College of Engineering and
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Material Emissions and Indoor Air Quality (IAQ)

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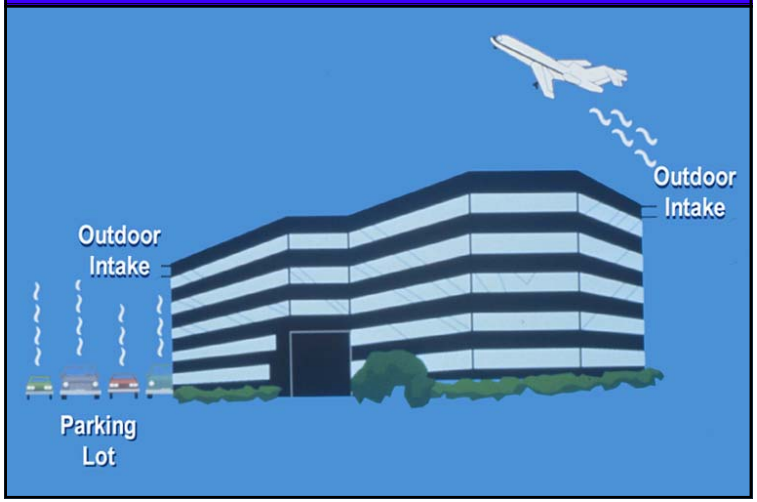
Outline

- Introduction
  - Common causes of IAQ problems
  - Typical contaminant sources
  - Why study material emissions?
- Material Emission Studies
  - "Finger print" --- What VOCs are emitted ?
  - How fast are the emissions?
  - Impact of material emissions on IAQ
- Summary
- Research needs

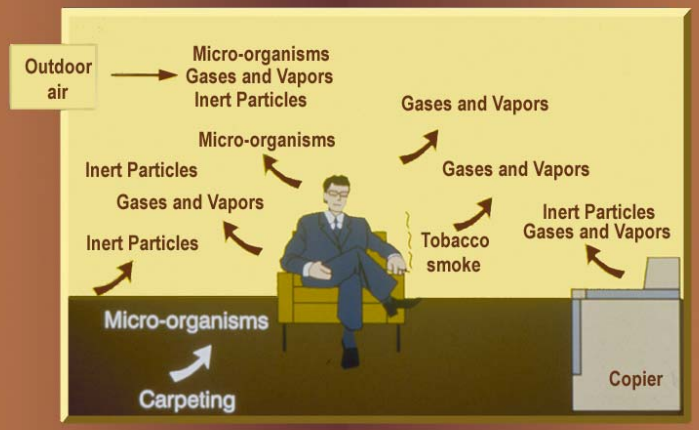
Common Causes of IAQ Problems

- Poor ventilation
- Outdoor and indoor contaminant sources
- Perceptions due to
  - poor thermal conditions (e.g., high RH)
  - poor lighting
  - high noise level
  - job stress, …, etc.

Typical contaminant sources: outdoors



Typical contaminant sources: indoors



Building material emissions

Why Study Material Emissions?

- 300+ VOCs identified (accounts for over 50% indoor contaminants)
- Many VOCs can cause discomfort and adverse health effects
- Indoor VOC concentrations are usually much higher than outdoors

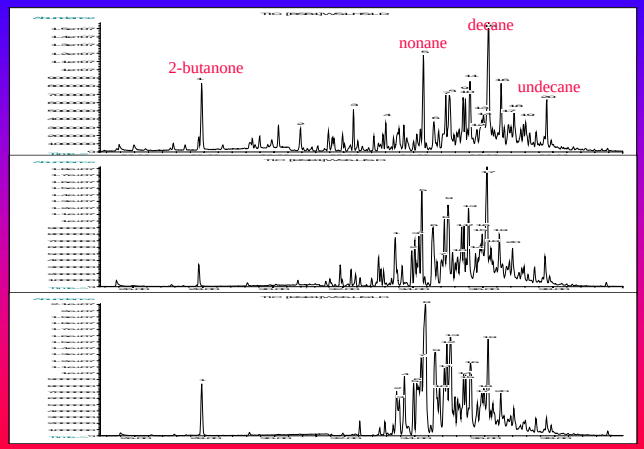
Material Emission Studies

- Chemical analysis: What are emitted?
  ----The "finger print"
- Emission rates over time -- How fast, how long and how much?
- Impact on Indoor Air Quality (IAQ)

