National Programs to Assess IEQ Effects of Building Materials and Products

Charge for this report

Background: Building materials, interior furnishings, surface treatments, paints, coatings and consumer products have been shown to contribute to indoor contaminants. Currently, information on potential hazards of these chemicals prior to specification, purchase or use of these products is limited. Except for a few cases, regulations to limit or prevent exposures to product-related emissions do not exist in the US. There have been several recent circumstances where introduction of new materials/products have resulted in wide scale exposures followed by research examining potential harmful effects.

Large scale changes to the built infrastructure along with the introduction of new products and energy sources will likely be stimulated by a societal response to climate change. These changes may adversely alter the indoor environments of buildings and homes and may disproportionately affect vulnerable populations such as children, the elderly, or low SES persons. A few nations have requirements in place to anticipant, prevent or mitigate the potential adverse indoor air quality impacts of building materials and products. In the US, the Greenguard Environmental Institute—a non-profit certifying organization—offers a voluntary standard for "qualifying building materials, finishes and furnishings as certified low emitting products for the indoor environment".

Report topic: Describe the national product evaluation programs of Denmark, Norway, Germany and Japan (Korea is also developing a program) and the GREENGUARD and any other US systems. Identify and provide any research that evaluates their impact on indoor environments.

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Introduction

Building materials, interior furnishings, surface treatments, paints, coatings and consumer products have been shown to emit volatile organic compounds (VOCs) and result in the presence of indoor air contaminants. (Andersen et al, 1974; Mølhave, 1983: National Research Council, 1981a, 1981b; Girman et al, 1986; Levin and Hahn, 1986; Tucker,1988, 1990; Levin, 1989a; Kelly, 1996; Hodgson, 1999; Weschler, 2009; ECA, 2007; 2010).

Currently, information on potential hazards of these chemicals prior to specification, purchase or use of these products is limited in spite of a notable increase in relevant activity during the past two decades. Complete information on the associated hazards requires adequate emissions, exposure, and health effects data, all of which are currently insufficient. The data on emissions of chemicals from products is limited to some of the many building products and materials in common use.

Except for a few cases, regulations to limit or prevent exposures to product-related emissions do not exist in the US or Europe. In contrast, in Japan a mandatory program has been established. There have been several recent circumstances where introduction of new materials/products have resulted in large scale exposures followed by research examining exposures and potential harmful effects (CDC, 2008; EPA, 2010a). These have been associated with sheet materials used in large quantities such as plywood, particleboard, and gypsum wall board. Some of the most notorious cases have involved products imported to the United States and widely used due to their lower cost or short-term material shortages, e.g., of gypsum wall board during the widespread rebuilding following Hurricane Katrina in the Gulf Coast states. (EPA, 2010a). Cost-competitive products have long been important in the American construction market, going back to the demise of steel production in the U.S. and the "off-shore" production of such essential steel building materials as nails, bolts, and screws. More recently competition from products manufactured abroad has penetrated the composite wood products industry, sometimes based on wood grown in North America, shipped to the Pacific Rim countries, manufactured, and shipped back to the U.S.

Large scale changes to the built infrastructure along with the introduction of new products and energy sources will likely be stimulated by a societal response to climate change. These changes may adversely alter the indoor environments of buildings and homes and may disproportionately affect vulnerable populations such as children, the elderly or low SES persons. Increased frequency and severity of storms, for example, already appear to have increased flooding in locations as diverse as Boston, Iowa, and the coastal states in the Southeastern United States. Uninsured or underinsured losses are not uncommon, with an estimate that half the losses attributable to such events result in uninsured property damage. (Nutter, 2010). Wildfires and hurricanes have also been recorded more frequently and caused property damage or loss that required temporary or permanent structural replacement (Nutter, 2010). Efforts to mitigate the damage or reduce the hazards already include materials that are marketed to reduce formaldehyde concentrations in indoor air (Sekine and Nishimura, 2001), conserve energy, or reduce mold growth (Leslie, 2008).

As climate-induced deterioration of air quality has already been noted and is expected to become more significant as the climate changes, the indoor environment must serve as shelter from the deteriorated external environment. Ventilation will become more critical, but a focus on energy conservation has already resulted in a dominant focus on reducing energy consumption without concomitant attention to reducing the sources of indoor pollution that ventilation partially addresses. For example, the U.S. Department of Energy, the U.S. Environmental Protection Agency, the American Society of Heating, Refrigerating, and Air-conditioning Engineers, Inc. (ASHRAE), and other organizations have programs and guidelines that encourage energy conservation in designs and occupant behavior while remaining silent on their programs' impacts on the quality of the indoor environment. (DOE, 2010; EPA, 2010b; ASHRAE, 2010).

Product Evaluation Systems and Programs

A few nations have requirements in place to anticipate, prevent or mitigate the potential adverse indoor air quality impacts of building materials and products. Most of these efforts were initiated independent of concerns about climate change, but they are important measures to reduce the negative impacts of changes that are expected to accompany a changing climate. Among these nations are several in Europe as well as Japan and the United States.

Programs exist that range from building material emissions testing and labeling schemes to comprehensive environmental performance evaluation and certification programs. Most existing systems and programs are based on non-regulatory authority and depend on voluntary participation by product manufacturers. Few programs exist at a supra-natural level and most are intended to be used on a national basis. The various programs differ in terms of the parties responsible for the development of the test standards, evaluation criteria, and approval, certification, and labeling. These differences result in a broad range of independence or connection between manufacturers/producers of the products and those responsible for elements of the processes of certification and labeling. Some of the programs focused on building products and materials alone provide evaluation criteria, information to use with these criteria, and ratings of particular products or classes of products based on available data. Finally, there are now a growing number of manufacturers' declarations of material or product content and emissions that include diverse levels of detail regarding emissions. There are efforts afoot now to "harmonize" (make compatible or similar) various labeling schemes in Europe, America and globally.

EMISSIONS TESTING PROGRAMS IN EUROPE

Emissions testing, certification, and labeling programs exist in several European Union Member States. The most prominent, Germany, Finland, and Denmark, are discussed in detail below. There are also programs in France and elsewhere. The European Commission is currently actively seeking to create a "harmonized" emissions test standard for use in evaluating product emissions of VOCs into indoor air. The purpose of the program is to facilitate international commerce and reduce trade barriers within the 27 Member States of the European Union. (ECA, 2005; ECA, 2010)[1]. The initiative will focus on developing product policy that will improve indoor air quality and its health effects on building occupants. There is also an initiative at the European Commission level under the Belgian Presidency to develop a Commission product policy that will enhance indoor air quality (Bluyssen, 2010).

Evaluation of building materials with respect to performance affecting indoor air quality includes sample selection, acquisition and handling, test procedures, and criteria for evaluation. The European harmonization effort currently in progress addresses only the emissions testing. The program that is likely to emerge will have some mandatory and some voluntary elements in order to accommodate the

[1] See excerpts from ECA Report 27 in Appendix ECA27

differences among the programs already in place in several Member States. The adoption of specific limit values or other pass/fail criteria or evaluation schemes will be reserved to the Member States to determine. Additionally, inclusion of testing for semi-volatile organic compounds (SVOCs) and odor testing will be determined by each Member State. The components of the harmonized standard will respect the major existing programs while focusing on the standardization of the emissions testing.

Emissions Testing, Labeling, and Certification Programs in the European Union

The results of emission testing can be expressed in different ways, the most widely used are 'Pass/Fail' systems or quality related classes. This issue has become a point of discussion with regard to labeling in the European Union under the Construction Products Directive (CPD) adopted by the European Commission. The Directive is intended to facilitate trade among the Member States.EU, 2007). Therefore, there is a need for an agreed convention for labeling based on the results of testing according to a harmonized test standard. The process of developing a harmonized standard is currently underway. A workshop was convened by the EU Joint Research Centre in Italy in June 2010 to develop consensus within a larger group including stakeholders. Consistent with the principle of subsidiarity in the European Union, the direction indicated by the process leadership at the workshop was that each Member State will define the criteria to apply to the data obtained by the harmonized standard emissions testing protocol. There will be mandatory as well as optional elements of the standardized protocol.

A second workshop, “Product Policy and Indoor Air Quality,” was scheduled to be held in Brussels in late September, 2010. Table E1 identifies the major emissions labeling programs in Europe.

Table E1. Main material labeling schemes (after Bluyssen, 2010)

Country	Scheme	Detail	Contact
Denmark	Indoor Climate Label (ICL),	Voluntary (private), promoted by Government; open to all types of products relevant to indoor air	http://www.dsic.org/dsic.htm
Finland	M1 Classification Scheme	Voluntary (private), promoted by Government, all types of construction products	http://www.rts.fi/english.htm
Germany	AgBB (Committee for Health-related Evaluation of Building Products),	Applied voluntarily to other building products; Mandatory through inclusion in approval procedure for selected construction products (floorings and adhesives) by DIBt (Deutsches Institut fur Bautechnik).	http://www.umweltbundesamt.de/building-products/agbb.htm
Germany	GuT,	Voluntary (private); textile floor Coverings	http://www.pro-dis.info/aboutgut.html?&L=0
Germany	EMICODE,	Voluntary (private); products for installation of floor coverings	http://www.emicode.com/
Germany	Blue Angel,	Voluntary (private), promoted by Government; several types of products for indoor use	http://www.blauerengel.de/en/blauer_engel/index.Php

Programs of European Countries

The earliest European emissions testing took place in Denmark. Ib Andersen and his colleagues, then at the Danish Building Research Institute, tested emissions of formaldehyde from chipboard (Andersen et al, 1975). Low ventilation rates and increased use of composite wood products made with formaldehyde-based resins had resulted in increasing concern related to occupant symptoms indoors. The research began the process of attending to emissions, especially formaldehyde emissions, from building materials during the 1970s,

Lars Mølhave conducted an extensive study on emissions of VOCs from building materials and eventually developed guidelines for indoor air exposures to VOCs (Mølhave, 1982; Mølhave et al, 1982). This work forms the basis of an important on-going issue in indoor air research, emissions testing, and professional and commercial practices regarding the use of the TVOC (total volatile organic compounds) concept. His guidelines evolved from experiments with a specific mixture of 22 VOCs based on the presence of the most prevalent compounds identified in the earlier work. He focused on the subjects' responses to various concentrations of the specific mixture in constant proportions, and he presented the guidelines in terms of concentrations of total volatile organic compounds (TVOCs) (Mølhave, 1991). The impact of his work is observable today in the continued use of the TVOC construct by many indoor air researchers and professionals. Limitations on its application and its use as an indicator of health hazards have been discussed widely (Mølhave and Nielsen, 1992; Hodgson, 1996; Andersson, 1997; Mølhave, 2003). But the simplicity of its use has supported its persistence in indoor air quality assessment and emissions testing and certification/labeling.

DENMARK

Danish Indoor Climate Labeling Program (DICL)

The Danish Indoor Climate Labeling scheme (DICL) was presented in 1995 as one of the very first emission classification schemes with respect to indoor air quality. The emissions from products are measured in climate chambers and converted into standard room concentrations. These are evaluated in relation to sensory irritation (eye and upper airways) and odor, considered common complaints in the indoor environment.

The DICL scheme has requirements for the standard room concentration of the substances of concern and also includes a sensory evaluation of the emissions. Substances of concern are those aldehydes and VOCs believed to have an impact on the odor intensity or to result in sensory irritation.

