“Architectural” perspectives on indoor chemistry, material selection and testing

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What architects want

- Payment
- No law suits
- Repeat customers
- Good buildings
- Awards for their designs from their peers
- Simple answers to complex questions
- Quick answers
- Cheap solutions
- Repetition: Tried and true – proven solutions

What architects want

“We don’t want to understand it. Just tells us what to do.”

-- Project manager, 1983 meeting of design team for a building to house 7,500 people in the San Francisco Bay Area

What's Important? –
The Most Important Question

- Where do the emissions originate?
  - Surface area
  - Mass to Volume ratio
  - Surface to Volume Ratio
- When do they occur?
  - During occupancy or not?
  - Frequently applied materials
- What does a concentration measurement mean?
- Wet applied materials.

Our Heritage

- Ambient air quality measurement methods and their uses:
  - NAAQS/regulation, Research
  - Design – EIRs, Siting, Mitigation
- Industrial hygiene – occupational health measurement methods and uses:
  - TLVs, PELs
- Health-based standards:
  - Ambient and occupational exposures
  - Virtually none for indoor air
  - Exception: (WHO Air Quality Guidelines for Europe)

“Building Ecology”

Levin, 1981. *Progressive Architecture.* April

- Indoor pollution: air, light, sound, + thermal
- Study of the dynamic interdependence of buildings, their occupants, and the larger environment
- Borrowed from ecologists and their conceptual models and methods for studying ecosystems
- The building is a “reactor,” contrary to the assumptions and desires of architects

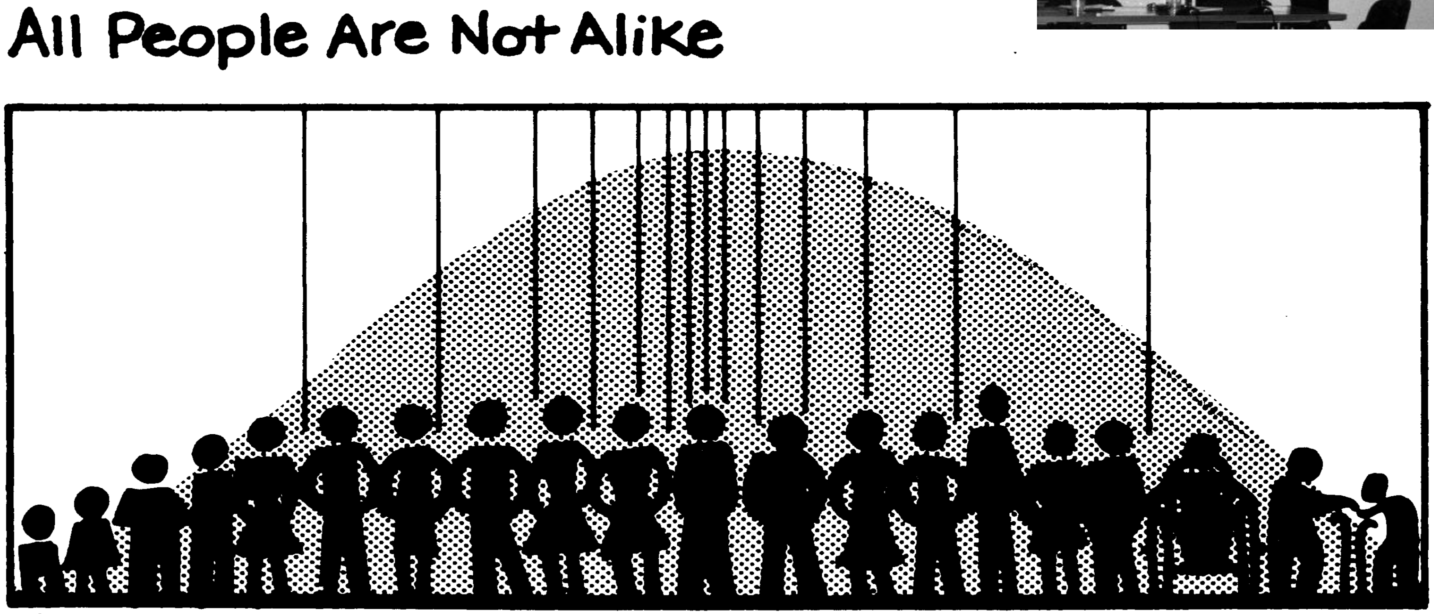
Architects vs. Building Ecologists

- Temporal: ~30 years ago
- Spatial: ~200 m SE of Faculty Club
- Temporal: then known as the "Men's Faculty Club"
  - – time matters
  - - space matters
  - - people matter
- Zen philosophy: Suzuki Roshi (also Rich Corsi, 18 July 2007) - "everything changes"
- This is a room full of Building Ecologists

