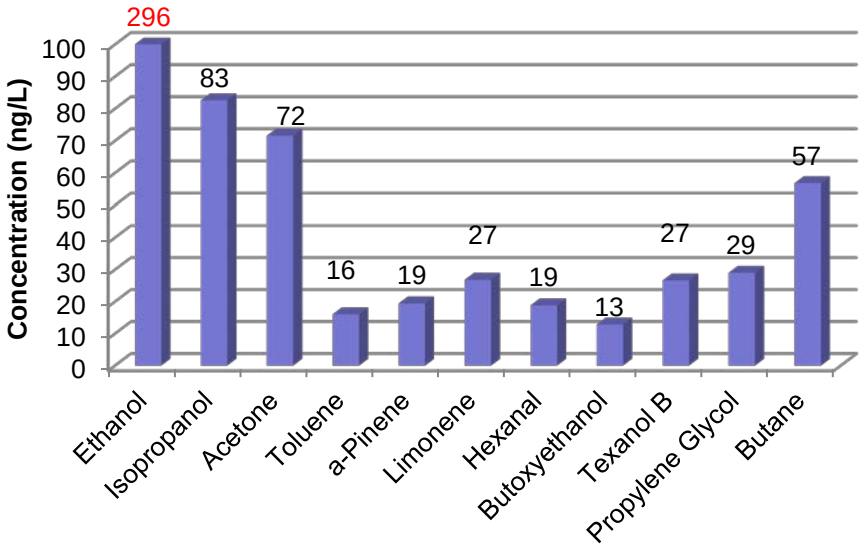
Limonene
a-Pinene
Myrcene
Camphene
Camphor
Eucalyptol