The parameter used as a criterion of acceptance is the time required for the emission of the substances to decay to the point where the room concentrations are below 50% of their sensory irritation estimate cited in VOCBASE[2] (Jensen and Wolkoff, 1996)). The use of 50% of the irritation threshold was adopted as a pragmatic safety factor that accounts for the possibility of contributions of the same substance from other pollution sources.

The time required for the model room concentrations to fall below the threshold is the so-called 'indoor-relevant time-value.' Carcinogenic compounds belonging to Category 1 of the IARC Monographs (except formaldehyde) must not be present in the emission.

The results of the chemical analyses are supplemented by a sensory evaluation of the emission. The evaluation covers acceptability and odor intensity and is performed by an untrained panel of at least 20 persons.

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[2] VOCBASE is a database of volatile organic compounds including thresholds for various effects. It was developed by the Danish National Institute of Occupational Health. It is no longer available outside Denmark due to concerns about the potential for lawsuits.

In addition to the chemical emission testing, ceiling systems are tested for the release of particles and fibers. Release of particles and fibers is classified in one of three categories: Low, Medium or High. Only ceiling systems with low or medium particle release can achieve the Danish Indoor Climate Label.

The labeling license has to be renewed every year by affirmation of the product information given to DICL. Emission testing and release of fibers and particles have to be performed every 5 years. Furthermore, the DICL requires the manufacturer to provide manuals for the labeled product's handling, storage, cleaning and maintenance to prevent deterioration of the product's IAQ properties during use.

The DICL scheme was peer-reviewed and published in 1996 (Wolkoff and Nielsen 1996) and appears as a recommendation in the Danish Building Code of 1995, 2005, 2008 and 2010, and in many performance requirements of Danish building societies.

The structure of the DICL is open and allows easy implementation of new product areas. The 11 existing testing and labeling criteria cover a wide range of products representing large surface areas in the indoor environment: e.g. ceiling and wall systems, textile flooring materials, resilient and wood-based floors, interior building paint and furniture. The maximum allowed time-value is set individually from product area to product area. This makes it possible to set the acceptance criteria dependent on the performance of the products on the market. As per January 2010 more than 2000 individual products are covered by a labeling license.

Testing conditions

Tests are conducted under standardized conditions and modeled on the basis of a standard room with specific dimensions. Thus, the labeling of a product is generic and does not take into account the actual use of the product in a particular building or the ventilation rate and regime where the product will be used. The standardization of the test conditions and the calculations allow comparison among products but do not provide for the variations in the use of products or the buildings where they are used.

Distinguishing characteristics: Evaluation criteria and results

A key features of the Danish Indoor Climate Labeling program, as distinguished from virtually all other programs in Europe and globally, is the nature of the test results. Threshold concentrations for irritation and odor are adopted from recognized authorities. The emissions test results are used to calculate the number of days after production that a material's emissions will be reduced to less than half the applicable threshold values. This number of days is the basic result of the DICL. In other words, the 'indoor-relevant time-value' is the time it takes from a product is installed till the emissions of all single substances are down at an acceptable concentration in the indoor air - based on odor and mucous irritation thresholds for eyes and upper respiratory passage as well as standard room considerations.

Carcinogenic and allergenic properties of chemicals are not currently included. The program plans to add these criteria when generally accepted indoor air threshold values concerning carcinogenic and allergenic effects are defined.

Air quality comfort thresholds for more than 800 chemical substances as well as other physio-chemical parameters are given in the databank "VOCBASE" (5), which is the reference databank of the laboratories. The odour often becomes the determining factor, as the odour thresholds generally are magnitudes lower than mucous membrane irritation thresholds and thresholds of more severe effects.

Particle Emission

For ceiling systems an examination of the particle emission is carried out in excess of emission testing (indoor-relevant time-value). Emission of particles from ceiling systems are determined by sedimentary dust consisting of particles including fibres, which could cause irritation on skin or in eyes, nose or upper respiratory passage in the first time after installation.

It is assumed that the irritative impact from more compounds at the same time is bigger than the irritative impact from an individual compound. When there are more compounds, which is often the case, the requirement to the concentration is made on the level of a sum of compounds and not on the level of one single compound. The sum formula does not apply in the case of odor. The measured indoor-relevant time-value is given in whole days.

Evaluation of Sensory Determination

When the indoor-relevant time-value is determined from the chemical analyses a sensory evaluation of the acceptability and intensity of the air is carried out at the time corresponding to the time-value based on chemical testing. The sensory determination is used as a total and supplementary determination of the air quality. The odor panelists indicate their evaluations on two continuous scales regarding intensity (scale from no odor to overwhelming odor) and acceptability (scale from clearly acceptable to clearly unacceptable) of the air compared to reference air. An acceptability of “0” (just acceptable) and an odor intensity of “2” (moderate odor) can, for example, be used as the limits for acceptable air quality.

A complete, detailed description of the DICL can be found at the web site of the Danish Indoor Climate Society, accessed 5 September 2010 at http://www.dsic.org/princip-uk.pdf

GERMANY

The German program is under the auspices of the AgBB (Ausschuss zur gesundheitlichen Bewertung von Bauprodukten - Committee for the health assessment of construction products) Mandatory implementation of emission tests beginning in October 2004 resulted in 260 approval licenses (based on 350 emission tests) for about 3000 different products in the broad variety of floor coverings. Emission requirements for other types of products including wall coverings, lacquers and other coatings for flooring, adhesives and underlayment are being implemented in 2009-2010 in Germany.

The following description of the AgBB Program is adapted from the English language description of the AgBB program, Health-related Evaluation Procedure for Volatile Organic Compounds Emissions (VOC and SVOC) from Building Products, available on the AgBB web site and is excerpted below (Umweltbundesamt, 2008).

“ In Germany the use of building products is subject to the provisions of the building codes of the Federal States (Länder). These provisions require that built structures shall be designed, built, and maintained in such a way that life, health or the natural environment are not endangered. Building products used in the construction of buildings or integrated in the building have to satisfy these requirements so that chemical, physical or biological influences do not result in any hazard or unacceptable nuisance.”

The Committee for Health-related Evaluation of Building Products, AgBB (Ausschuss für die gesundheitliche Bewertung von Bauprodukten,) considers as one of its main tasks to establish in Germany the fundamentals for a uniform, health-related assessment of building products so that the requirements specified in the building codes of the Federal States (Länder) and the Construction Products Directive are satisfied, and the evaluation procedure that results is as traceable and objective as possible.

In this context, the Committee has presented a procedural scheme for health-related evaluation of VOC emissions from building products used for application indoors [AgBB, 2000]. Within this scheme, volatile organic compounds are defined as those compounds within the retention range of C6 to C16. These compounds are considered both as individual substances and also in calculating a sum parameter following the TVOC concept (Total Volatile Organic Compounds), and semivolatile organic compounds (SVOC) within the retention range from C16 up to C22.

The evaluation criteria are based on the assessment of individual compounds although building occupants are exposed to a multitude of substances. This is accounted for by the total concentration of volatile organic compounds (TVOC). However, it should be emphasized that a TVOC guideline value – due to the varying composition of the VOC mixture occurring in indoor air – cannot be based on toxicological conditions. However, there is sufficient evidence that with increasing TVOC concentration the likelihood of complaints and adverse health effects also increases.

Since VOC emissions are often combined with odor perception, which may result in health impairment, sensory testing is an important element of the evaluation of building products. However, [AgBB finds that] …it has not yet been possible to integrate this aspect into the current evaluation of building products. Although many different odor measurement methods exist, a harmonized and generally accepted procedure for odor assessment of building products is not yet available.

[F]or residences, the outdoor air flow rate per square meter, i.e., the area-specific air exchange rate is between 1 and 1.5 m3h-1 m-2) depending on the actual living area. Taking the upper limit of this range…, an air exchange rate of approx. 0.5 h-1 is obtained for a room 2.7 m high and with a surface area of 3m x 4m. This value corresponds to the average encountered under practical conditions. Choosing these conditions for the chamber test of, e.g., flooring materials, the substance concentration measured in the test chamber corresponds approximately to that to be expected in such a room. However, differences due to potential sorption effects are not taken into account in this approach.

The AgBB testing and evaluation process is described in Figure AgBB1

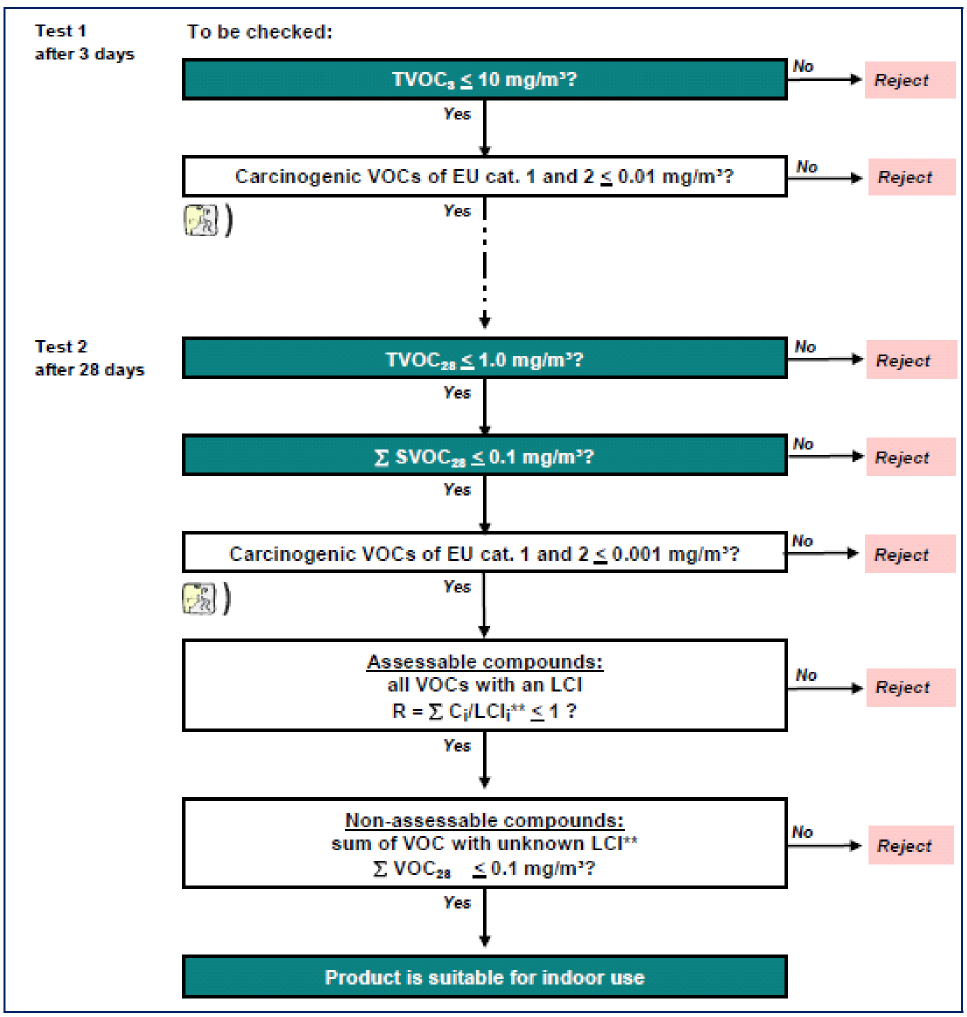

Figure AgBB1. Flow chart for the evaluation of VOC* and SVOC*emissions from building products

The steps in the process are described in more detail below.

Measurement and testing after 3 days
TVOC3: A product satisfies the criteria, if the TVOC value after 3 days (TVOC3) is ≤ 10 mg/m³.