Buildings are Pataphysical
i.e., every building is unique

- Pataphysics: Science of Exceptions to the Rule
- Variation from building to building, constructed by the same crew, same design, temporally successive
- Variation from space to space
- Variation within spaces
  - Personal or micro-environmental space vs. "representative sampling locations"
  - Height above floor: children, various postures and sized adults
- Variations over time
  - Ventilation ~ 10x
  - Pollutant source strengths ~ $0 – 10^2 - 10^{10}$

One size does not fit all



Who chooses building materials?

- Architect-designed buildings = < 10% of all occupied space:
  - hospitals
  - schools
  - large offices
  - large multi-family housing and high-end, “custom” SFD homes
- Architect designed buildings tend to be the public spaces where people spend time except for retail.
- Furnishings, carpet renewed many times during building life time.
- Engineer, contractor, and owner-designed buildings comprise the majority of buildings.

Residential Design

- Majority are contractor or builder designed
- 10 – 15% are “owner-built” – Owner acts as general contractor and does 0 to 100% of work.
- Remodel/renovation of houses comprises ~50% of all building materials sold for residential construction

Material Selection

- Most materials are selected by contractors for both residential and non-design professional commercial buildings, even in many projects “designed” by design professionals (architects, engineers).
- Advice received from retail providers of buildings materials major factor.
- Manufacturers representatives say what they think the architects want.
- Marketing departments drive product development.

What do architects care about?

- Function: depends on surface and use
  - Durability, cleanability, acoustical properties
- Cost
- Aesthetics: color, texture, pattern
- Installation requirements (e.g., special skills or equipment needed? Timing)
- Availability
- Warranties
- Service life
- “Green” aspects: e.g. Indoor Air Quality, recycled content, “natural” material, energy considerations.