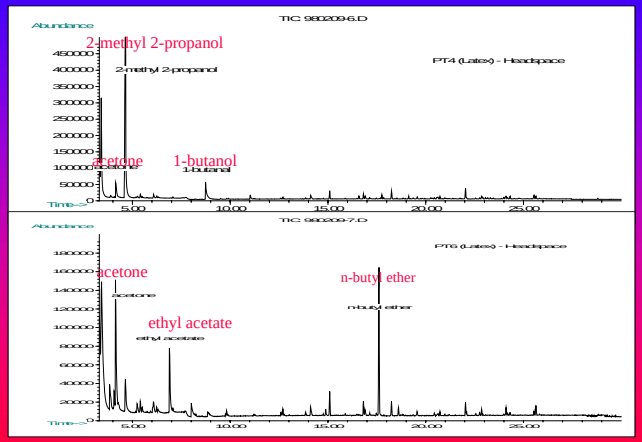
Identification of VOCs emitted: headspace analysis

Chemical Analysis Systems (GC/FID and GC/MS)

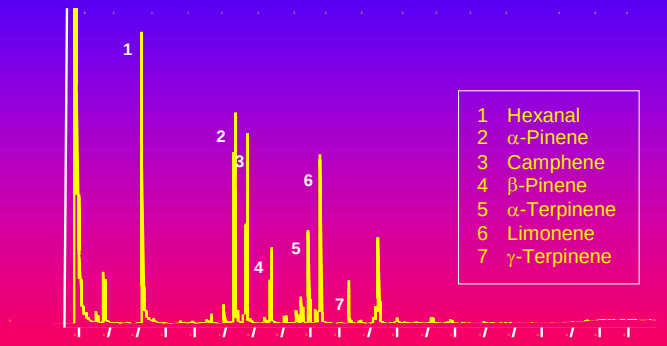
Three Oil-based Wood Stains - Headspace



Two Water-based (Latex) Paints – Headspace



Particleboard (at t=24 h, by GC/FID)

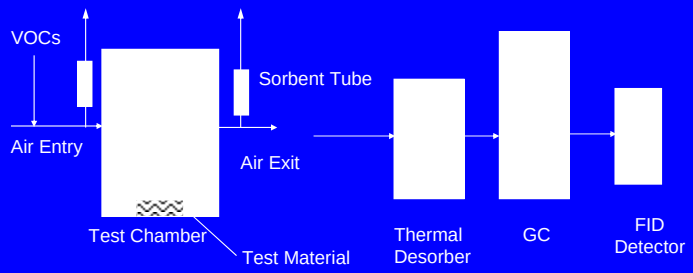


Material Emission Studies

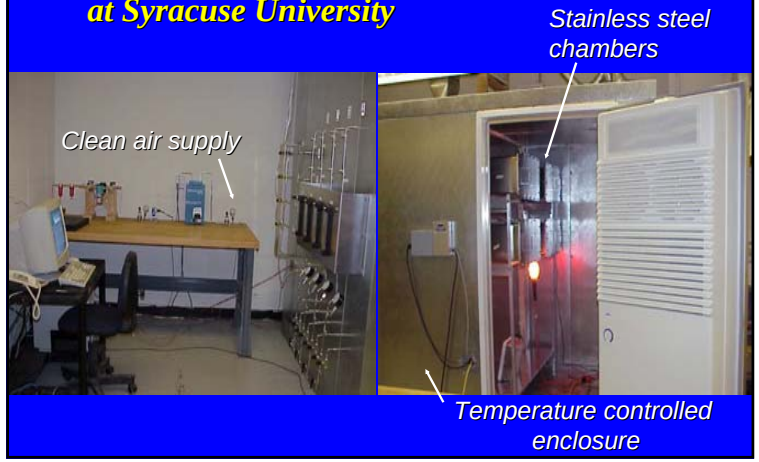
- Chemical analysis: What are emitted?
  - ----The "finger print"
- Emission rates over time -- How fast, how long and how much?
  - Environmental chamber testing
    - Small chambers
    - Full-scale chambers
  - Mathematical modeling
    - Emission models (sources)
    - Sorption models (sinks)
- Impact on Indoor Air Quality (IAQ)