Carcinogenic substances: Every building product has to meet the general requirement of not emitting any carcinogenic, mutagenic or reprotoxic substances. Substances with mutagenic or reprotoxic properties and those with potential carcinogenic effects are checked within the LCI[3] concept) and assigned higher safety factors if necessary. Carcinogens have to be quantified using their individual calibration factors.

First sensory testing: For determining the equally important sensory properties it will be necessary to agree upon more precise details before an initial sensory test can be performed at this stage of the flow chart. Until an adequate test method is available, there is only a reference in the flow chart to the necessity of a sensory test.

Measurement and testing after 28 days
TVOC: In order to assess the long-term behaviour of the VOC emissions from a building product, the TVOC value is determined again after 28 days. This is done in the same way as described for TVOC3. When calculating the TVOC28 value, in addition to the instructions given in DIN ISO 16000/6, it is important to be as complete as possible in the identification of compounds to permit the evaluation of individual substances. A product satisfies the criteria, if the TVOC28 value is ≤ 1.0 mg/m³. Products with a TVOC value higher than that are rejected.

Semivolatile organic compounds (SVOC): Products that satisfy the criteria for VOC emissions but instead exhibit increased emission of SVOC should not be given advantages. To prevent this from happening the SVOC concentration in the chamber air shall also be determined

Products that satisfy the criteria for VOC emissions but instead exhibit increased emission of SVOC should not be given advantages. To prevent this from happening , the SVOC concentration in the chamber air shall also be determined. A product satisfies the criteria if the sum of the SVOC concentrations in the chamber air does not exceed 0.1 mg/m³. This corresponds to an additional content of 10 % of the maximum allowable TVOC28 concentration of 1.0 mg/m³. Higher concentrations result in rejection.

Carcinogenic substances: The emission of carcinogenic substances of EU categories 1 and 2 [Directive 67/548/EEC] is tested again, with an emphasis on the long-term behavior from the user's point of view. No carcinogen of categories 1 or 2 [Directive 67/548/EEC[4]] may exceed the value of 0.001 mg/m³ after 28 days.

A product satisfies the criteria if the sum of the SVOC concentrations in the chamber air does not exceed 0.1 mg/m³. This corresponds to an additional content of 10 % of the maximum allowable TVOC28 concentration of 1.0 mg/m³. Higher concentrations result in rejection.

Second sensory testing: Until the test procedure has been agreed upon finally, the requirement for a second sensory test after 28 days is indicated. The reason for a second test is that chemical reactions may only occur within the product which may lead to odor or other sensory perception.

Evaluation of individual substances: In addition to evaluating the emissions of a product via the TVOC value, the evaluation of individual VOC is also necessary. For this purpose all compounds whose concentration in the chamber air equals or exceeds 1 µg/m³ are first identified, listed with their CAS number, and quantified according to a detailed procedure. The concentrations are then compared with the LCI values for each compound.

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[3] LCI – Lowest Concentration of Interest

[4] The Directive on Dangerous Substances, originally adopted June 27, 1967: It has been amended 30 times since its adoption. An "unofficial" consolidated version is available, accessed 16 September 2010 at http://ec.europa.eu/environment/chemicals/dansub/pdfs/67_548_en.pdf.

A critical aspect of all labeling and certification schemes based on product content or emissions is the basis for acceptance. AgBB uses a list of compounds of interest (LCI) with values for such use. The process of adoption of the values for each compound is described below with text taken from the AgBB 2008 version publication (AgBB, 2008):

> "Since the German regulation TRGS 900 (TRGS: Technical Regulations for Hazardous Substances), does not contain values for all VOC/SVOC possibly emitted from building products, a simplified method has been developed that permits to make use, in addition to the TRGS, of similar (workplace-related) values employed by other European countries. A stepwise procedure is used that takes into account the maximum currently available toxicological evidence for each individual substance, thus enabling the assessment of as many substances as possible. Those substances that still cannot be evaluated are subjected to a strict limitation of their total amount, within the AgBB scheme. The selection criteria are:
>
> I. First, each individual substance is checked, whether it has been evaluated via TRGS 900 and/or an OEL (Occupational Exposure Limit) value by the European Commission. If this is the case, the lowest value is used to establish the LCI value.
>
> II. If condition I is not met, relevant lists from other countries for evaluation of substances in workplace air are examined and the lowest scientifically plausible value used to establish an LCI value.
>
> III. As a further option, a MAK value of the German Research Association (Deutsche Forschungsgemeinschaft, DFG) and/or a TLV® value of the American Conference of Governmental Industrial Hygienists (ACGIH) or a Workplace Environmental Exposure Limit (WEEL) of AIHA (American Industrial Hygiene Association) may be used.
>
> IV. In case a substance cannot be evaluated using conditions I., II. or III., it is checked if an individual substance assessment can be performed, preferably by referring to a substance class with similar chemical structure and comparable toxicological assessment. The lowest LCI value for a substance within this assigned substance class is then used.
>
> V. If a substance fails to meet any of the requirements in items I. to IV., it is then assigned in the scheme to the category of the substances 'with unknown LCI value', the so-called nonassessable compounds (see flow chart). Non-identified substances fall also into this category. "

GUT product labeling system

A private labeling scheme (GUT) for textile floor coverings has been in existence in Germany since 1990. GUT was established in 1990 originally as a German based organization and evolved into a European organization during its first 5 years • Today nearly 90% of the EU producers of wall to wall carpets voluntarily participate in the GUT-System for low VOC-emitting floor-coverings • The GUT-system integrates the whole production chain -from raw materials to final products

FINLAND

Finnish Classification System: Emission Classification of Building Materials

The Finnish classification system is arguably one of the most successful in the world. It is widely accepted by indoor air scientists and professionals as well as manufacturers and other stakeholders. There are now more than 1,500 products classified as M1

[The following description of the Finnish Classification of Building Materials is edited and/or excerpted from the program's web site[5]]

The aim of the classification is to enhance the development and use of low-emitting building materials

The classification presents emission requirements for the materials used in ordinary work spaces and residences with respect to good indoor air quality. M1 stands for low emissions.

Emission Classification is product-specific: Companies which have been granted the right of use of the M1 label may use it for marketing purposes. The Building Information Foundation RTS maintains and publishes a directory of currently classified products and holders of right of use on its website.

The emission classification of building materials is a voluntary labeling system open to all manufacturers, importers and exporters of building products. The Classification does not overrule official building codes or interpretations of them. However, many developers, architects and design engineers favor M1 classified products when selecting materials for their projects. The Finnish Association of Building Owners and Construction Clients (RAKLI), the Finnish Association of Architects (SAFA) and the Finnish Association of Consulting Firms (SKOL) recommend that their members use the classification system in order to promote high-quality construction.

The classifications are granted by the Building Information Foundation (RTS). The Building Information Foundation is Finland's leading information service for the building and construction sector. Its mission is to foster and promote good planning and construction practices as well as sound property management procedures. The Building Information Foundation is a private foundation with representatives from 49 Finnish building organizations.

Classification work is developed and supervised by Committee Indoor Air Classification (EPT 24) appointed by the Director General of the Building Information Foundation. Classification applications and matters relating to classification decisions are examined by a separate classification working group elected by the Committee. The Building Information Foundation treats all documents and information submitted by applicants in support of their application in confidence.

The details of the classification system are described in the following documents (all available for viewing and downloading on the Internet through links on the RTS web site):

- General Instructions
- Classification of Indoor Environment 2008 (Classification of Indoor Environment 2008. Target Values, Design Guidance, and Product Requirements. (2010)
- Testing protocol

The first version of the emission classification was developed by the Finnish Society of Indoor Air Quality and Climate (FiSIAQ) in 1995 as part of Classification of Indoor Climate, Construction, and Finishing Materials. The first emission classifications were granted in 1996.

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[5] Emission Classification of Building Materials (Accessed 5 September 2010 at http://www.rakennustieto.fi/index/english/emissionclassificationofbuildingmaterials.html

M1 criteria and the use of classified products

M1 stands for low emissions. The classification divides building materials into three categories of which M1 is the best. The M1 label means that the product has been tested in an independent and impartial laboratory, and that it has fulfilled the specified criteria at the age of 4 weeks.

Products within classification: The classification presents requirements for the materials used in ordinary work spaces and residences. Design guidance provided in the Classification of Indoor Environment 2008 places no restrictions on the use of following products:

- brick
- natural stone
- ceramic tile
- glass
- metal surfaces
- board and log surfaces made of unprocessed wood (excluding hardwood). The VOC emissions of fresh wood may nevertheless exceed the limit value of emission class M1.

Materials that have not been tested cannot be granted a classification label.

*Criteria for Emission Classes*The emission classification of building materials has three emission classes. Emission class M1 corresponds to the best quality and emission class. M3 includes materials with the highest emission rates.

Classified materials have to fulfill the following criteria at the age of 4 weeks'.

Examined qualities	**M1 [mg/m^{2}h]**	**M2 [mg/m^{2}h]**
The emission of total volatile organic compounds (TVOC).A minimum of 70% of the compounds shall be identified.	< 0.2	< 0.4
The emission of formaldehyde(HCOH)	< 0.05	< 0.125
The emission of ammonia (NH_3)	< 0.03	< 0.06
The emission of carcinogenic compounds belonging to category 1 of the IARC monographs (IARC 1987)[1*]	< 0.005	< 0.005
Odor (dissatisfaction with odor shall be below 15 %)[2*]	Is not odorous	Is not significantly odorous

1* IARC 1987, does not apply to formaldehyde (IARC 2004)
2* The result of sensory evaluation shall be > + 0,1.

(Source: accessed 5 September 2010 at http://www.rts.fi/M1classified.htm)Details of the sample acquisition, handling, conditioning, testing , and evaluation are described in the Testing protocol available on the RTS web site, (https://www.rakennustieto.fi/material/attachments/newfolder/5opVeipbi/Testing_protocol_version_15122004.pdf).

FRANCE

In 2007, the French Government launched a concerted action (so-called Le Grenelle Environnement) for the identification and improvement of key issues regarding environment and health. Le Grenelle Environnement (2007) defined very ambitious objectives for the building sector in terms of energy saving. As this objective should not be achieved without taking into account IAQ in building design, Le Grenelle Environnement also defined three actions aimed at improving IAQ:

- Mandatory labeling of VOC emissions from building and decoration products,
- Ban of carcinogenic, mutagenic and toxic for reproduction substances category 1 and 2 (according to 67/548/CEE directive classification)
- Setting IAQ monitoring and providing corresponding information in some public buildings (e.g. schools, kindergartens, hospitals, etc.).

Transposition of those actions into French regulation is under progress, but the mandatory labeling of VOC emissions from building and decoration products will be based on four emissions classes from TVOC and a short list of 11 compounds selected because of their dangerous substance classification and because of their occurrence indoors and in product emissions. (http://ec.europa.eu/enterprise/tris/pisa/app/search/index.cfm?iYear=2009&sCountry=F&FUSEACTION=pisa_search_results&STYPE=STRUCTURED&lang=en)

AFFSET

French AFSSET agency ((Agence Française de Sécurité Sanitaire de l'Environnement de Travail) published the guideline ”Protocole AFFSET”, updated in 2009, for limiting VOC emissions into indoor air. It specifies chamber emission testing and limit values after 3 and after 28 days of storage in a ventilated test chamber - the 28 days test is regarded as representative for long-term emissions. This guideline is not binding and there is no procedure for showing compliance, but AFSSET agency recommends to base evaluations of VOC emissions from products on this guideline.