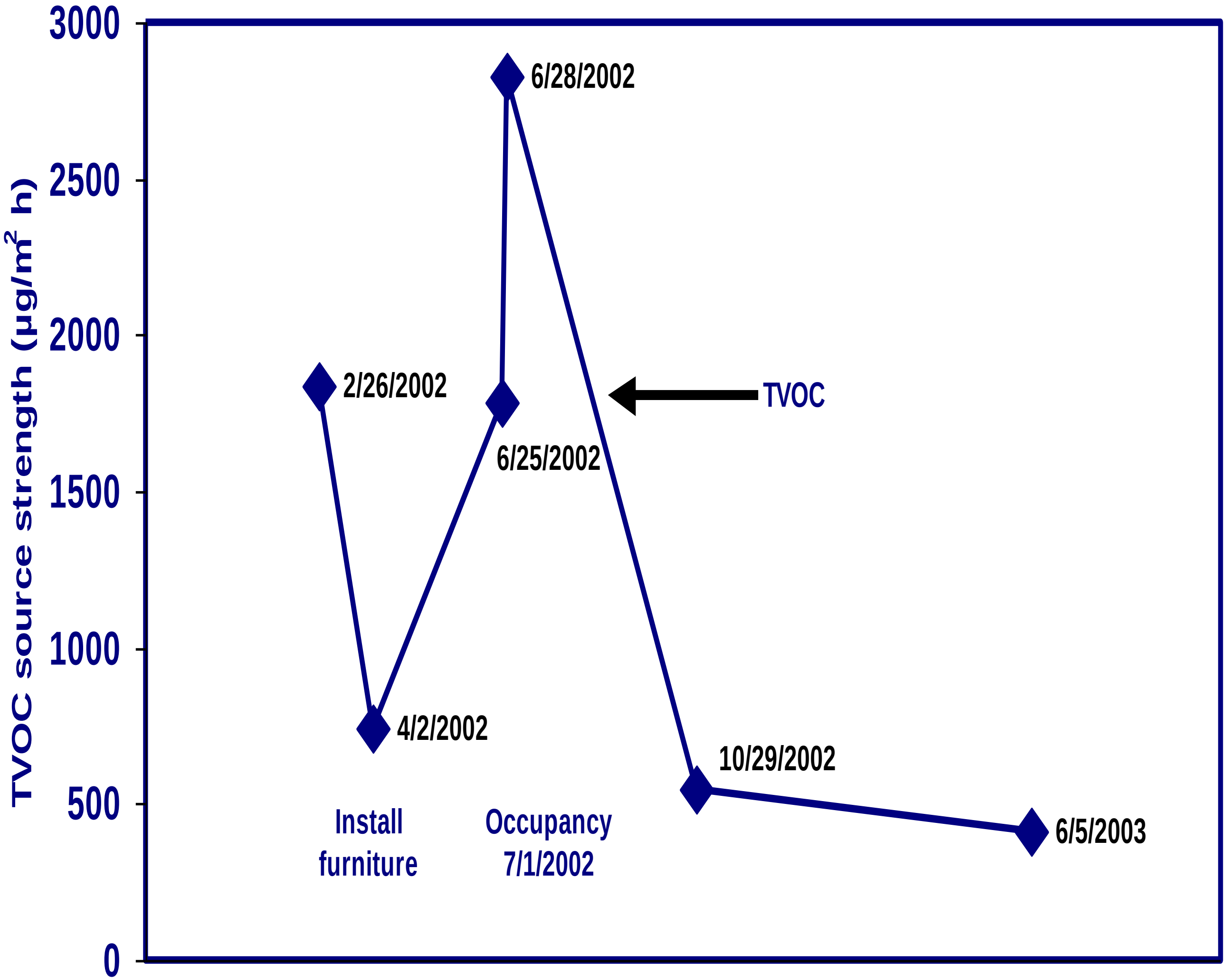
Green Materials – Diverse Criteria

- Recycled content
- Low VOC content
- “Non-Toxic”
- Certification:
  - Greenguard
  - Green Seal
  - CHPS
  - CRI Green Label Plus
  - Floor Score
  - California Section 01350
- Life Cycle Assessment – service life matters

Who decides what to buy?

- Interior designers, consultants
- Architects, engineers, specifications writers
- Contractors
- Clients
- Users
- Sales representatives
- Homeowners
- Construction workers (whatever is in the truck)

6th floor TVOC source strengths (µg/m² h)