Small Environmental Chamber Facility

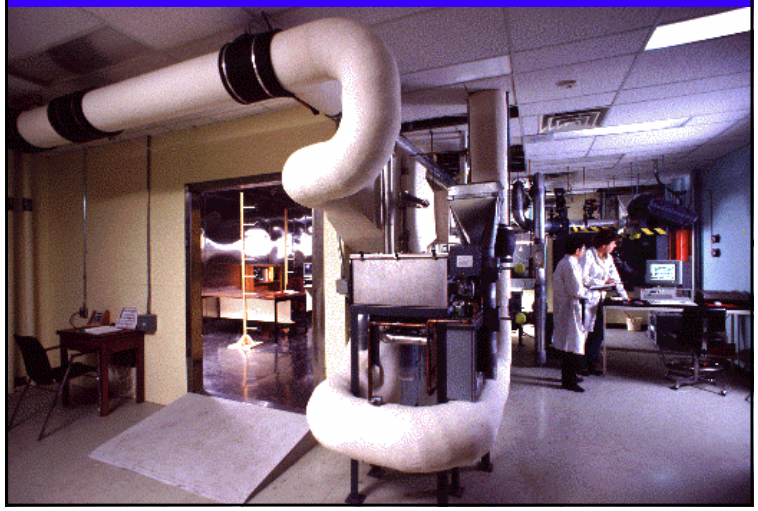
-- Testing of sources/sinks, air purifiers, & sensors



Small Environmental Chamber Facility at Syracuse University



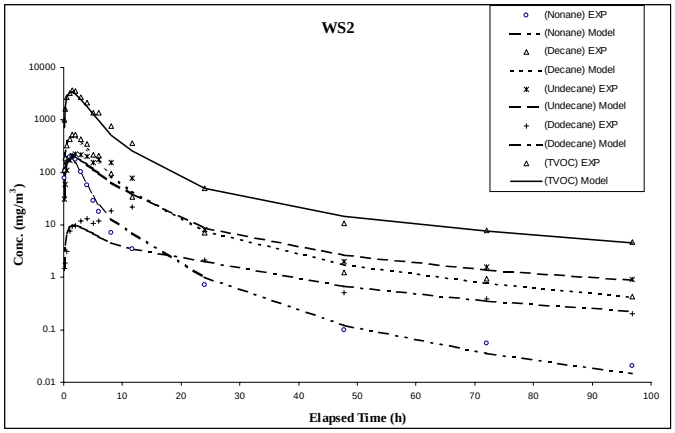
A Full-scale Chamber System at NRC



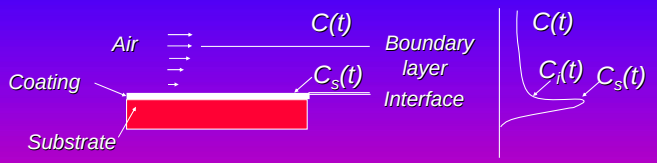
VOC emission characteristics of a wood stain

Emission from wood stain: -- a three period process

Comparison between modeled and measured concentrations



A CFD Model for "Wet" Coating Materials

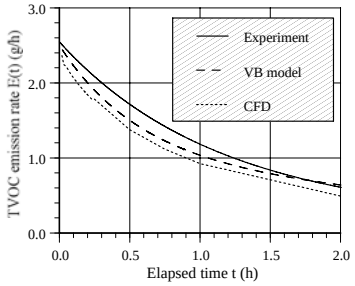


- Room flow: Computational Fluid Dynamics (CFD) model
- Boundary layer: Convective mass transfer model
- Interface: Equilibrium sorption model
- Coating: Evaporation/diffusion
- Substrate: Diffusion

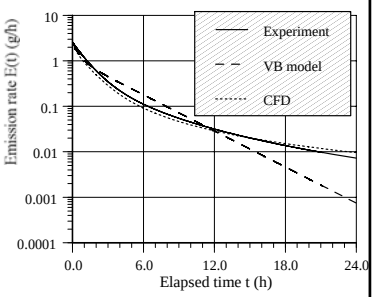
Comparison between modeled and measured emission rates

--TVOC emissions from wood stain applied on oak substrate (Yang et al. 1999)

a. First 2 hours



b. First 24 hours



Emission Characteristics

"Wet" materials:

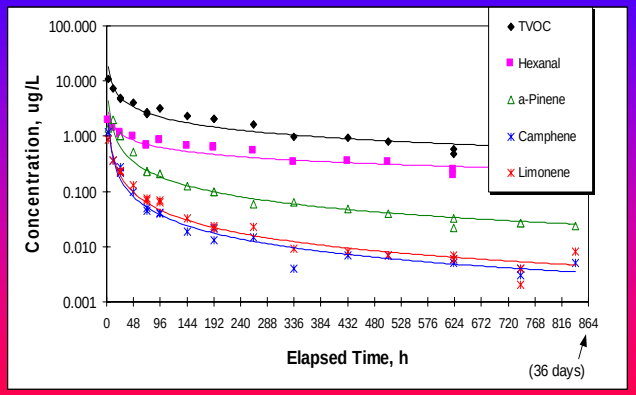
- High initial emission rates and fast decay rate
- Three emission periods
  - evaporative controlled initial period
  - transition period
  - diffusion controlled final period
- Affected by air velocity