NORWAY

At one time, the Danish Indoor Climate Labeling program was in use in Norway. The organization in Norway was established on basis of the Danish Indoor Climate Label with Norsk Forum for Inneklimamerking as the normative body and Norsk Inneklima Merking as the label issuing body.Currently, there is no formal, mandatory program unique to Norway in effect at this time.

ADDITIONAL RELEVANT ACTIVITIES IN EUROPE

WHO European Office (http://www.euro.who.int/en):

– Index project,
– IAQ Guidelines
• (Dampness/Mould, Published 2009)
• Pollutants (soon to be completed?)

• EU Projects (www.EUROPA.EU)

– REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) - (http://ec.europa.eu/enterprise/sectors/chemicals/reach/index_en.htm)

LABELING PROGRAMS IN ASIA

JAPAN

A standard for emission rates of volatile organic compounds from building products was established April 1st, 2008, overseen by the Committee for Standardization of Emission Rate of VOC from Building Products. The Secretariat is the Japan Testing Center for Construction Materials.

In Japan, testing is required under the Building Standards Law. Voluntary certification is done through the JIS product certification for some of materials. The testing and evaluation under the Building Standards Law is mandatory. JIS certification system is voluntary.

The Japanese standard for emission of VOCS covers the following building products:

1) Building boards, wallpaper, and floor materials
2) Adhesives
3) Paints and coating materials
4) Heat-insulating material boards
5) Others. That is a product using target VOC and it is able to estimate rationally within the document.

The standard uses a number of test methods, specifically, the following.

- JIS A1901:2003 Small chamber method - Determination of the emission of volatile organic compounds and aldehydes for building products
- JIS A1902-1:2006 Determination of the emission of volatile organic compounds and aldehydes for building products - Sampling, preparation of test specimens and testing condition . There are specific standards for the various types of products listed above.

Table Japan1 Target VOC and the standard value

Target VOC	Standard value of emission rate
Toluene	38μg/m^{2}h
Xylene	120μg/m^{2}h
Ethylbenzene	550μg/m^{2}h
Styrene	32μg/m^{2}h

Note: Loading factor 3.4 m^2/m^3 was used in the calculation of the standard value of emission rate. It was assumed to be a realistic residential condition.

Table Japan 2:Test condition.
1) Two test specimens per each test condition
2) Loading factor:
General: 2.2 m^2/m^3.
Adhesives: 0.4 m^2/m^3
3) Air sampling period: 1, 3, and 7 days after the start of the measurement

Guideline Values for Indoor Air: The guideline values for indoor air concentrations mean that, given the current available scientific knowledge, no adverse health effects would be caused in humans with the lifetime exposure of the chemical at the level no more than the value. These values may be revised in the future, as necessary, depending on further available knowledge and/or progress in international assessment works based on such scientific knowledge. (Ministry of Health, Labor and Welfare)

Table Japan 3. Guideline Values

Substance	Guideline	Date
Formaldehyde	100μg/m3	1997.6.13
Acetaldehyde	48μg/m3	2002.1.22
Toluene	260μg/m3	2000.6.26
Xylene	870μg/m3	2000.6.26
P-dichlorobenzene	240μg/m3	2000.6.26
Ethylbenzene	3800μg/m3	2000.12.15
Styrene	220μg/m3	2000.12.15
Tetradecane	330μg/m3	2001.7.5

CHINA

Currently the certification or labeling scheme relates to formaldehyde emissions from composite wood products and conforms to the requirements of the California Air Resources Board regulations concerning emissions of formaldehyde from composite wood products.

KOREA

Korea has established testing programs and limits on emissions. Studies of occupied buildings have shown that the effect of the emissions programs is not widely-observable, as the concentrations measured in homes and other buildings frequently exceed the limit values. As noted elsewhere, ventilation rates can play an important role, and it is difficult to evaluate the effectiveness of emissions testing, certification and labeling on the basis of measured concentrations without sufficient ventilation data to determine emission source strengths.

There is no central authority for IAQ or emissions testing, certification and labeling in Korea. Various ministries have adopted guideline values for indoor air pollutants, and these are not consistent among the ministries involved, as shown in Table Korea-1.

Table Korea-1. IAQ Standards adopted by Korean Ministries (Kim, 2010)

Ministry / Pollutants	Ministry of Environment "Act on air quality management in underground space"	Ministry of Environment "Act on indoor air quality management in public facilities	Ministry of Health and Welfare "Act on management for public health"	Ministry Construction and Transportation "Act on management in parkage"	Ministry of Labor "Act for industrial health"
PM10	150㎍/㎥	100~200㎍/㎥	150㎍/㎥	-	150㎍/㎥
CO	25ppm	10~25ppm	25ppm	50ppm	10ppm
CO_2	1000ppm	1000ppm	1000ppm	-	1000ppm
SO_2	0.25ppm	-	-	-	-
NO_2	0.15ppm	0.05~0.3ppm	-	-	-
HCHO	0.1ppm	120㎍/㎥	-	-	0.1ppm
Pb	3㎍/㎥	-	-	-	-
Total suspended bacteria	-	800CFU/㎥	-	-	-
Radon	-	4pCi/l	-	-	-
VOCS	-	400~1000㎍/㎥	-	-	-
Asbestos	-	0.01/cc	-	-	-
O3	-	0.06~0.08ppm	-	-	-

A unified set of standards for emissions has been adopted for application to public facilities. The emission limits are not very stringent, as shown in Table Korea-2.

Table Korea-2. Restriction on the use of pollutant-releasing construction materials

Standard for release (mg / m^2·h)	Adhesives	Materials in general
Formaldehyde	4 or more	1.25 or more
VOCs	10 or more	4 or more

Table Korea-3. Standards for release of VOCs from building materials

Standard for release (mg / m^2.h)		Adhesives	Paint	Sealant	Putty	Building materials in general
Formaldehyde	~ 2010	0.5 or more				
	2011 ~	0.12 or more				
TVOC		2.0 or more	2.5 or more	1.5 or more	20.0 or more	4.0 or more
Toluene		0.080 or more				

The Korean National Institute of Environmental Research tested/analyzed 1,400 different construction materials from 2004-2006. As a result, they issued a notice of restriction on the use of 145 materials exceeding the standards. The results from their testing are shown in Table Korea-4 below.

Table Korea-4. Results of Korean National Institute of Environmental Research tests of 1,400 different building materials.

Year	No. tested	No. of restricted materials				
		Total	Flooring	Paint	Adhesive	Wallpaper
Total		145	7	121	15	2
2004	200	14	-	10	4	-
2005	400	35	1	28	6	-
2006	800	96	6	83	5	2

A time-series study of dwellings conducted by the National Institute of Environmental Research found that formaldehyde and acetaldehyde concentrations increased considerably after occupancy suggesting the sources were related to furnishing and/or personal care and household consumer products.

The Korean government and research institutions continue aggressively to develop policies and regulations regarding emissions testing and to monitor indoor air quality in a range of residential and non-residential environments.

EMISSION AND CERTIFICATION PROGRAMS IN THE U.S.

BACKGROUND

The earliest emissions testing in the modern era was done in the 1970s by the National Aeronautics and Space Administration (NASA) for the materials used inside spacecraft. Emissions testing in the U.S. began as a response to increased complaints of health effects associated with reduced ventilation intended to conserve energy in the 1970s following the 1973 oil embargo and the increased use of composite wood products made with formaldehyde resin binders. Testing by Andersen and Mølhave in the late 1970s and further work by Mølhave in the early 1980s revealed the significance of formaldehyde emissions. The U.S. Consumer Products Commission (CPSC) and the U.S. Department of Housing and Community Development (HUD) became interested in formaldehyde emissions and initiated independent activities leading to restrictions on urea formaldehyde foam spray-applied insulation and emissions from composite wood products respectively.

HUD established regulations limiting formaldehyde emissions from plywood used in HUD-insured or -subsidized housing in 1984. Standardized testing was developed and remains in place largely unchanged today.

With the increase in attention to indoor air quality during the early 1980s , EPA's Office of Research and Development began an emissions testing program focused largely on methods development. The work done by EPA's ORD resulted in the develop

Problems at EPA's Headquarters Building in Washington, the Waterside Mall, brought attention to emissions and particularly to carpet. As a result, EPA established the Carpet Policy Dialogue (1991) leading to a strong focus on emissions carpet and carpet-associated products. Before the Carpet Policy Dialogue was concluded, the Carpet and Rug Institute announced its Green Label program.

SPECIFIC TESTING AND EVALUATION PROGRAMS IN THE U.S.

Carpet and Rug Institute (CRI) (CRI, 2010)

Based in Dalton, Georgia, the Carpet and Rug Institute (CRI) is a nonprofit trade association representing the manufacturers of more than 95 percent of all carpet made in the United States, as well as their suppliers and service providers. CRI coordinates with other segments of the industry, such as distributors, retailers and installers, to help increase consumers' satisfaction with carpet and to show them how carpet creates a better environment.

Policy is determined by a board of directors composed of chief executive officers from member companies and is implemented by a full-time professional staff. Additional member company personnel provide time and expertise to more than 40 committees and subcommittees. The wide range of assembled information provides a focal point for issue discussion and a voice for the industry. The overall fields of interest are technical services, member services, governmental and consumer affairs, and public relations. CRI membership and staff are intensely involved in facilitating cooperative solutions to all industry challenges.

CRI initiated its GreenLabel carpet certification program in 1991 during the conclusion of EPA's Carpet Policy Dialogue (EPA, 1991). Testing is performed by Air Quality Sciences according to a standardized small chamber test protocol. Sample collection, handling, and testing are all standardized to ensure comparability of results. The results are reviewed by CRI and manufacturers whose products fail to pass are informed of the test results. This produces product improvement and serves as an effective screen to disincentivise high emitting carpets from entering the marketplace.

Carpet and Rug Institute Green Label Plus

Testing Protocol and Product Requirements: Green Label Plus is an independent testing program that identifies carpet with very low emissions of VOCs to help improve indoor air quality. It is an enhancement to the CRI Green Label Carpet Testing Program originated to meet the more stringent requirements established by the State of California for its own buildings. Green Label Plus carpet and adhesives meet more stringent requirements than the GreenLabel program.and include many of the lowest emitting products on the market. The GreenLabel Plus certification enables the specifier or purchaser to meet the requirements to receive LEED, Green Globes, or Green Guide for Health Care points.

To receive initial certification, carpet products undergo a 14-day testing process, as required by California's Section 01350 that measures emissions for a range of possible chemicals.

Carpet products: An independent laboratory tests carpet products for emission levels for seven chemicals as required by Section 01350, plus six additional chemicals as required by CRI. The 13 chemicals measured are as follows:

GreenLabel Plus Chemicals Required by CRI

Acetaldehyde
Benzene
Caprolactam
2-Ethylhexanoic Acid
Formaldehyde
1-Methyl-2-Pyrrolidinone
Naphthalene
Nonanal
Octanal
4-Phenylcyclohexene

Styrene
Toluene
Vinyl Acetate

- Initial Test – The carpet is tested to ensure that it meets all the compound emissions standards as outlined by California DHS Section 01350.
- Quarterly Test – As a quality control measure the carpet is tested in accordance with established emissions testing criteria for the total level of volatile organic compounds (TVOCs).
- Annual Test – The carpet is tested in accordance with established emission testing criteria to ensure that it meets very stringent emission criteria for thirteen individual compounds as well as testing for TVOCs.