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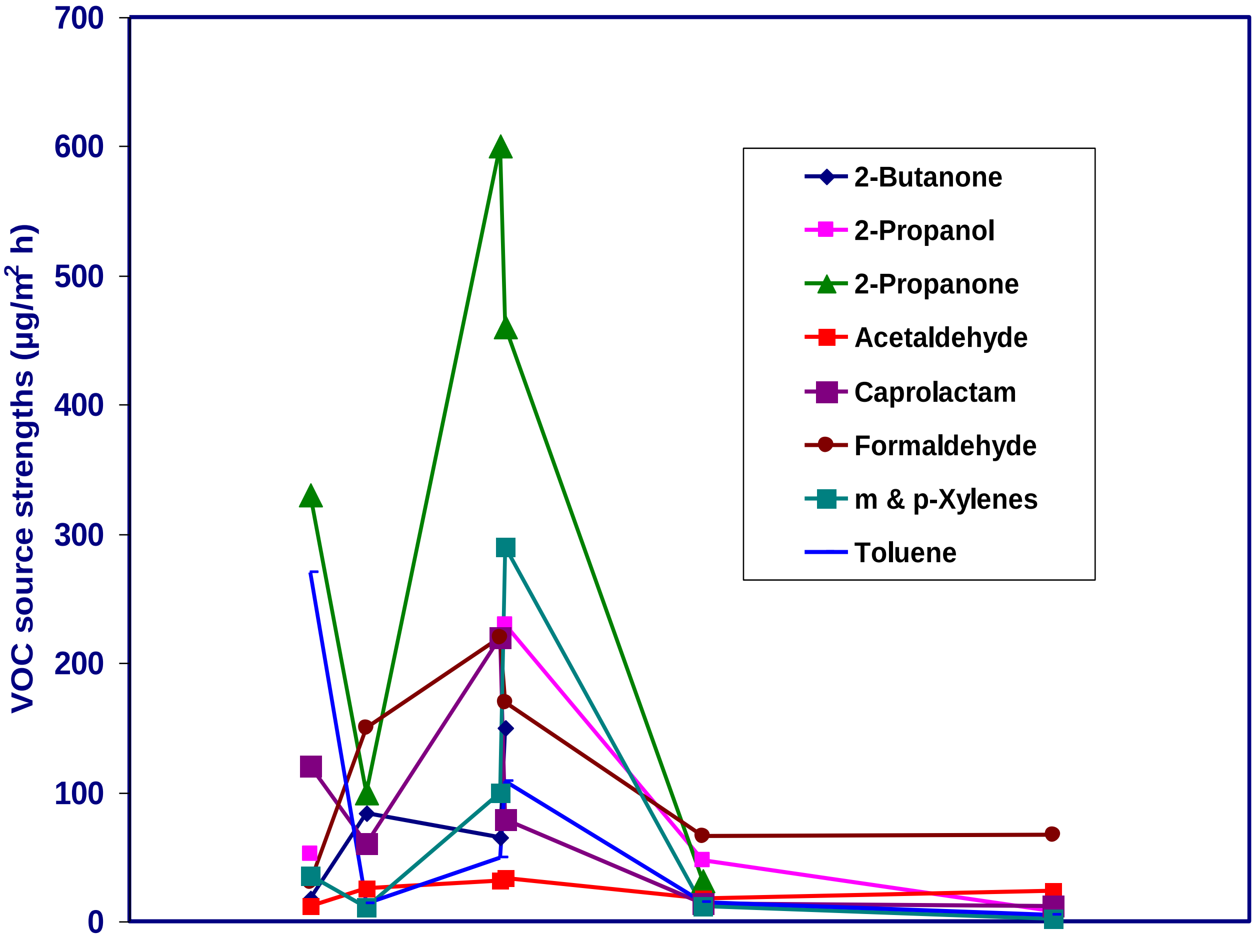

Emissions Test Standards

- ASTM D5116 -- General guidelines
- California Section 01350 (01351)
- BIFMA
- FloorScore
- SCS
- Various European standards, e.g. E1

Reasons to do emissions testing

- Purpose of test determines →
  - Characteristics of the specimens tested
  - Test systems
  - Analysis and use of resulting data
- Emissions tests →
  - Improve indoor air quality
  - Reduce potentially harmful sources
  - Protect occupant health
  - Reduce odor and irritation effects
- Improved air quality enhances occupant comfort and productivity
- Useful to manufacturer
  - increased knowledge, confidence in products' performance
- Reliable, relevant data assist design and purchasing decisions

Historical perspective

- 1970s, NASA tests everything on-board spacecraft -- astronaut safety, protection of technical equipment and spacecraft materials
- Early 1970s, Danish testing composite wood products for formaldehyde - occupant-reported irritation, odor perception, and illness in buildings
- Late 1970s in US, Formaldehyde emissions products used in manufactured housing and mobile homes – health, irritation effects; complaints, litigation
- Early 1980s -- tests of combustion appliances
- DOE: reduced emissions would reduce need for dilution ventilation/energy consumption
- Methods for testing emissions from building materials were developed
- EPA's Office of Research and Development (ORD) began developing methods for testing emissions from building materials
- 1990 -- ASTM small chamber test guidance document, D5116-90, basis for European small chamber emissions test standards

Today Testing is More Common

- **Emissions test results used for existing and proposed design standards and guidelines**
  - **US Green Building Council's LEED rating systems**
  - **State of California buildings, study**
  - **European Commission/member states guidelines and standards**
  - **CEN standards**
  - **ISO standards**
  - **Many state and local government building projects**
- **Draft IAQ guidelines by EPA's Indoor Air Division**
- **Green building guidelines --> EPA's Office of Pollution Prevention and Toxics**
- **Tichenor report on EPA IAQ web site.**

Current Status

- Many U.S. groups (including Scientific Certification Systems, GreenGuard) developing certifications based on emissions test results
- California standards development produced important innovations in testing practices, interpretation of results (health basis)
- Trade association test standards in Europe and America, especially for floor coverings, paints
- Major issues remain to be addressed adequately

Different Types of Test Apparatus

- Chambers:
  - Various “traditional” small and large chambers
  - Field and Laboratory Emission Cell (FLEC)
  - Climpak
  - Several variations of these devices
- Test chamber materials:
  - Mostly polished stainless steel
  - Glass in some test systems (*e.g.*, the Danish Building Research Institute’s Climpak)
- Non-uniformity increasing?