Emission Characteristics

Dry materials:

- Low emission rates and slow decay rate
- Diffusion controlled process
- Not significantly affected by air velocity

Particleboard (PB-6): small chamber test results



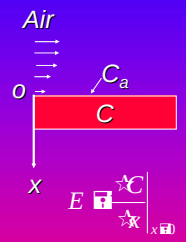
A Diffusion Model For Dry Materials

- Inside the material

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial x^2}$$

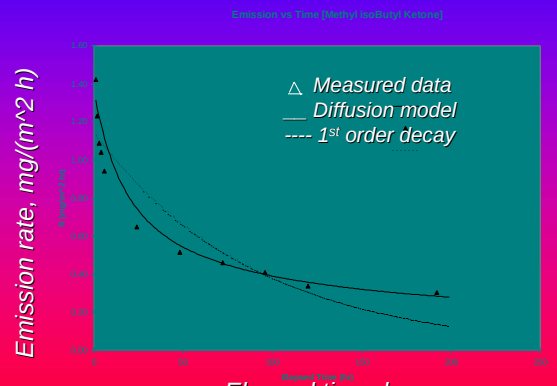
- At the material-air interface

$$C(x=0) = k_e C_a$$



C = concentration in the material;
t = time;
D = effective diffusion coefficient of a VOC in the material;
x = the spatial coordinate (assuming 1-D diffusion).
C_a = concentration in air at the material-air interface;
k_e = partition coefficient.

Prediction by a diffusion model



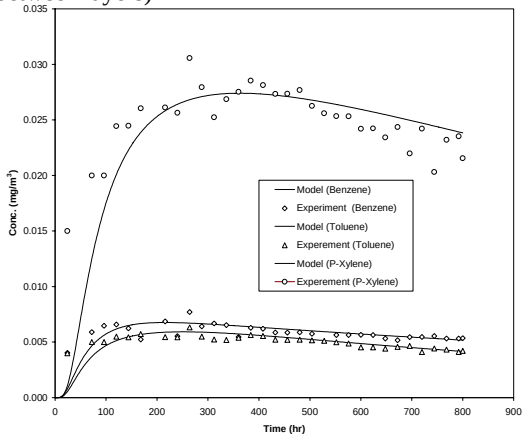
Classification of Building Materials

- "Wet" materials
  - wood stain, polyurethane, floor wax, paint
  - adhesive, caulking
- Dry materials
  - particleboard, OSB, plywood
  - oak, maple, spruce, pine
  - gypsum wallboard, ceiling tile, vinyl tile
  - carpet, underpad
- Material assemblies
  - Wall, floor assemblies, etc..

VOC Emissions from a multi-layer assembly

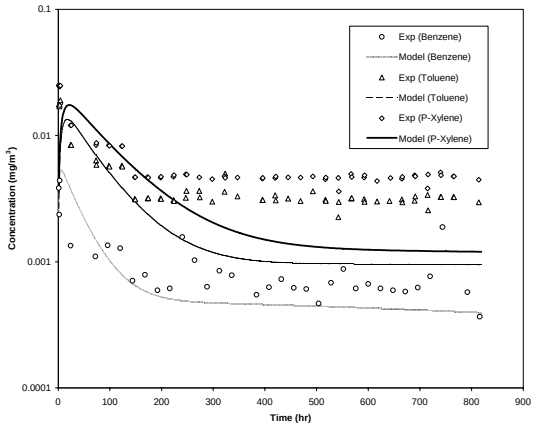
VOC emissions from a multi-layer assembly

(Sealed bottom and edge surfaces & complete contacts between layers)