Figure CRI-1. GreenLabel Plus Carpet Emission Test Criteria

CARPET 24-HOUR & 14-DAY EMISSIONS TEST CRITERIA

Target Contaminant	CAS #	24-Hour Testing		14-Day not to exceed Criteria	
		Maximum Emission Factor (EF) (μgm²·hr)	Maximum Air Concentration (μg/m³)	Maximum Emission Factor (EF) (μgm²·hr)	Office Building Target Air Concentration (for reference only) (μg/m³)
Acetaldehyde	75-07-0	130	70	130	70
Benzene	71-43-2	55	30	55	30
Caprolactam	105-60-2	130	70	190	100
2-Ethylhexanoic Acid	149-57-5	46	25	46	25
Formaldehyde	50-00-0	30	16.5	30	16.5
1-Methyl-2-pyrrolidinone	872-50-4	300	160	300	160
Naphthalene	91-20-3	8.2	4.5	8.2	4.5
Nonanal	124-19-6	24	13	24	13
Octanal	124-13-0	13	7.2	13	7.2
4-Phenylcyclohexene	4994-16-5	50	27	50	27
Styrene	100-42-5	410	220	410	220
Toluene	108-88-3	280	150	280	150
Vinyl acetate	108-5-4	190	100	190	100

CRI also has an adhesive emissions testing program, GreenLabel Plus Adhesives test program. and a carpet cushion program to complete its basic GreenLabel Plus Certification program. These programs have different chemical limits more appropriate to the two different product types.

Adhesives Products Test Program: Adhesive products are also independently tested for emission levels for 10 chemicals as required by Section 01350, plus 5 additional chemicals. The 15 chemicals measured are as follows:

Acetaldehyde
Benzothiazole
2-Ethyl-1-Hexanol
Formaldehyde
Isooctylacrylate
Methylbiphenyl
1-Methyl-2 Pyrrolidinone
Naphthalene
Phenol

4-Phenylcyclohexene (4-PCH)
Styrene
Toluene
Vinyl Acetate
Vinyl Cyclohexene
Xylenes (m-,o-,p-)

Figure CRI-2. GreenLabel Plus Adhesives Emissions Test Criteria

ADHESIVE EMISSIONS TEST CRITERIA

Target Compounds	CAS #	24-Hour Testing: Maximum Emission Factor (EF) (µg/m²·hr)	24-Hour Testing: Office Building Target Air Concentration (for reference only) (µg/m³)	14 Day Testing: Maximum Emission Factor (EF) (µg/m²·hr)	14 Day Testing: Office Building Target Air Concentration (for reference only) (µg/m³)
Acetaldehyde	75-07-0	130	70	130	70
Benzothiazole	95-16-9	30	16.5	30	16.5
2-Ethyl-1-Hexanol	104-76-7	300	160	300	160
Formaldehyde	50-00-0	30	16.5	30	16.5
Isooctylacrylate	29590-42-9	690	370	690	370
Methyl biphenyl	28652-72-4	95	50	95	50
1-Methyl-2 Pyrrolidinone	872-50-4	300	160	300	160
Naphthalene	91-20-3	8.2	4.5	8.2	4.5
Phenol	108-95-2	190	100	190	100
4-Phenylcyclohexene (4PCH)	4994-16-5	50	27	50	27
Styrene	100-42-5	410	220	410	220
Toluene	108-88-3	280	150	280	150
Vinyl acetate	108-05-4	190	100	190	100
Vinyl cyclohexene	100-40-3	85	44	85	44
Xylenes (m-, o-, p-)		650	350	650	350
TVOC		8000			

CRI GreenLabel Plus Carpet Cusion Program: CRI has established the Green Label program to test for VOCs in cushion used under carpet. Cushion products that meet the current emissions criteria can display the program's green and white seal. Products are retested regularly for continued compliance, so specifiers seeking a low-emitting cushion can confidently select one bearing the Green Label.

Cushion products are characterized as prime polyurethane, bonded polyurethane, mechanically frothed polyurethane, rubber-hair, rubber–jute, synthetic fiber, resinated or coated synthetic fiber, rubber and rubberized polyurethane. Cushions are tested for total volatile organic compounds (TVOCs), butylated hydroxytoluene (BHT), formaldehyde and 4-phenylcyclohexine (4-PCH). The CRI web site does not specify the frequency of testing or the chamber conditions for cushion product tests. The criteria for carpet cushions are shown in Table CRI-3.

Table CRI-3 GreenLabel Plus Carpet Cushion Emission Test Criteria

TVOCs:	1000 µg/m² · hr
BHT	300 µg/m² · hr
Formaldehyde	50 µg/m² · hr
4-PCH	50 µg/m² · hr

Comment on carpet assemblies: The emissions from the different carpet system components are assessed against their applicable criteria independent of the other components. The carpet "system" (carpet, adhesive, and cushion) may collectively emit compounds at rates greater than the criteria for the three components of the system. This is applicable not only to carpet assemblies but also significantly to wall and ceiling assemblies as well.

CALIFORNIA SECTION 01350

California's "Section 01350" originated as a section in the Construction Specifications section of the bid documents for a new California State Office Building in Sacramento. The award of the Design-Build contract was based on criteria that rewarded proposals that included "green" features. Among the features proposed by the successful bidder for the building known as Block 225 of the Capital Area East End Complex was the testing of emissions and evaluation of the results in the selection of products to include in the construction. The proposal also included extensive indoor air quality testing at various stages of product completion to compare concentrations to those from the emissions tests as a quality control measure.

Section 01350 (2000) was one section of the construction specifications focused on environmental requirements. It was a new section among the standard construction documents sections at the time it was developed. Among other things, it included specifications of emissions testing conditions designed to limit exposures to VOCs with chronic, non-cancer, health effects. The limit values for emissions of any listed compound were one-half of the Chronic Reference Exposure Levels (CRELS) developed on the basis of health-hazard assessments by Cal/EPA OEHHA toxicologists. The basis of OEHHA's recommended concentrations was for safety for long-term exposure of general population. The consultants chose a 14-day time point as a compromise to account for the stronger emissions early in a product or material's exposure to the environment and its generally far lower long-term emissions.

Conceived as Architectural Design Tool: Section 01350 was conceived as an architectural design tool to be used by a design team with relatively high awareness of indoor air quality science and practice. It was a whole building approach that allows architects to design for acceptable IAQ through the following aspects:

- Requires actual emission data for large surface area materials and other important VOC sources
- Estimates of concentrations of VOCs in the project building are done by mass balance modeling using actual building parameters. For simplicity, uses a quasi-steady state mass-balance model
- Standard exposure scenarios are used for estimating VOC concentrations
- Most important parameter (for chamber tests and building concentration estimates) is area-specific air flow rate, m^3 hour of clean air per m^2 of material (m/h)
- Each VOC is considered separately – Effects are not summed
- Each product can contribute no more than ½ CREL to standard scenario

Measurements made at Block 225 are discussed later in this report.

Evolution of Section 01350 into a product testing and evaluation standard: The rise of building certification programs with points for the use of low-emitting materials led to the adaptation of Section 01350 as a design tool into a Pass/Fail assessment of VOC emissions. This is a compromise on its original purpose and use since designers no longer receive complete reports on the emissions of products they are considering and manufacturers simply focus on meeting the criteria. There is no built in incentive for continuous improvement in the reduction of emissions from various important indoor pollutant sources.

The approach used in Section 01350 is now the IAQ performance option in BSR/ASHRAE/USGBC/IESNA Standard 189.1-2009, Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings. Standard 189.1 is now incorporated in significant part into the new International Green Construction Code (IgCC) which is expected to be adopted by many local and state jurisdictions throughout the United States and in many foreign countries. It is likely to strongly influence many of the most influential green building labeling and certification schemes.

Section 01350 has been revised into two standard practices by the California Department of Public Health. These practices are available on the web site of the indoor air quality program of the Department. They underwent a revision in 2009. The Standard Method for the testing and evaluation of volatile organic chemical emissions from indoor sources using environmental chambers, Version 1.1, is now available at the California Department of Public Health's Indoor Air Quality Program web site .(CalDPH, 2010). The method is being further revised though an open, ANSI-like process, open and consensus based, and is expected to be published as Version 2 by early next year.

GreenGuard Environmental Institute

In the US, Air Quality Sciences was established in the late 1980s to provide emissions testing services to industry. One of its earliest, major clients came from the carpet industry which was subjected to many law suits in the late 80s and began voluntary testing of carpet products leading to the formation of the Carpet and Rug institute's labeling program, the Green Label. Related activities engaged carpet cushion manufacturers, floor-covering adhesives manufacturers, and the resilient floor covering industry.

Later, AQS management established the GREENGUARD Environmental Institute—a non-profit certifying organization— that offers a voluntary standard for "qualifying building materials, finishes and furnishings as certified low emitting products for the indoor environment". Today Greenguard certifies over xxxxx building products.

The GREENGUARD Environmental Institute (GEI) began certifying indoor products for low chemical emissions in 2001. Testing procedures for the program were developed and applied by Air Quality Sciences to cover a breadth of product types and building applications. The science of measuring product emissions developed from research conducted by the Environmental Protection Agency, Department of Energy, the Department of Housing and Urban Development, the Consumer Product Safety Commissions, California Department of Health Services, the State of Washington Department of General Administration, and additional national and international researchers. Air Quality Sciences, Inc. was the first, in 1989, commercial facility worldwide to offer product testing and consulting services to end users and manufacturers of products.

In 2000, Air Quality Sciences established the GREENGUARD Environmental Institute to 1) bring together performance based, field validated standards to define low emitting products and materials for the indoor environment; 2) provide a third party, non-industry and publicly available certification process for manufactured products; and 3) establish a public directory of certified products for architects, designers, specifiers, purchasers, and consumers.

Explanation of GG Certification: [6]GREENGUARD Environmental Institute (www.greenguard.org) is a not-for-profit, industry-independent organization that oversees the GREENGUARD Certification programs – GREENGUARD Indoor Air Quality & GREENGUARD Children & Schools. GREENGUARD strives to develop leadership test methodologies and standards for many interior products including building materials, interior furnishings, cleaners, electronics and children's products. The test methodologies utilized provide leadership to the industry in numerous ways, but one of the most important is that the products with the highest probability to have high VOC emissions are determined by an approved test laboratory through profile study testing of multiple product line components. GREENGUARD believes this ensures the initial certification test for a product line has been proven to be the worst possible emitter.

There are many different theories which are being use around the globe on how to prove that a product is actually low-emitting, and GREENGUARD has tried to marry the best science of each of these theories to ensure that the standards are used are as protective of human health as possible. The most stringent standard, GREENGUARD Children & Schools, incorporates over 360 individual chemical

[6] Adapted from text provided by Greenguard Environemntal Institute

limits to ensure that individuals are protected from the chemicals of concern which science knows about currently.

Additionally, due to the more than 10,000 chemicals that can come off of man-made products, it is also necessary to go beyond the known, which is why the GREENGUARD Children & Schools standard also sets a limit on the Total Volatile Organic Compounds (TVOC) emissions. TVOC alone is not something that should be used to prove that a product is low-emitting as a single harmful chemical could be very high emitting and the product still passes. TVOC is used as an addition to a number of individual chemical limits as a backstop against the unknown chemicals it helps to ensure that any chemicals for which scientific evidence is lacking might be recognized if the TVOC emissions are high. Finally a representative product from every product line certified must be sent in for testing every quarter and a worst case scenario product is sent in for testing every year. This helps provide the purchasing public with a sense of security that the formulation for a product has not changed in a way to be harmful to their indoor air.