Benzene
Toluene
Xylenes
Styrene
Trimethylbenzenes
Naphthalene

Propylene glycol
Ethylene glycol
Butoxyethanol
DEGBE
DEGEE
PGPE
PGMEA

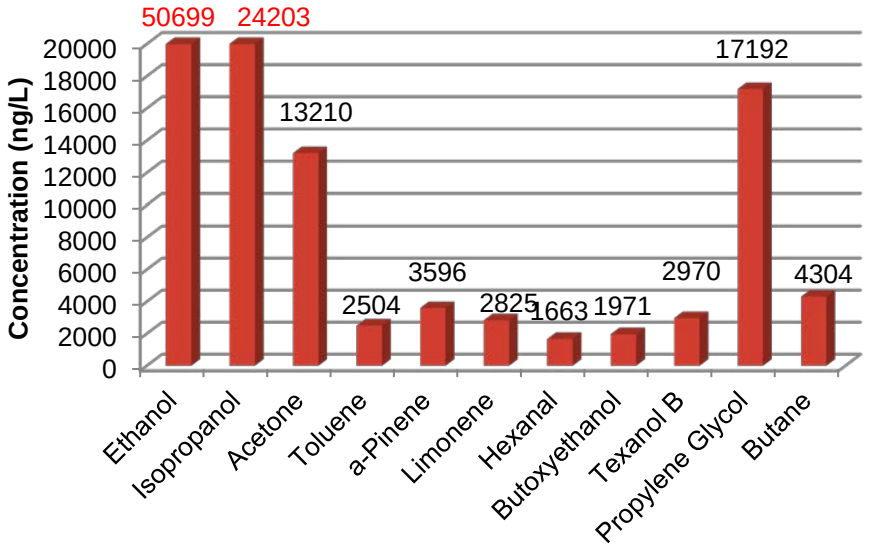
Typical Home VOCs

Wide range of VOC types and concentrations



Average Concentrations for Common Home VOCs

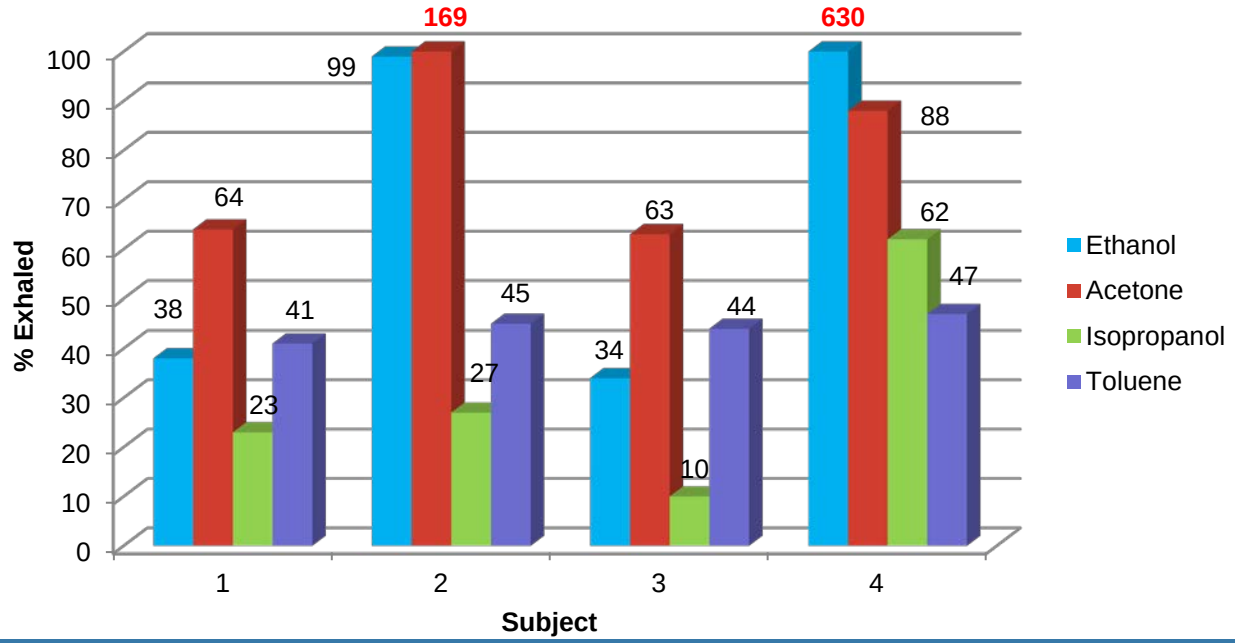
Maximum Concentrations for Common Home VOCs



VOCs Absorbed by Lungs

4 Subjects Exposed to Airborne VOCs

- Similar to normal home exposures
- VOC levels measured in respired air after ~1 hour exposure
- 750 mL deep lung air sample collected on each subject



MOLD TESTING

Mold – What is the Concern?

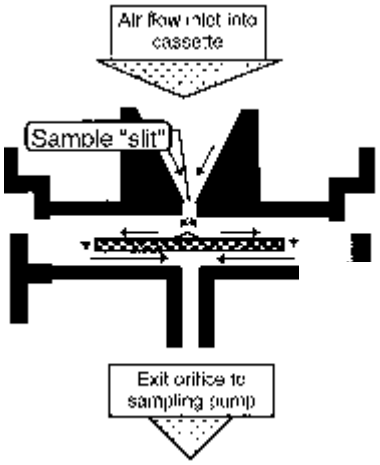
- **Potential health effects**
  - Allergic reactions, asthma, respiratory complaints
- **Damage to materials inside building**

- **No practical way to eliminate all mold/mold spores in indoor environment**
- **Moisture control is key**

- **No official limits for mold or mold spores**

Mold Spore Sampling

- **Air samplers**
  - Collect onto plate or filter
  - Active (requires sampling pump)
  - Air-O-Cell, Anderson impaction
- **Settling plate**
  - Collection by gravitational settling
- **Tape lift**
  - Small surface area
- **Dust**
  - Settled dust
  - Vacuum collection
- **Bulk material**
  - Typically visibly moldy material
  - Species identification

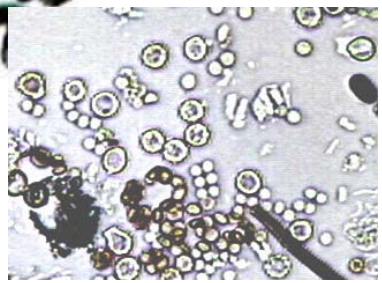


Mold Spore Analysis

- **Culture**
  - Grow mold from sample
  - Identifies genus/species
  - Air, surface, dust, bulk samples
- **Microscopy**
  - Spore count
  - Identifies genus/species
  - Air, tape lift samples
- **DNA (PCR – polymerase chain reaction)**
  - EPA Environmental Relative Moldiness Index (ERMI)
    - Identifies 36 species of molds
    - Group 1: mold species and groups of species that thrive in water damaged locations
    - Group 2: 10 species or groups of species in locations with or without water damage; common, typically cause fewer and less severe symptoms
  - Dust samples

Stachybotrys

Cladosporium



Penicillium/Aspergillus/hyaline

Example Mold Spore Count Report

Category Sample # -->	AIRBORNE MOLD SPORE CONCENTRATIONS (Cts./m^3) -- Spore Trap Sample Analysis 14-0001A
Total Mold Spores (Cts/m^3)	3360
Alternaria	69
Aspergillus/Penicillium	343
Ascospores	137
Basidiospores	480
Botrytis	
Chaetomium	
Cladosporium	1646
Curvularia	
Drechslera/Bipolaris Epicoccum	
Fusarium	
Nigrospora	
Oidium/Peronospora Pithomyces	
Rusts	
Smuts / Myxomycetes / Periconia	
Stachybotrys	
Stemphylium	137
Torula	343
Ulocladium	
Other Hyaline Fungi	
Other Fungi	69
Unidentified Fungi	
	137
Hyphae fragments	
Algal / fern spores	
Insect parts	