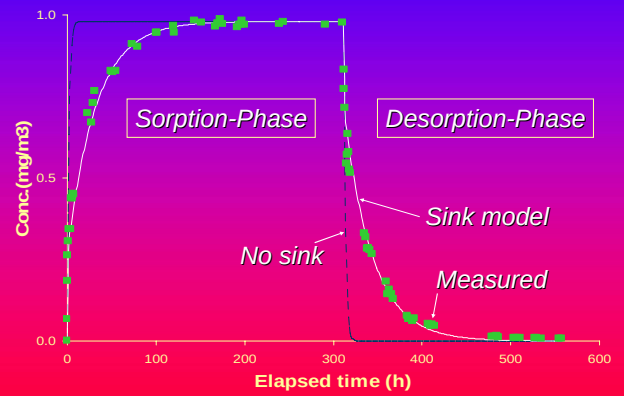


VOC emissions from a multi-layer assembly

(Unsealed bottom and edge surfaces & incomplete contacts)



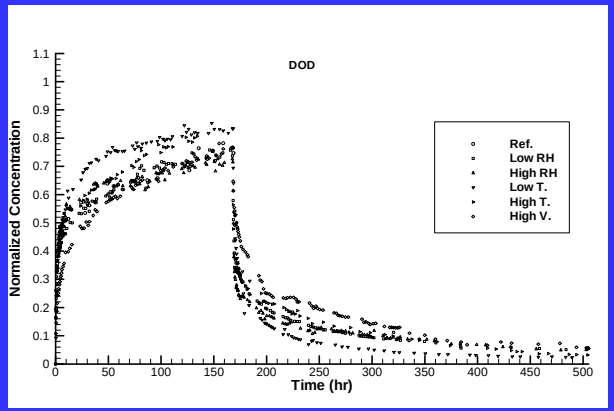
Sorption (sink) effect: dodecane on a carpet



Effect of Environmental Conditions on VOC Sorption (ASHRAE RP-1097)

a. Painted drywall b. Ceiling tile c. Carpet

Effect of Environmental Conditions on VOC Sorption (ASHRAE RP-1097): Dodecane on carpet



Material Emission Studies

- *Chemical analysis: What are emitted? ----The "finger print"*
- *Emission rates over time -- How fast, how long and how much?*
- *Impact on Indoor Air Quality*

Principle of IAQ Control

Principle of IAQ Control

- Goal:

$$C < C_{crieteria}$$

- Governing equation:

$$V\,dC/dt = R(t) - Q(t)\,[C(t) - C_s(t)] - F(t)$$

Rate of contaminant accumulation = Rate of source emission − Rate of dilution by ventilation − Rate of reduction by purification

A Computer Tool for IAQ Analysis

- "MEDB-IAQ"-- Material Emission Database and IAQ Analysis
  - A database of sources and sinks
  - A room simulation model