GEI/NSF ANSI Standard Development[7]

GREENGUARD Environmental Institute and NSF International have initiated the development of the first ANSI health-based product emission standard. There are many standards and methodologies used around the globe, but the three most prominently used in the United States are the GREENGUARD Certification Standards, the California Department of Public Health's Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers Version 1.1 (CA 01350), and the ANSI/BIFMA M7.1-2007 test methodology and ANSI/BIFMA X7.1-2007 standard.

GEI and NSF initiated this ANSI standard development in response to the positive and negatives of each of the most popular standards. The GREENGUARD and CA 01350 test methodologies and standards are health-based and are considered leadership, but they were not developed in a recognized consensus manner. The BIFMA standards were developed in a recognized consensus process, but are limited to business furniture, not health-based, and is an industry association standard. This ANSI standard looks to take the best of each test methodology and standard and incorporate them into one national, consensus, health-based product emission standard.

GEI/NSF have convened a joint committee of around 30 members. This committee has balanced representation from the Academic, Industry, Product Certifiers/Testing Labs, Public Health/Regulatory, and User sectors. This group will help develop the standard and assist in response to public comments which are received from stakeholders at large. This diverse group on the committee and the public comment periods will ensure that there will be representation from a diverse group of people and input from around the globe.

ANSI/BIFMA Furniture Emissions Standards and Related Certification Programs[8]

The Business and Institutional Furniture Manufacturers Association International (BIFMA) standards address VOC emissions from furniture in three standards:

1. ANSI/BIFMA M7.1 *Standard Test Method for Determining VOC Emissions from Office Furniture Systems, Components, and Seating*, (BIFMA 2007),
2. ANSI/BIFMA X7.1 *Standard for Formaldehyde and TVOC Emissions of Low-emitting Office Furniture Systems and Seating*, (BIFMA 2007), and
3. BIFMA e3 *Furniture Sustainability Standard* (BIFMA 2009).

[7] Adapted from text provided by Greenguard Environemntal Institute
[8] Adapted from text provided by BIFMA

These standards are based on extensive research, utilize a consensus process with a broad range of stakeholders, are widely used throughout North America and are cited internationally. The first two standards were released in 2005, following ten years of development by a broad group of stakeholders. Dr. Jianshun Zhang of Syracuse University led the final technical development of the test method and the M7.1 and X7.1 standards were approved as American National Standards in 2007. The standards have been widely adopted in whole or in part by the USGBC LEED standards, California and Minnesota state government purchasing criteria (California 2008), the Collaborative for High Performance Schools (CHPS 2009) criteria, the State of California Department of Public Health Standard Method for Testing of VOC Emissions from Indoor Sources (California 2010), the Greenguard Environmental Institute (GEI), Scientific Certification Systems, and others.

In 2009, BIFMA released the BIFMA e3 Furniture Sustainability Standard (BIFMA 2009), following three years of consensus development in partnership with the National Sanitation Foundation International (known as "NSF International") and over 60 stakeholder organizations. The BIFMA e3 standard is a multi-attribute sustainability standard that includes 90 points covering the entire supply chain in four key areas: materials, energy and atmosphere, human and ecosystem health, and social responsibility. By earning and maintaining additional points, manufacturers can achieve increasingly rigorous levels of compliance (level™ 1, 2, or 3). The BIFMA e3 standard integrates the ANSI/BIFMA furniture emissions standards and the health-based 14-day criteria from California (California 2004, and 2008). The VOC emissions requirements of the BIFMA e3 standard have been incorporated into the ANSI/ASHRAE/USGBC/IES 189.1 standard (ASHRAE 2010).

While first and second-party claims of compliance are possible, hundreds of thousands of products are third-party certified as compliant. Third-party certification to BIFMA e3 is currently available from a variety of independent organizations including Bureau Veritas, Intertek, LGA, NSF International, Scientific Certification Systems, and UL Environment, all under the BIFMA level™ program (www.levelcertified.org). The Greenguard Environmental Institute (GEI), Material Analytical Services (MAS), and Scientific Certification Systems (SCS) offer certification to VOC emissions requirements under their own programs, which are based in whole or in part on the ANSI/BIFMA standards. Partial adoption, especially of the exposure scenarios, has contributed to market confusion. For example, while marketed heavily, certification from GEI does not always demonstrate compliance with all of the VOC emissions requirements of BIFMA e3 nor ASHRAE 189.1, in particular for office chairs, tables, and other individual furniture items used in open plan environments. Instead, GEI uses their own proprietary criteria for these products, created in collaboration with their partner business, Air Quality Sciences.

Efficacy of these BIFMA standards begins with clearly defined test methods, exposure scenarios linked to actual environments by data, and awareness of the inherent measurement repeatability and reproducibility. Supporting research includes:

1. Defining standard office exposure scenarios from over 5,000 workstations, (Carter, Zhang, 2007),
2. Validation of power-law parameters for determination of 14 day emissions from measurements at day three and seven, (Zhang, et.al, 2006),
3. Development of scaling from small chamber test results on representative materials to determine compliance of assembled furniture products, (Hodgson, et.al, 2009), and
4. Reducing measurement variation through round-robin and other studies (Zhang, et.al, 2009).

COLLABORATIVE FOR HIGH PERFORMANCE SCHOOLS (CHPS)

The Collaborative for High Performance Schools is a non-profit organization dedicated to making schools better places to learn. CHPS was founded in 1999 as a collaboration of California's major utilities to address energy efficiency in schools. The program quickly expanded to address all aspects of school design, construction and operation.

CHPS lists products and materials tested using the State of California Standard Test Method and Standard Practice, described above. The products listed by CHPS are deemed acceptable for credits under the USGBC's LEED certification program. In effect, CHPS functions as a certification body, although its certifications are dependent entirely on the reports from the laboratories submitted to it for listing.

CHPS provides resources – in many cases, free resources – to schools, school districts and professionals about all aspects of high performance school design, construction and operation. CHPS develops tools that help make schools energy, water and material efficient, well-lit, thermally comfortable, acoustically sound, safe, healthy and easy to operate. These resources include a well-respected six-volume best practices manual, training and conferences, a high performance building rating and recognition program and other tools for creating healthy, green schools.

Accomplishments to date:

• There are 46 completed CHPS schools across America.
• There are approximately 300 schools underway in the U.S. seeking CHPS recognition.
• 41 school districts, with over 1.5 million total students enrolled, have committed to building new schools or modernizing to the CHPS high performance building standard, or using CHPS resources.
• Eleven states have state or region-specific high performance school building Criteria, including California, Washington, New York, Massachusetts, and the New England States (Maine, Vermont, New Hampshire, Connecticut, and Rhode Island), and Texas and Colorado under development.
• Over 225 organizations are members of the collaborative, including utility companies, professional design and construction firms, product manufacturers, non-profit organizations, schools and school districts, and professional societies.

CHPS believes in the collaborative approach for the development of all of its resources. To this end, the board of directors and technical committee are made up of representatives from all aspects of school design, construction and operation. All of CHPS resources are subject to two public reviews before they are released for public use.

HEALTHY BUILDING NETWORK – PHAROS

The Pharos Project (Pharos, 2010) attempts to connect a network of building professionals and manufacturers committed to transparency as a core value in pursuit of sustainability. Pharos is not a certification or label, it is information: the critical health and environmental data about the manufacture, use, and end of life of building materials specified and used every day delivered in a web-based tool

The Pharos Framework provides the descriptions of each of the impact categories that the Pharos system addresses and the protocols through which they are evaluated. Each category has the following elements in its framework:

Problem: Statement of the impacts this wedge is addressing

Goal: What can be done to address the problem

Ideal: The attributes of a product that would be considered ideal for this wedge and would get the highest rating

Scoring Protocol: The data items Pharos collects and how this data is evaluated into a 10 point rating

Definitions: Terms used in the evaluation

Issues: Outstanding issues that remain to be addressed to improve the framework

Category Areas

The Pharos categories are grouped into three general areas of concern:

Health & Pollution: Building materials are associated with health impacts on the building occupant, the fenceline communities near the supply chain of the manufacturing process and the global community. Healthy building products avoid use of materials that cause health and environmental damage from cancer to global warming, in resource extraction, refinement, and production as well as in use and end of life.

Environment & Resources: Every stage of a product's fabrication expends resources and yields waste. Green product design will reduce usage of energy and water for the manufacture and ongoing operation of building products; maximize use of renewable energy, reduce waste and habitat destruction and set up closed loop material cycles to infinitely recycle materials into new products.

Social & Community: A company is responsible for more than the products it sells. A company's operations impact the well being of employees and the community in which it operates. Manufacturers have a responsibility to ensure safe working conditions with fair pay and equitable opportunities, to actively engage with and support the local community and to reporting on and improve their overall corporate impact.

Pharos applies these criteria to a wide range of products and produces a profile for each product that enables the user to understand a range of environmental impacts. It does not provide direct comparisons, overall ratings, or certification/labeling.

GreenSeal

GreenSeal is a well-established and widely cited certification/labeling program in use in the United States. However, until now has not based their assessments on emissions testing.

DISCUSSION

Evaluation of Testing Protocols

Testing of products is most commonly done only on a very limited sample of the total range of products represented by the test. For example, typically, one type of carpet product or paint with several or even many variations available in the market place will be represented by testing of a single sample once a year or, in some cases, quarterly. In some instances, a product may only be tested when new and labeled or certified as a result of that single test at the beginning of its commercial availability or labeling.

In addition, test results are based on test conditions that represent only a small fraction of most products' total service life. Exposure strongly depends on amount of a material used, ventilation rates in buildings where the products are used during occupancy periods, corresponding occupancy patterns, and especially for consumer products, the timing and quantities used in relation to occupancy.

Most emissions testing is done with a standardized loading ratio (amount used and ventilation rate) over a time period (i.e., between a few days and a month) that is relatively quite short in relation to the total service life (i.e., from years to decades) of the material in the building. These conditions are standardized in order to facilitate comparison between products and to reduce the number of tests that must be performed. Testing is costly, and only in the past decade has it become relatively common for many building products. Emissions tests of most consumer products (vs building products) are still virtually non-existent.

There are limited data available on the health effects of many of the commonly emitted chemicals. There is very little knowledge about the effects of exposure to the mixture of chemicals that results from the diverse emissions of chemicals from individual products and even less understanding of the effects of exposure to the combinations of the large number and type of chemicals emitted by the products whose emissions affect the indoor environment.

Since emissions result in concentrations and exposures that are strongly affected by ventilation rates, a focus on emissions alone can never accomplish the public health objectives unless 1) emissions are reduced to inconsequential levels or the emitted agents are harmless or 2) ventilation is always assured at a level consistent with the emissions testing protocols and product evaluation procedures.

Comparison of U.S. and European Emissions Test Standards[9]

In emissions testing, there are many factors that determine accuracy, reproducibility, and applicability. Some of these are different in the dominant American and European approaches. The following briefly highlights some of the important differences and their implications.

United States: The widely shared goal among those involved in the development of emissions test standards is to optimize chamber conditions based on practical considerations – air flow rate, sample size. Various chamber sizes are used for various product types. Comparisons of the performance of the chambers allow informed judgments regarding the applicability of each chamber type and size. There is also much focus in the United States and Canada now on the development of realistic exposure models for different types of environments – offices, schools, residences, office furniture, etc. In the U.S, modeling of chamber results is done for each of these different environments to determine acceptance.

European Union: There is a drive to use one 'conservative' model (ISO 16000-9 & CEN/TC351) to achieve "harmonized" test practices. In spite of this, there will be some discretion left to the individual Member States by standards adopted at the European Union level.

