

we have prepared the recommended test report format in Table 1; its use will assist

in comparing results among different tests. ♦

Table 1 — Recommended test report format

- A. TESTING LABORATORY
- Name
 - Phone
 - Address
 - Certifications
- B. TEST SPECIMEN
- 1. Product Identification
 - a. Manufacturer
 - b. Product Name
 - c. Color or pattern
 - d. Model Name, Style, or Numerical Designation
 - e. Other Identifying Information
 - 2. Acquisition and Handling
 - a. Date Received
 - b. Test Specimen Age or Date of Manufacture
 - c. Description of Packaging
 - d. Storage Conditions
 - 3. Conditioning
 - 4. Preparation of Test Specimen
- C. CHAMBER TEST CONDITIONS
- 1. Temperature
 - 2. Humidity
 - 3. Air velocity
 - 4. Air exchange rate
 - 5. Dates of testing
- D. SAMPLE COLLECTION
- 1. Timing and Duration
 - 2. Chamber Loading Ratio
 - 3. Collection Media
 - 4. Sampling Rate
 - 5. Chemical identification/quantification methods and procedures
- E. RESULTS
- 1. Procedures Used for Identification of Compounds
 - 2. Emission Factors for Predominant Compounds*
 - 3. Emission Factors for Specified (additional) Compounds*
 - If absence of any substance is claimed, the relevant detection limit(s)
 - 4. Total measured organic compounds (in units of toluene equivalents)
- F. QUALITY ASSURANCE AND QUALITY CONTROL

* Measure emission factors as follows:

surface materials and coatings, milligrams/hour per m²
 sealants and adhesives, milligrams/hour per kg;
 furniture, machines, and other items, milligrams/hour per unit .

Research Briefs

Europeans Report Materials Test Results

Researchers at The Environment Institute of the Joint Research Centre (part of the Commission of the European Communities) in Ispra, Italy, have just reported another valuable research project. The article describing the work is titled "Chamber Testing of Organic Emission from Building and Furnishing Materials." It describes in detail the study of emissions from samples of three building material assemblies.

The article reports on several aspects of the work that will be useful to others developing and conducting small chamber emissions tests for various products. We highlight some of those aspects in this article, including chamber construction and operation, sample material preparation and conditioning, chemical sampling and analysis, compound identification and quantification, test results, data interpretation, and health implications of the dominant emitted compounds.

The Materials Tested

The tests were part of an inter-laboratory comparison organized by the Hygiene Institute of the Aarhus University, Denmark. Material samples arrived in aluminum foil envelopes reportedly sealed between two and four months after manufacture. Tests were made of duplicate sample specimens. The materials were the following:

- 1) Particle board (thickness = 22 mm, 7/8 in) with glued-on carpet (thickness = 5 mm, 0.2 in) of "high resistance."

- 2) Gypsum board with glued-on wallpaper on both sides (overall thickness 18 mm, 0.7 in).
- 3) Plywood sandwich with outer layers 1 mm thick, one of which was stained and painted with polyurethane lacquer (overall thickness = 6 mm, $\sim 1/4$ in).

Edges of cut samples were sealed with sodium silicate to avoid bias due to the normally higher emissions from cut surfaces.

Test Chambers Construction and Characteristics

Two glass chambers were each 100 x 80 x 60 cm (39 x 31 x 24 in), with an internal volume of 450 l (~ 15.9 cu ft). A stainless steel frame supported the glass which was attached with "Loctite" adhesive. A silicon seal on the outside of the frame-glass joints provided further protection against leakage. Researchers sealed the inside edges of the joints with self-adhesive PTFE tape.

One of the smaller side walls served as a door. The sealant was a Gore-Tex gasket. Several 20-mm holes drilled through the glass allowed attachment of air inlets, outlets, instrument connections, and sampling ports. The researchers used PTFE flange joints for appropriate diameter (generally 6 mm) stoppers of the same material.

The researchers evaluated chamber tightness experimentally and found infiltration rates equivalent to 0.0027 - 0.0060 air changes per hour (ACH). This infiltration level is approximately 1-2% of the air flow rate used in the chamber.

A nine-cm diameter metal fan operating at 2,700 RPM mixed air in the chamber. The internal circulation produced by this fan equaled 13.7 m^3 per hour, or 30.5 ACH. Mixing within the chamber

appeared adequate according to the results of samples collected at various points in the chamber. A pure air generator (Aadco 737) produced clean air from filtered air supplied by the laboratory network. Air flow through the chamber was controlled by an electronic mass-flow controller and maintained between 1 and 20 liters per minute. This air contained a residual of $5.4 \pm 1.1 \mu\text{g}/\text{m}^3$ in the volatility range covered under the experiments.