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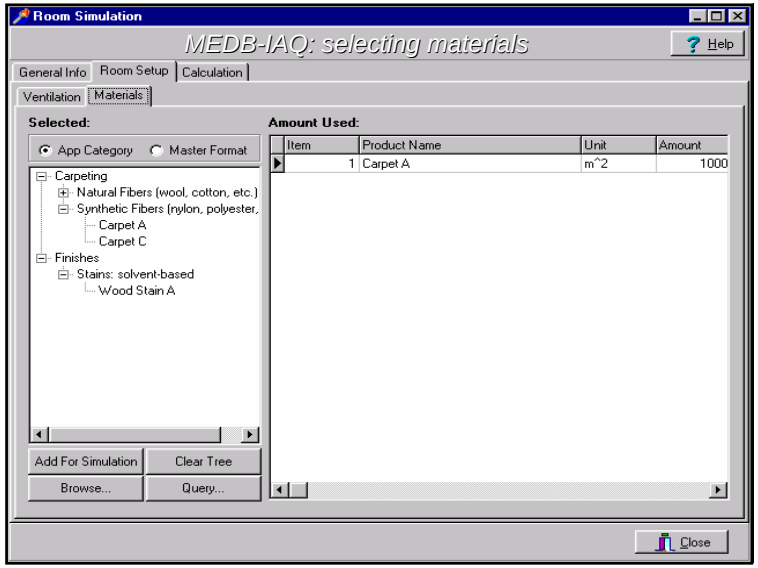
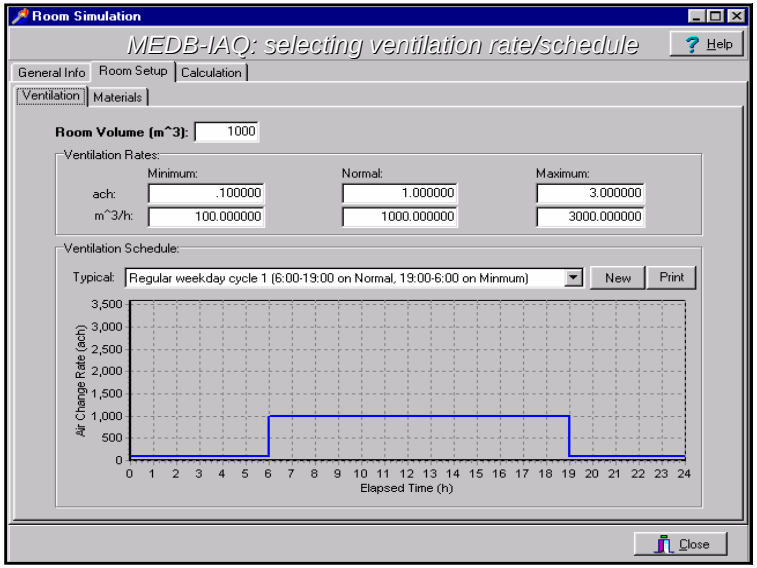
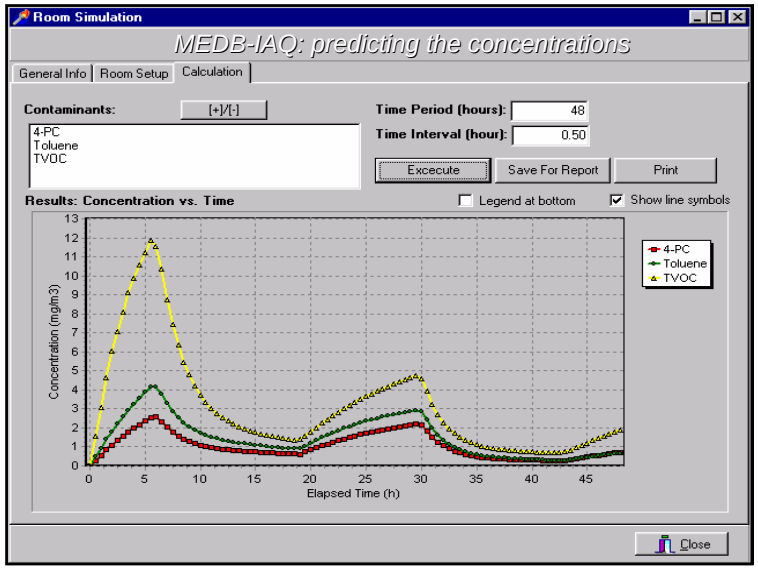
Impact of Material Selections and Ventilation on Indoor Air Quality







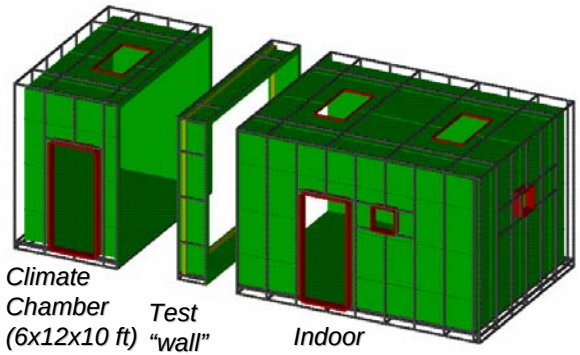
Summary

- Material emission studies
  - The "finger print" -- What are emitted?
  - Emission rate over time -- How fast and how much?
    - Environmental chamber testing
    - Mathematical modeling
    - "Wet" and dry individual materials
    - Material assemblies
  - Impact of material emissions on IAQ
    - Material emission database
    - A computer simulation tool for IAQ analysis
      - Source control, ventilation and air purification

Research Needs

- VOC emissions and transport in multi-layer material systems
  - Air leakage paths
  - Diffusion through porous materials
- Effect of environmental conditions on
  - VOC emissions, sorption and transport
- Outdoor to indoor contaminant transport
  - Combined heat, moisture and contaminant transport
- A comprehensive database
  - Individual materials and material assemblies
- An integrated model
  - IAQ and energy analyses

A Full-scale Thermal & Air Quality Research Facility at Syracuse University



Thermal & Air Quality Research Facility

- *Applications*
  - *Characterization of emission sources*
  - *Performance of air cleaning devices*
  - *Room air & contaminant distributions*
  - *Microenvironment modeling for exposure & health risk assessment*
  - *Thermal and IAQ performance of wall & window components/systems*
  - *Evaluation of HVAC control systems*
  - *Evaluation of IAQ sensors*
  - *Impact of outdoor climate on indoor environment*
  - *……*