Comparison: In his presentation at the Joint Research Centre's workshop on harmonization of emissions test standards, June, 2010, Al Hodgson presented an analysis showing some of the limitations of a single test standard. Following sections are drawn from that presentation.

Scenarios for application of emissions test results are critical to the derivation of concentrations to be compared to established or adopted limit values, whether for pass-fail or other systems of certification and labeling. Hodgson compared the area specific air flow rates in three different models including 3 different building types in the California Standard Method Version 1.1, BIFMA s ANSI/BIFMA Standard M7.1 for open office furnishings, and the CEN committee 351's exposure scenario. The results are shown in Table Hodgson-1.

Table Hodgson-1. Comparison of Area-Specific Flow Rates

Parameter	Units	BIFMA Open Plan	Calif. SM Version 1.1 Classroom	Office	New SF Home	CEN 351
Floor area	m^2	5.94	89.2	11.15	211	12
Height	m^2	2.74	2.59	2.74	2.59	2.5
Volume	m^3	16.3	231	30.6	547	30
Air flow rate	m^3/h	15	191	20.7	127	15
Floor area	m^2	5.94	89.2	11.15	211	12
Ceiling area	m^2	5.94	89.2	11.15	217	12
Wall area	m^2	0	94.6	33.4	562	33
Paint area	m^2	0	94.6	33.4	779	33
Floor SFR	m/h	2.53	**2.14**	**1.86**	**0.60**	**1.25**
Ceiling SFR	m/h	2.53	**2.14**	**1.86**	**0.59**	**1.25**
Wall SFR	m/h	--	**2.02**	**0.62**	**0.23**	**0.45**
Paint SFR	m/h	--	**2.02**	**0.62**	**0.16**	**0.45**

The results show clearly that a single area specific flow rate would result in widely divergent levels of protection or accuracy in prediction of indoor concentrations resulting from the use of tested materials.

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9 Adpated from a presentation by A.T. Hodgson

Some questions raised by Hodgson require reasoned answers for the development of robust emissions testing standards for certification and labeling.

- Is simple mass-balance model suitable for compounds with low vapor pressures?
- How fast do emissions decay?
- How many exposure scenarios are needed?
- Should occupancy patterns be considered?
- Is ½ CREL allowance per product reasonable?
- Should product categories with very high area specific flow rates be included?
- How should layered assemblies be treated?
- How to treat insulation & other wall cavity products?
- How can more exposure guidelines be developed?

Studies that evaluate the effectiveness of testing, labeling and certification schemes

Studies have been reported of indoor air quality, occupant perceptions of indoor air quality, and occupant reports of symptoms or self-assessed productivity in buildings were emissions-tested, certified, or labeled building materials and furnishings have been specified and installed. Emissions testing and the labeling and certification of building materials and furnishings can only provide source strength information for those sources of indoor air pollution. However, chemical emissions to indoor air in occupied buildings are always mixed with the emissions from occupant activities and equipment as well as with pollutants entering the building in ventilation air and the products of chemical reactions occurring between and among chemicals in air or on surfaces. Cleaning and maintenance materials as well as consumer products can also be important sources of primary and secondary chemical emissions to indoor air (Nazaroff and Weschler, 2004; Nazaroff et al, 2007).

A further and rather significant limitation is that without concurrent characterization of ventilation rates, pollutant concentrations in indoor air do not give a direct indication of chemical source strengths (Levin, 2003). Very few studies report concurrent ventilation rates and indoor air pollutant concentrations. When ventilation is measured simultaneously with indoor air concentrations, approximate source strengths can be calculated by an oversimplified equation source strength (emissions) equal concentration) divided by ventilation rate. This can then be translated into area-specific source strength in order to compare sources on a comparable basis, emissions per unit-area per unit of time.

As a result of the limitations in the available data, there is no direct evidence and very little indirect evidence of the impact or effectiveness of emissions testing in terms of producing improved indoor air quality. Following is a discussion of some of the available and relevant evidence.

Direct Evidence

There is a paucity of evidence that allows direct evaluation of the effectiveness of emissions testing programs, partly due to the lack of measurements of source strengths in completed buildings and partly due to the confounding factors in occupied buildings. Nevertheless, there are studies that provide some insights of interest.

A study of houses in Finland built with classified materials under the Finnish Classification, **"**Reference values for building material emissions and indoor air quality in residential buildings" (Järnström, 2007).

The study was an investigation of air concentrations and emissions from eight residential buildings during construction and the first year of occupancy. VOCs, formaldehyde and ammonia concentrations and emissions were measured along with temperature, humidity, and ventilation. TVOC concentration was found to be generally above the S3-class limit of 600 $\mu g/m^3$ immediately after construction. The concentrations generally decreased to below the S3-level and in some apartments below the S1-level of 200 $\mu g/m^3$ within six months.

The largest decrease in concentrations of major VOCs occurred during the first six months of occupancy (mean concentration levels of 5-15 μg/m^3). The ventilation system the floor covering, the ceiling surface material, the wall surface, season, relative humidity and temperature of indoor air, and occupancy had the strongest influence on the concentrations.

Relative humidity (RH) had the greatest effect on ammonia and formaldehyde concentrations when RH was above 50% during the follow-up. The formaldehyde concentration did not significantly exceed the S2-class level of 50 μg/m^3 during the first year in any of the apartments. In some newly finished buildings and during the follow-up, the indoor air concentrations of ammonia were above the S3-level of 40 μg/m^3. The emission measurements performed from the complete floor construction showed that the emission was affected by all of its components, i.e., the structure, leveling agent, adhesive, and floor covering material. Significantly higher emissions were often measured on-site from the complete floor structure than from the single materials measured in the laboratory. The impact of adhesives on VOC emissions from the complete PVC- coated structures was clearly seen as higher emissions from those with a more permeable types of PVCs.

The contribution of the average on-site measured emissions to indoor air concentration was ~550 μg/m^3 (~57% of the measured concentration) for TVOC and ~45/ 40 μg/m^3 (~100% of the measured concentration) for ammonia and formaldehyde in the newly finished building. The TVOC contribution from surfaces decreased to ~200 μg/m^3 in six months whereas the contribution of ammonia and formaldehyde remained about the same. The ceiling structure contributed the most to the concentration levels whereas the contribution from walls was lower than expected based on the large surface area.

Järnström concluded that the study confirmed that the Finnish material classification system provides a basis to achieve good IAQ when comparing to the target values for pollutant concentrations given by the classification in real buildings. However, she also concluded that the use of classified building materials alone did not guarantee good IAQ and that effective ventilation was also required. She recommended that the air flow rate recommendations per unit of floor area presented in the first version of the classification in 1995 should be reintroduced. She also found that the contribution of sources other than from surface materials was significant, and that the importance of these sources increased with time. Therefore, she suggested that the planned extension of the Finnish classification system to include furniture and cleaning agents would be a valuable improvement.

Beyond that, she observed that the incorporation of target values for VOC groups and critical VOCs (e.g. 2-ethylhexanol and TXIB) in the material classification would be advantageous from the consumer's point of view. In addition, she suggested that supportive testing of material combinations as real structures would further improve the efficacy of the Classification system in protecting building occupants .

CAPITOL AREA EAST END PROJECT, SACRAMENTO, CALIFORNIA

In the post occupancy monitoring of the five building State of California office complex known as the Capitol Area East End Project, ventilation rates and indoor air pollutant concentrations were measured concurrently over an extended period of time following occupancy. A study, "Long-Term Building Air Measurements for Volatile Organic Compounds (VOCs) including Aldehydes at a California Five-Building Sustainable Office Complex," was conducted by the California Department of Health Services in conjunction with private sector partners. The study involved monitoring of indoor air quality in the 5 new State of California office buildings that had been constructed with interior materials tested by two different emissions testing programs. The Final Report describes the study and the results (Alevantis et al, 2006). This is perhaps the most relevant study of the efficacy of emissions testing available in the literature because of both the duration of the study and extent of emissions testing prior to material selection in the design process. The Executive Summary is quoted extensively below.

Background: In 1999, the State Legislature directed the Department of General Services (DGS) to incorporate sustainable practices in the design and construction of a 1.5 million ft^2 of the Capitol Area East End Complex (CAEEC). To address the Legislature's directive, a multi-agency team, known as the Green Team, was formed under the leadership of the Secretary of the State and Consumer Services Agency and, in partnership with the Department of Health Services, California Integrated Waste Management Board, California Energy Commission, California Air Resources Board, and Department of Water Resources worked with DGS to develop sustainable criteria for the CAEEC. These criteria, among others, included several to ensure good indoor air quality, including setting target limits on chemical emissions from interior finishing building materials and conducting airborne contaminant testing after completion of the construction and prior to occupancy. Two design/build teams were selected: one for Building 225 and another for the remaining four buildings (171, 172, 173, 174). The design/build teams were responsible for the design of the buildings (the basic shell design had been done previously by the State) and the construction.

Goals: In order to ascertain the post-occupancy indoor air quality of a sustainable complex such as the CAEEC and to find out how it performs over time, the concentrations of Volatile Organic Compounds (VOCs) and aldehydes were measured along with local and building ventilation rates. Based on the measured VOC concentrations and ventilation rates, emissions from building materials and occupant activities to the indoor environment (such as cleaning products and perfumes) could be identified and their temporal changes could be studied. It is noted that due to the narrow scope of this study, other important aspects of indoor environmental quality, such as semi-volatile organic compounds, or noise and lighting were not studied. The specific goals of this research study were to:

1. Measure VOC including aldehyde concentrations periodically during and after occupancy of the five buildings for at least 12 months after occupancy. Compare measured concentrations to those referenced in: (a) Section 1350 as issued for the project and in its most current version; and (b) U.S. EPA's indoor air quality database of 100 randomly-selected office buildings known as the Building Assessement Survey and Evaluation (BASE) study.
2. Study temporal changes of measured concentrations to determine the effect of building materials, office furniture, occupant activities, and cleaning/maintenance products on indoor air quality.
3. Determine whether or not emissions of target chemicals in the indoor environment can be calculated reasonably well using emission data from small chamber tests.
4. Compare the occupant survey results for Blocks 225 and 172 collected by Center for the Built Environment (CBE) at University of California, Berkeley with the measured VOC and aldehyde concentrations.
5. Discuss the lessons learned that can be used in future projects.

Results:

1. The concentration target limits established for this project were not exceeded in the majority of the locations, however, acetaldehyde and formaldehyde target limits were exceeded in numerous locations of more than one building. Concentrations of chemicals measured at the newly-constructed CAEEC were also compared to those reported in the BASE study in which older office buildings were monitored. The concentrations of common chemicals to both studies were comparable and only the concentrations of a few chemicals at the CAEEC were higher than those reported in the BASE study.
2. Eight building- and occupant-related chemicals were identified to determine the effect of building materials, office furniture, occupant activities, and cleaning/maintenance products on indoor air quality. The five building- related chemicals are: acetaldehyde, caprolactam, formaldehyde, naphthalene, and nonanal; the three occupant-related chemicals include: benzaldehyde, d-5 and d-limonene. However, very few chemicals could be traced to a unique source. Only one building-related compound (caprolactam) and one occupant-related compound (d-5) were clearly identifiable from unique sources. In the case of caprolactam, there was a clear decrease over time in the emissions of this chemical and in the case of d-5, there was a clearly identifiable increase over time in the emissions of this chemical. Emission factors of some of the other target chemicals (i.e., acetaldehyde, benzaldehyde, naphthalene, d-limonene, and nonanal) fluctuated throughout the study.