A glass spray nozzle, driven by air flow derived from the main stream of clean air, maintained relative humidity between 10 and 90%. The researchers developed the device in the laboratory. A sensor with 3% precision controlled the device. It had fluctuations within 0.2% caused by the regulation mechanism.

The test chambers and humidification devices were located within 10 m^3 environmental chamber with temperature control between 15 and 35 °C (± 0.5 °C).

Chambers were calibrated with known concentrations of organic solvents to determine the proper working of the chamber as well as the collection and recovery efficiencies of the sampling and analytical system. Tests carried out using three common solvents resulted in a 0.987 ± 0.036 ratio of observed to expected concentrations, not significantly different from a value of one. The researchers note that sinks were observed for some compounds.

Conditioning Period

To determine the conditioning period in the chamber (time required to reach equilibrium) the researchers measured their emissions as a function of time. They measured emissions for each

product for different periods reflecting the different time constants associated with emissions decay. These periods were about 14 days for particle board, 2.5 for gypsum board, and 10 for plywood.

The concentrations versus time were plotted and an empirical mathematical model developed to describe the results and plot the rate of change of concentration (the slope of the curve). The conditioning period was limited to the time after which the decrease in the ratio of slope to concentration was $\leq 10\%$ per day. This convention resulted in conditioning periods of 8, 18, and 6 days respectively for the three materials. For practical reasons, the researchers used conditioning periods of 7, 2, and 5 days.

The appendix of the published article describes the calculation method for deriving the "best fitting equation." Because the testing itself can be expensive and time-consuming, mathematical modeling and calculation is an economical way to maximize the benefits of an emissions measurement program.

Figures 1 - 4 show the concentrations versus time of selected compounds from four of the curves plotted from the tests. Note that the scales of both the x- and y-axis are different in the four plots. There are large differences in the shapes of the curves, indicating some of the very large range of differences that must be considered when determining conditioning time for emissions test.

Test Conditions

The test conditions are listed in Tables 2 and 3.

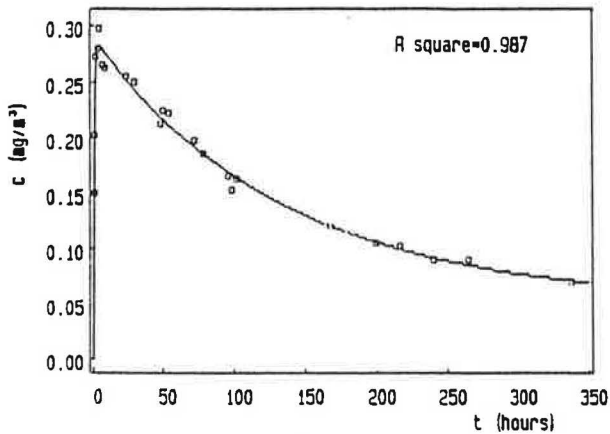


Figure 1 — Best fit to concentration data of longifolene from particle board.
A = 0.2909; B = 1.343; c = 0.2385; D = 0.0075.

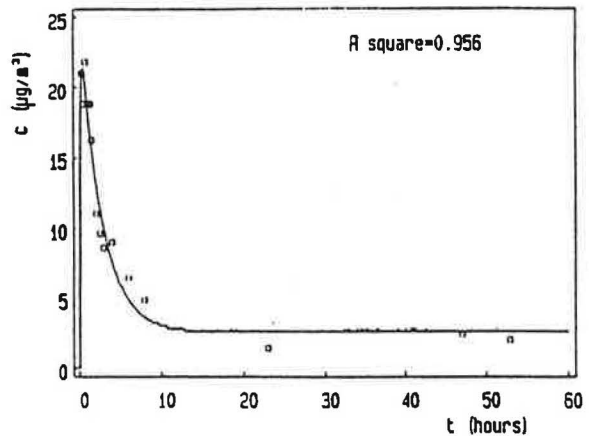


Figure 2 — Best fit to concentration data of toluene from gypsum board.
A = 25.81; B = 8.320;

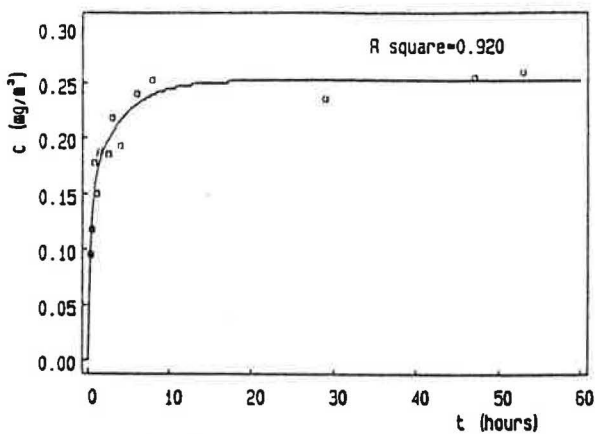


Figure 3 — Best fit to concentration data of hexanedioic acid, bis(2-methylpropyl) ester from gypsum board.
A = 0.1485; B = 3.379; C = 0.1039; D = 0.2627.

