ASTM Conference on Indoor Emissions Testing—Methods and Interpretation
Sponsored by Committee D22 Air Quality and Subcommittee D22.05 on Indoor Air
October 4-5, 2004, Washington, DC

Indoor Source Emissions Testing: State of the Science and the Art

H Levin

Building Ecology Research Group, Santa Cruz, CA
Phone: 831 425 3946 Email; hal.levin@buildingecology.com

Abstract
The purpose of this presentation is to provide a brief overview of building materials emissions testing and its place in indoor air and to identify the major issues that remain to be resolved. The focus will be on major accomplishments, critical issues, and current challenges.

Introduction
There are many reasons to do emissions testing, and the purpose of the test should determine the nature or characteristics of the specimens tested, the test systems, and the analysis and use of resulting data. Emissions tests are done primarily to improve indoor air quality by reducing potentially harmful sources, thereby protecting occupant health and reducing odor and irritation effects. It is believed that such improved air quality will result in enhanced occupant comfort and productivity. Emissions testing is also useful to manufacturer who gain increased knowledge of and confidence in their products' performance. Finally, reliable, relevant emissions test data can assist in design and purchasing decisions.

Historically, beginning in the 1970s, the National Aeronautics and Space Administration (NASA) tested everything that went on board spacecraft to ensure the safety of the astronauts and the protection of the technical equipment and spacecraft materials. In the early 1970s, Danish researchers began testing composite wood products for formaldehyde and other emissions believed responsible for occupant-reported irritation, odor perception, and illness in buildings. Formaldehyde emissions from composite wood products used in manufactured housing and mobile homes became a major focus for health and irritation effects complaints and litigation in the late 1970s. In the early 1980s, a few organizations including Lawrence Berkeley Laboratory (LBL) tested combustion appliances for emissions that might be life threatening or capable of other, less serious health effects. It was recognized that reducing emissions could reduce the need for dilution ventilation and, thereby, reduce building energy consumption, so methods for testing emissions from building materials were developed. Shortly thereafter, EPA's Office of Research and Development (ORD) began its program developing methods for testing emissions from building materials. That work eventually produced the first general ASTM emission test guidance document, D5116-90, now under revision as D5116-97. That document formed the basis for European emissions test standards and is still regarded internationally as the most important guidance document on emissions testing.

Today, emissions test results are being used as the basis for existing and proposed design standards and guidelines including US Green Building Council's LEED rating systems, State of California buildings, European Commission and member states guidelines and standards, CEN standards, ISO standards, and many state and local government building projects. Draft IAQ

guidelines are being developed by EPA's Indoor Air Division and are being included in broader building guidelines being drafted by EPA's Office of Pollution Prevention and Toxics (OPPT).

Current Status

A number of major issues remain to be addressed adequately. California State government has engaged in a process of standards development in recent years that has produced some important innovations in the testing practices and interpretation of results. Many groups in the United States including Scientific Certification Systems (SCS) and GreenGuard are developing certifications based on emissions test results, and there are many issues that have emerged as a result of these developments.

California became involved in IAQ issues earlier than most states due to problems in some innovative state office buildings beginning in 1981. As a result, not only state buildings but also many private sector buildings were the focus of more intense efforts to control indoor air including attention to emissions from building materials and furnishings. Some of these developments are documented in a paper by Levin and Alevantis on the state's emissions testing specifications (2003). One of the primary goals was to develop testing that was health-based and that looked at chronic exposure rather than worst-case initial emissions.

In Europe test methods are being developed by industry associations including various German and Scandinavian materials manufacturers, the Danish Building Research Institute, and many others. Among the fundamental issues are the characteristics of the test specimens, the duration of tests, and the criteria used to evaluate the results. The Germans have also developed a health-based set of criteria for determining the pass-fail status of tested materials.

There are also a number of different types of test apparatus being employed including "traditional" small and large chambers, the Field and Laboratory Emission Cell (FLEC), the Climpak, and other variations on the basic configurations of these devices. Some of these issues are discussed below. Most test chambers are made from polished stainless steel although glass is still used in some test systems (e.g., the Danish Building Research Institute's Climpak).