Example ERMI Mold Report

Moldiness Score of Sample based on *Penicillium* and *Aspergillus* Concentration Detected

Sample ID: MM050511-1-1

Description: Master Bedroom

Assay	Spores / Sample
PenAsp*	61,729
Stach*	1

Moldiness Score of *Penicillium* and *Aspergillus*:	**4.79**
***Stachybotrys chartarum* Detected:**	**YES**

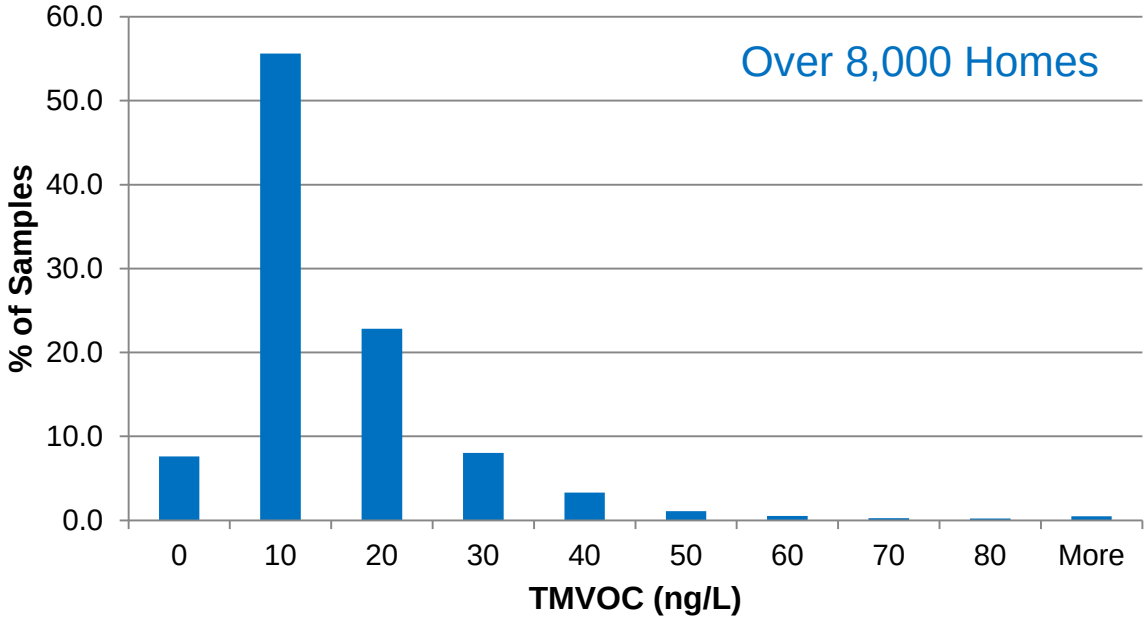
MVOCs and Active Mold

- **Mold VOCs produced during mold metabolism**
  - Indicates active mold growth
  - Subject to same factors as other VOCs
- **21 compounds used as surrogate for hundreds**

Furan	2-Pentanol	1-Octen-3-ol
2-Methylfuran	3-Methyl-1-butanol	3-Octanone
3-Methylfuran	2-Methyl-1-butanol	3-Octanol
Methyl ethyl ketone	1-Pentanol	2-Ethyl-1-hexanol
2-Methyl-1-propanol	2-Hexanone	1-Octanol
2-Methyl-2-butanol	2-Heptanone	2-Isopropyl-3-methoxypyrazine
3-Methyl-2-butanol	2-Pentylfuran	Geosmin

TMVOC Interpretation

- No limits specified by any government or organization
- Qualitative estimates of possible effects
  - Sensitive individuals or those with chronic or respiratory issues may experience effects at much lower levels



TMVOC	Level
< 8	Minimal or Ambient
8 – 30	Active – Moderate
30 – 80	Active – Elevated
80 – 150	Active – High
> 150	Active - Severe

ALLERGEN TESTING

Allergens – What is the Concern

- **~50 million North Americans affected by allergic conditions**
- **Immune system overreaction to certain substances**
  - Symptoms: hay fever, asthma, eye irritation, respiratory irritation (wheezing, sneezing, coughing), eczema, hives, allergic shock
- **Allergens: dust, ragweed, pollen, mold, pet dander, rodent, cockroach, dust mites, certain foods, etc.**