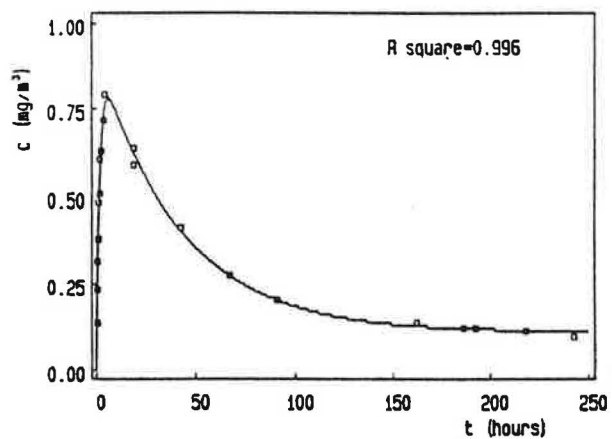


Figure 4 — Best fit to concentration data of n-undecane from plywood.
A = 0.9185; B = 0.5627; C = 0.8079; D = 0.0240.

Table 2 — Chamber test conditions

Temperature = 23°C
Relative humidity (RH) = 45%
Chamber ventilation rate = 0.25 ACH (air changes per hour)

Test Results

The results from the separate materials differed significantly from each other in the number of quantifiable and identifiable compounds and the magnitude of the measured emissions. The total of quantified VOC emissions for the

particle board/carpet assembly was 25 times higher than that of the gypsum board/wallpaper assembly. The total of measured VOC emissions from the plywood assembly was between the other two.

Quantified emission rates for individual compounds ranged from a high of 2.44 mg/m²/hr for hexanal emitted from the particle board/carpet assembly down to 0.0060 mg/m²/hr for formaldehyde from the plywood assembly. The four highest emission rates were for four compounds emitted by the particle board/carpet assembly. Only formaldehyde was measured

Table 3 — Loading ratios of materials (square meters, both sides of material) per chamber volume (cubic meters)(m²/m³)

Particle board:	0.4 m ² /m ³
Gypsum board:	1.4 m ² /m ³
Plywood:	0.2 m ² /m ³

in the emissions from all three test materials.

Particle Board/Carpet Assembly

The particle board measurements resulted in quantification of 22 compounds comprising >80% of the FID (flame ionization detection) response in area counts. The researchers identified eighteen additional compounds, and 13 compounds could not be identified. Thus, the researchers observed a total of 53 compounds emitted from this material.

Gypsum Board/Wallpaper Assembly

The researchers reported quantification of six compounds, four of which accounted for 94% of the FID signal. They identified an additional 13 compounds for a total of 19 identifiable compounds emitted from the test specimen.

Formaldehyde emissions were unexpectedly high: >10% of the value observed for the particle board sample and higher than the plywood emission. The researchers separately evaluated the gypsum board and the paper-glue assembly to determine the source of the formaldehyde emission. The results (12 µg/g and 0.5 µg/g from the paper-glue layer and the gypsum board layer respectively) indicate that the emissions were almost exclusively from the paper-glue layer.

Stained, Painted Plywood

Thirteen quantified compounds emitted from this material represent about 50% of the total FID signal. The researchers identified 90 additional compounds and were unable to identify six more. Thus, this material emitted a total of 109 compounds. (See Table 4.)

The researchers noted a "surprisingly high" emission rate for hexanal contained in the lacquer covering one side of the panel. They pointed out that the hexanal emission rate from this material was higher (0.12 mg/m²/hr) than the formaldehyde emission rate from the particle board sample (0.077 mg/m²/hr).

Occurrence Indoors and Significance of the Measured VOC Emissions

The researchers state that the most important class of compounds from a health standpoint is the aldehydes, known to be strong irritants. Of these, "...formaldehyde appears the critical compound." Therefore, they modeled a hypothetical room (23.5 m³ volume) with walls covered by the particle board. This would constitute a loading ratio of 1.33 m²/m³. Using an assumed air change rate of 0.5 ACH, they calculated an equilibrium concentration of 0.21 mg/m³. They point out that the emission rates will decrease with time but that other materials and household products will also emit formaldehyde. They

compare the formaldehyde equilibrium concentration to the WHO guideline value (0.1 mg/m³) for general population exposure and to reports in the literature of mean and 90th percentile formaldehyde concentrations of 0.060 and 0.12 mg/m³.