There is a need to develop standardized "realistic" substrates for wet applied products, especially paints and floor coverings with adhesives. Emissions from adhesives applied to glass or stainless steel cannot behave as they do when applied to wood products, concrete, drywall, or plaster. The result is distortion of the drying and associated emissions process and misleading test results. Since these products are usually the most frequently replaced products in existing buildings, occupants tend to be exposed to them closer to the installation time point and more frequently over the life of the building. In addition, building finish material surface cleaning and refinishing products and procedures need to be evaluated for similar reasons related to the greater likelihood of occupant exposure to their emissions.

Challenges and Opportunities

There are many challenges related to emissions test protocols that remain to be addressed. Among these are 1) Specimen Acquisition, 2) Number and frequency of tests – (sampling issue), 3) History of specimen environmental exposure or pre-test conditioning, 4) Chamber

performance, 5) Sample collection and analysis, 6) Exposure scenarios for models to calculate potential concentrations, and 7) Pass-Fail criteria vs. relative or absolute values.

Issues to Resolve

Numerous major issues remain to be addressed by the indoor air and emissions testing communities. Among them are the following:

- Specimen Acquisition, Handling, and Conditioning: What is the most representative sample collection and preparation?
- 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 and the potential effects of oxidants on emissions and the 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: A general problem for IAQ and an important problem for interpretation of emissions test results. Need criteria for 1) Acute effects, 2) Chronic effects, and 3) Genotoxic effects.
- Significance of 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 factors.
- Emissions Testing Considerations for 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 and Responsibility in Quality Assurance, variability within and between batches and factories, source chemicals.
- 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* (Magee *et al*, July 2003): Variability within a single sheet of sheet materials, production run, day-to-day variations, different plants from a single manufacturer, different manufacturers of similar products, storage conditions and ages of specimens.
    - *Analytical Uncertainty* (Magee *et al*, 2003**)** can result from the following**:** Chamber air flow rate, Specimen surface area, Sampling volume, Integrated chromatographic peak area, Response factor, and 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 on the interpretation of labels or other uses of emission test results

Conclusions

While much progress has been made to date, a large number of technical and institutional issues remain to be resolved. Some of these can be addressed in the standards development process. Other issues require further research as well as collaboration between and among industry and those who do and use emissions tests. Further emphasis must be placed on development of protocols and selection and use of "realistic" substrates for tests of wet-applied products. Some issues need to be resolved prior to efforts to codify practices and utilize unrefined testing protocols to guide decisions for which the results are being used. Development and use of emissions test results databases must be conducted with extreme care and disseminated with sufficient protection against misinterpretation or misuse of results.

References

1. Levin and Alevantis, 2003. "California Indoor Air Quality Specifications for Open Office Systems Furniture and Building Materials." EPA/AWMA Indoor Air Quality Problems and Engineering Solutions, Research Triangle Park, NC, July 2003.
2. Magee, RJ, D Won, CY Shaw, E Lusztyk, and W Yang, 2003. "VOC Emissions from building materials – the impact of specimen variability – a case study." EPA/AWMA Indoor Air Quality Problems and Engineering Solutions, Research Triangle Park, NC, July 2003

Links to Selected URLs of Interest

http://www.cal-iaq.org/VOC/
http://www.oehha.org/air/chronic_rels/allChrels.html
http://www.ciwmb.ca.gov/GreenBuilding/Specs/
http://www.ciwmb.ca.gov/greenbuilding/Specs/Section01350/METStudy.htm
http://www.oehha.org/risk/chemicalDB/acutereference.asp?name=formaldehyde&number=50000
http://eetd.lbl.gov/ied/
http://www.epa.gov/iaq/
http://www.sbi.dk/english/
http://www.ami.dk/?lang=en
http://www.wki.fhg.de/english/index.html
http://www.umweltbundesamt.de/uba-info-daten-e/daten-e/voc.htm