Challenges and Opportunities

- Specimen Acquisition
- Number and frequency of tests – (sampling issue)
- History of specimen environmental exposure or pre-test conditioning
- Chamber performance
- Sample collection and analysis
- Realistic Substrates for wet-applied products
- Exposure scenarios for models to calculate potential concentrations
- Pass-Fail criteria vs. relative or absolute values.

Standardized “Realistic” Substrates

- Need for realistic substrates for wet applied products, especially adhesives, paints or floor coverings
  - Adhesives on glass or stainless steel don’t behave “realistically”
  - Real substrates are wood products, concrete, drywall, or plaster
  - Distortion of the drying and associated emissions process
  - Misleading test results
- Importance: these products frequently replace products in existing buildings -- occupants exposed to them close to installation time point and more frequently over building life
- Need to evaluate surface cleaning, polishing, refinishing products/procedures -- greater likelihood of occupant exposure to emissions

Issues to Resolve

- Specimen Acquisition, Handling, and Conditioning
- Standardized, “Realistic” Substrates for Wet Products, Assemblies: What can “inert” substrates tell us about what we want to know?
- Frequency of Testing – Do product variability and modifications require more frequent testing than is now done, or are the changes unimportant?
- Generalization of Results from limited “representative” sample testing – how much testing is needed? How much uncertainty is tolerable?
- Chamber standards and performance criteria: calibration, performance verification, certification, maintenance
- Test atmosphere: potential effects of oxidants on emissions and formation of secondary products
- Laboratory analytical chemistry performance standards and inter-comparisons: Need for standards, certification, and maintenance
- Odor-based Evaluations and Methodology Development
- Health-Based Concentration Limits Needed: general problem for IAQ, important problem for interpretation of emissions test results -- criteria for 1) Acute, 2) Chronic, 3) Genotoxic effects

Issues to Resolve - 2

- Total VOC Concentrations (as indicator of product stability, test system stability, health effects, odor). Absolute versus relative values, methods of calculation/quantification, SumVOC vs. TVOC, response factor.
- Semi-volatile organic compound (SVOC) emissions, sink effects, length of testing required for stable system
- Sustainability Criteria related to emissions: short and long-term considerations
- Manufacturer Product Improvement Initiatives & Responsibility in QA
- Need/Demand for Simplification of Tests and of Test Results vs. Accuracy and Completeness, Usefulness, Database inputs
- How to Handle Uncertainty? How much Uncertainty is Acceptable?
  - *Test Specimen Variability* -- within sheet materials, production run, day-to-day variations, different plants, manufacturers of similar products, storage conditions and ages of specimens
  - *Analytical Uncertainty* -- Chamber air flow rate, Specimen surface area, Sampling volume, Integrated chromatographic peak area, Response factor, Relative response factor for VOCs
- Governance of Emissions Testing? Who Decides What for Whom?

Future Steps

- Develop ASTM Standards for General Protocols and Requirements
- Develop Product Class-Specific Standards for Emissions Testing
- Inter-laboratory comparison criteria and “round-robin” tests
- Education and training of emission testing personnel and users of results
- Additional Acceptable Reference Exposure Level Criteria– odor, acute, chronic, and cancer endpoints
- Emission Testing Protocols for Cleaning and Maintenance Products
- Development of Standardized Substrates for Composite Samples and Testing of Material/Product Assemblies
- Reliability of Test Results: Laboratory Quality Assurance and Certification
- Standards and Procedures for Certification of Materials, Certification of the Certifiers
- Database design, development, quality assurance, and long-term maintenance
- Public education: interpreting labels, other uses of emission test results

Beginnings (vs. conclusions)

- We are just beginning to understand the complexity of the environment
- Carefully identify the material, product, specimen, “species” that you are studying
- Keep working, don’t give up
- “The best way to predict the future is to create it.”