Although the concentrations of other measured compounds observed in indoor environments are normally much lower than guideline or threshold limit value (TLV) concentrations, the researchers point out that these values are not based on exposure of susceptible populations for more than a normal work week. Furthermore, they state that the indoor pollution of concern consists of complex mixtures of many compounds in which synergistic mechanisms may pertain. While these facts point to the need for long-term epidemiologic investigations, they suggest that the "dominant role of indoor air pollution must be adequately taken into account in the exposure evaluation."

Conclusions

- The researchers concluded that their procedures and equipment appear "adequate for testing small samples of different building or furnishing materials."
- They state that their methods would not adequately detect very volatile compounds. [They

Table 4 — Emissions by material

Product	Number of Quantified Compounds	Number of Identified Compounds	Total Number of Compounds
Particle board:	22	18	53
Gypsum board:	6	13	19
Plywood:	13	90	109

used Tenax as their sorbent. — Ed.]

- The wide variations in emission-versus-time profiles were due to the different volatility of the compounds and the different material components. These circumstances and chamber factors may influence emission rates. Therefore, they believe extreme care is necessary to obtain reliable emission rate factors.
- Simple mathematical models are needed that adequately describe the complex physical phenomena occurring in the test chambers. More work is needed to arrive at such models.

Implications

We believe that the work discussed here demonstrates that emissions tests can be successfully and reliably performed. Clearly more research is needed to help testing organizations minimize the time and cost involved. But, for large manufacturers and suppliers, the cost and effort is minimal in relation to the potential benefits. These include identifying emissions that can or should be reduced in their products. Improved products can result in decreased liability and new marketing opportunities.

For More Information

A. Colombo, M. De Bortoli, E. Pecchio, H. Schauenburg, H. Schlitt, and H. Vissers, "Chamber Testing of Organic Emission from Building and Furnishing Materials." *The Science of the Total Environment*, Volume 91, (1990) pp. 237-249. ♦

Legionella Pneumophila Grows on Surfaces

Researchers in Calgary, Canada, have found that *Legionella pneumophila* not only is capable of growing on various metallic and nonmetallic surfaces but is "preferentially found on surfaces." This finding has important implications for researchers, building investigators, and building operators.

The researchers suggest that bacteria adhering to surfaces may be an important reservoir of "potential pathogens in aquatic environments." The researchers conclude that efforts to comprehensively monitor the occurrence of *L. pneumophila* "must include not only water samples but also an examination of the adherent populations."

The researchers believe that by monitoring surface-adhering *L. pneumophila* populations, it may be possible to predict the likelihood of a Legionnaires' Disease outbreak.

By developing a unique sampling apparatus, the researchers were able to aseptically remove samples for examination by scanning electron microscopy. Researchers examined both planktonic (passively floating organisms in water) and sessile (attached by the base) samples to determine the number of bacteria present in both populations, both *in vitro* and *in situ*.

In situations where investigators or building operators know or suspect the presence of *L. pneumophila*, it may be useful to analyze surface samples as well as water samples in the suspected reservoirs.

Where sampling demonstrates the presence of unacceptably high levels of *L. pneumophila* in water, surfaces should be cleaned during

decontamination efforts to prevent reinfestation.

For More Information

J. B. Wright, I Ruseska, M.A. Aathat, S. Corbett, and J. W. Costerton, "*Legionella pneumophila* Grows Adherent to Surfaces *in vitro* and *in situ*." *Infect Control Hosp Epidemiology* 1989; 10(9):408-415. ♦

News and Analysis

Mandatory Building Bake-outs?

California state legislators are considering a bill to require bake-outs of all new buildings slated for public occupancy. A bill recently introduced into the State Assembly requires "detoxification" of all new buildings. The bill mandates the California Department of Health Services to promulgate regulations for the detoxification process.

The word "detoxification" replaced the term "bake-out" because the Legislative Analyst's Office was not familiar with the term. The bill does not spell out details of the requirements; it leaves that to Health Services, which has conducted some interesting pilot tests of building bake-outs. (See *IAQU*, December 1988, July 1989, February 1990.) No money is authorized to support the effort at Health Services.

A proper bake-out takes a minimum of three to four days, and ideally at least a week. It could cost a building owner \$0.25 to \$0.50 per square foot in direct costs plus foregone rents for the delayed occupancy time.

The bake-out process is not yet adequately understood, and considerable laboratory and field research