Example Allergen Report

Sample Description: Composite: Living Room, Master Bedroom, and Play Room

Allergen Tested	Results	Interpretation	Detection Limit
Cat			
Fel d 1	0.56	LOW	0.16
Cockroach			
Bla g 1	<1.6	Below Detectable Limits	1.6
Dog			
Can f 1	3	MODERATE	0.39
Dust Mite			
Der f 1	<0.39	Below Detectable Limits	0.39
Der F 2	<0.39	Below Detectable Limits	0.39
Mouse			
Mus m 1	Not Tested	Not Applicable	Not Applicable
Rat			
Rat n 1	Not Tested	Not Applicable	Not Applicable

*Concentrations are in micrograms of allergen per gram of dust with the exception of fecal cockroach allergen being measured as units of fecal matter per gram of dust.

Interpretation based upon information from the National Survey of Lead and Allergens in Housing funded by the National Institute of Environmental Health Sciences and the US Department of Housing and Urban Development

PARTICULATE/DUST TESTING

Particulates – What is the Concern

Microscopic solid or liquid matter

- Fine < 2.5 μm
- Respirable Coarse 2.5 – 10 μm
- Coarse (Dust) > 10 μm

- **Health symptoms**
  - Allergies, asthma, respiratory conditions, cardiovascular conditions, cancer
- **Indicate home conditions and activities**

Particulate Sampling

- **Surface**
  - Tape Lift
  - Bulk

Tape Lift

- **Air**
  - Impaction (e.g., Air-O-Cell®)
  - Particle Counters
  - Size-Selection

Impact Sampler

Particulate Analysis

- **Optical microscopy**
  - Low power stereo
  - Bright field
  - Polarized light
  - Reflected light dark field
- **Electron Microscopy**
  - Scanning Electron / Dispersive X-Ray
  - Transmission Electron / Dispersive X-Ray
- **Gravimetric**
  - Amount of respirable or nuisance dust

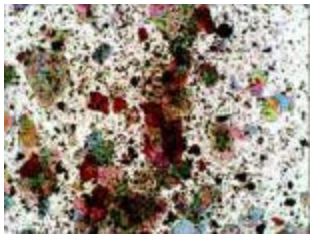
Particulate Sources (by Microscopy)

- **Outdoor indicators**
  - Bioaerosols (mold, pollen, plant parts, insect parts, etc.), infiltrated soil and combustion particles

- **Indoor indicators**
  - Building materials (carbonates, silicates, sulfates), corrosion and building shedding, skin cells, fibers (fabric, paper, man-made), cosmetic particles

Particulate Source Analysis (by Microscopy)

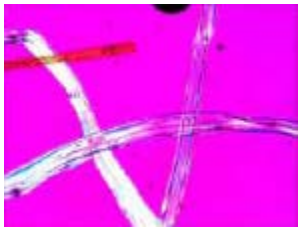
- **Occupancy**



Cosmetics

Skin Cells

Insects

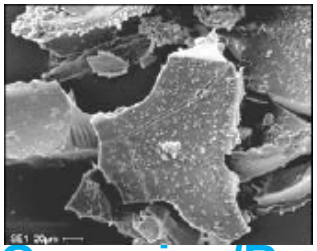


Clothing/Paper

- **Building Shedding**

Fiberglass

Patching Cpd



Corrosion/Rust

SUMMARY

Why measure Indoor Air Quality?

- **Detect unseen materials that cause health issues**
  - Chemicals, mold spores and allergens you can not smell or see
  - 20+ million adults have asthma & most chronic childhood illness
  - Infants, pregnant women and elderly are susceptible IAQ issues
- **Detect significant to severe home contamination**
- **Detect carcinogens like formaldehyde**
- **Detect defects in HVAC systems**
- **Peace of mind for prospective buyer**

Causes of Poor Home Air Quality

- **New construction**
  - New homes do not “breathe” (improper ventilation)
  - VOCs can concentrate causing chemical sensitivities
  - Building materials out-gas VOCs
  - Paints, stains, and sealants produce significant VOCs
- **Water leaks**
  - Plumbing leaks behind walls can cause mold growth – not visible
  - Minor roof leaks may not be noticed and generate hidden mold
- **Lifestyle**
  - Increased use of cleaning & “freshening” products add to VOC level
  - Animals, rodents and pests can produce significant allergen levels

Indoor Air Quality Assessments

- **Detects the non-observable**
  - HVAC, chemical, mold and allergen issues
- **Provides home buyers more information on the home**
  - Home buyers want quality homes that are safe
- **Significant business opportunity for Home Inspectors**

Questions

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