   Post-occupancy local emission factors of some of these eight chemicals were fairly uniform within each building, whereas, others differed substantially from building median values. Chemicals with highly variable local emission factors were: d-5 (occupant-related), d-limonene (cleaning-related), caprolactam (variable only in certain sampling scenarios – this chemical is emitted by carpeting and variability was presumably due to hallway carpet replacement), and formaldehyde (variability was presumably due to local generation of this chemical from cleaning and other activities).

3. One of the goals of this study was to determine whether or not emissions of target chemicals in indoor environments could be calculated reasonably well using emission data from small chamber tests. Caprolactam (a chemical with unique source, carpet) was selected for this analysis, and its emissions after carpet installation were predicted within a factor of 2.
4. We could not compare our findings to those by CBE conducting occupant surveys in two of the five buildings because their final report has not been issued yet.
5. There was a number lessons learned. These included:
   a. Lack of data on cleaning and maintenance activities, touch up or other introduction of building materials, and furnishings, or finishes after the initial occupancy. Collection of emissions data from cleaning and maintenance products was beyond the scope of this study, but would have been useful to have had collected these data.
   b. Variations of building ventilation rates and local ventilation rates. Despite the efforts to provide consistently the same amount of ventilation from one sampling session to the next by setting the ventilation systems to provide their minimum design outdoor airflows, variations of building ventilation rates and local ventilation rates occurred from one sampling session to the next, necessitating ventilation measurements during each sampling scenario.
   c. Emissions testing of building material samples by their manufacturer does not necessarily guarantee that materials of similar chemical profile would be delivered and installed in a building. Despite the fact that the office furniture systems for the entire complex were tested to the State's IAQ emissions specifications, there were substantial differences in the formaldehyde concentrations of two buildings (172 and 225) and those of the other three buildings in which systems furniture was supplied by a different vendor.
   d. Accurate characterization of indoor air chemical concentrations requires numerous samples and ventilation measurements at several locations over an extended period of time. Many variables need to be considered and controlled in the building, or accounted for in the data analysis.
   e. Analytical procedure variations need to be accounted for when air sampling in buildings is conducted to determine whether concentration target limits have been met. It is important that duplicate samples are collected at each site and samples with variability above a pre-determined threshold be discarded.

VOC Source strengths in pre- and post-occupancy periods: California State office building

In addition to the post-occupancy monitoring study reported by Alevantis et al (2006), a more focused pre-occupancy and 14-months post-occupancy monitoring study was done in one of the five buildings known as Block 225. The results of that monitoring, reported separately by Levin (2003), show the expected decay in indoor air concentrations from new building materials and furnishing prior to initial occupancy and beyond. Monitoring was done immediately after carpet installation but prior to installation of office work stations, after work station installation, and several more times before and after initial occupancy, with the last monitoring 14 months after initial occupancy. The monitoring included concurrent ventilation rate and pollutant concentration measurements, enabling the researchers to calculate and report source strengths for each chemical compound found indoors.

All of the major interior materials and furnishing were tested prior to selection for use in the building using Section 01350, a portion of the construction specifications developed for this project by the project's design-build team. Included in Section 01350 were various environmental requirements but the major portion was emissions testing procedures and pass-fail criteria based on California Office of Environmental Health Hazard Assessment (OEHHA) chronic reference exposure levels (Levin and Alevantis, 2003). This represented a significant move toward the inclusion of relevant health-based criteria for evaluation of the results emissions testing.

The results of key time points in the monitoring are shown in Figures Levin1 and Levin2 and Table Levin-1 below as source strengths.

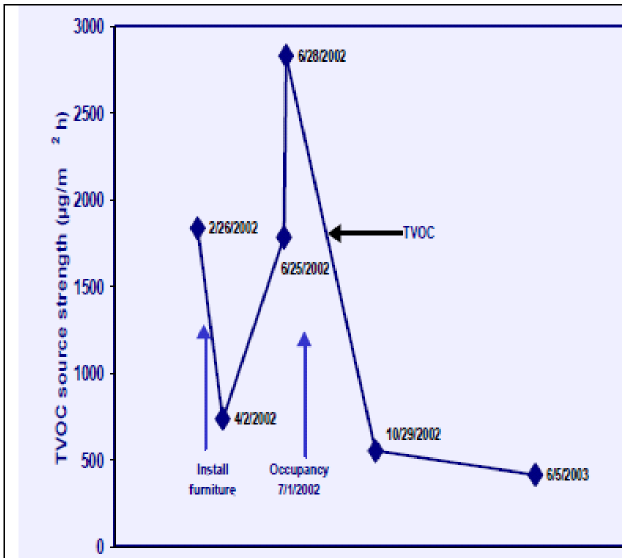

Figure Levin1. 6th floor TVOC source strengths (µg/m² h) (source: Levin, 2003

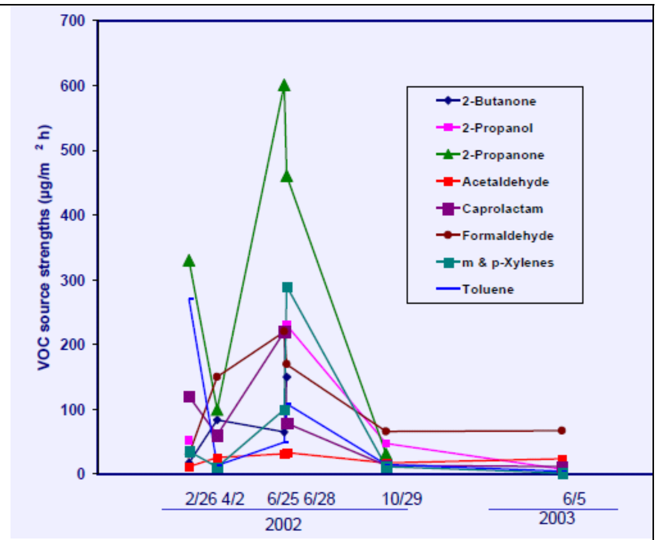

Figure Levin2. 6th floor VOC source strengths (µg/m² h) (source: Levin, 2003)

Table Levin-1. 6th floor VOC source strengths (µg/m² h) of 18 relatively abundant compounds

	2/26/'02	4/2/'02	6/25/'02	6/28/'02	10/29/'02	6/5/'03
air change rate (h-1)	4.3	3.6	4.9	1.3	0.9	0.8
Acetaldehyde	12	25	31	33	18	23
1-Butanol	40	23	20	41	12	11
2-Butanone	18	84	65	150		1
Caprolactam	120	60	220	79	13	12
n-Decane	77	11	10	53	5	2
2-Ethyl-1-hexanol	36	21	22	26	5	6
Ethyl acetate	33				4	4
Ethylene glycol				210		
Formaldehyde	31	150	220	170	66	67
Hexanal		90	59	160	41	25
d-Limonene				12	17	35
n-Nonane	27	3	10	33	1	
Nonanal	74	56	100	39		10
Phenol	49	39	69	47	6	11
2-Propanol	52			230	47	8
2-Propanone	330	100	600	460	32	
Texanol 1 & 3	42		22	41		12
Toluene	270	13	49	110	14	5
n-Undecane	36	9	16	34	5	3
m & p-Xylenes	36	11	100	290	12	2
TVOC	1840	740	1780	2830	550	420

Figures Levin1 and Levin2 and Table Levin-1 show clearly show the expected decay in source strengths over time after installation of materials. However, samples collected on June 25 and June 28th, 2002, just 3 and 6 days prior to initial occupancy of the building, show that final cleaning and maintenance procedures performed by the contractor resulted in large increases in source strengths for several chemicals. Most of these were presumably used for cleaning the building and for polishing metal and other building components since no new building materials or furnishings were introduced during that time period.

Note the increased source strengths of Caprolactam, 2-Propanone (acetone), and m- and p-xylene on June 25 and June 28. Caprolactam is a precursor of Nylon 6, and the carpets are the only known source for Caprolactam found in the building. The elevated concentration on June 25 and 28 were unexpected. Its source strength had decreasd from 120 $\mu g/m^2\ h^{-1}$ on the first sampling date, right after carpet installation, to 60 $\mu g/m^2\ h^{-1}$ six weeks later. Yet on June 25, more than four months after carpet installation, the calculated source strength was 220 $\mu g/m^2\ h^{-1}$. Since Caprolactam is highly water soluble, it is likely that carpet cleaning with a wet process contributed to the elevated concentration and source strength,

In contrast, the 2-Propanone and the m- and p-xylene are not attributable to the carpet cleaning since they are insoluble in water. These are chemicals commonly used as solvents in cleaning and polishing products, and neither of these was strongly emitted by the tested building materials and furnishings selected by the design team for the project. Ethylene glycol was higher on June 28 indicating the likelihood of touch-up painting or other last-minute operation before the occupant move-in.

The Total VOC (TVOC) source strengths (Figure Levin1 and Table Levin1) alone do not indicate potential health effects, nor are the useful for determining the efficacy of the emissions testing. Since the testing was done with individual VOC emission criteria based on chronic health effects limit values, the individual VOC data are far more useful than the TVOC data. But even the individual data after occupancy must be interpreted with caution due to the limitation imposed by the presence of VOC sources other than building materials and furnishings after initial occupancy.

Indirect evidence

There are many whole building labeling or certification schemes that award credits or points toward certification or labeling for materials that meet standards or guidelines based on emissions testing of products used in the buildings. There two major emission testing protocols and criteria, from GreenGuard Environmental Institute and the California Department of Public Health are often referenced in these programs. Studies of occupant responses to the indoor environment may provide some suggestive evidence of the efficacy of the emissions testing programs, However, the fact that ventilation rates and material loading factors may vary considerably between testing and the actual building decreases the potential usefulness of such studies. Furthermore, the certification or labeling of a building under the US Green Building Council's LEED rating system does not necessarily require that points have been obtained for low-emitting materials in order to obtain a high certification level or label. The CHPS program also awards credits toward certification or labeling and points for low-emitting materials are not necessary to receive the listing. Both GreenGuard and CHPS maintain lists of approved materials for which points can be received by the building rating schemes.

Various studies have been done of LEED rated buildings to determine whether LEED rating results in a higher quality indoor environment. . In general, these studies have focused more on the buildings' energy performance rather than the indoor environmental quality. One of these studies, summarized below, examined worker absenteeism and work hours affected by health effects attributable to the indoor environment.

Effects of Green Buildings on Employee Health and Productivity

Singh et al (2010) performed 2 "retrospective– prospective case studies" to investigate …the effects of improved indoor environmental quality (IEQ) on perceived health and productivity in occupants who moved from conventional to green (according to Leadership in Energy and Environmental Design ratings) office buildings." They reported that "…improved IEQ contributed to reductions in perceived absenteeism and work hours affected by asthma, respiratory allergies, depression, and stress and to self-reported improvements in productivity." Like many post-occupancy studies of LEED rated buildings, there were no measurements of the indoor air quality nor reporting of the building characteristics related to indoor air quality for which LEED points were received, The authors qualified their "preliminary findings" writing that they "… indicate that green buildings may positively affect public health." (Singh, 2010)

The study is of limited help due to the fact that occupants moved from older buildings to a LEED certified buildings. So there is no comparison between the effects of emissions from new materials in conventional and LEED-certified buildings.

European Policy Evaluation

In an analysis of public health benefits of IAQ policies, Jantunen (2010) found that IAQ testing and labeling of building materials, equipment, and products would be moderately effective relative to 9 other policy options in terms of the benefits to public health. See figure Jantunen1.This is indirect evidence based on modeling that an IAQ emissions testing program would be an important contributor to public health.

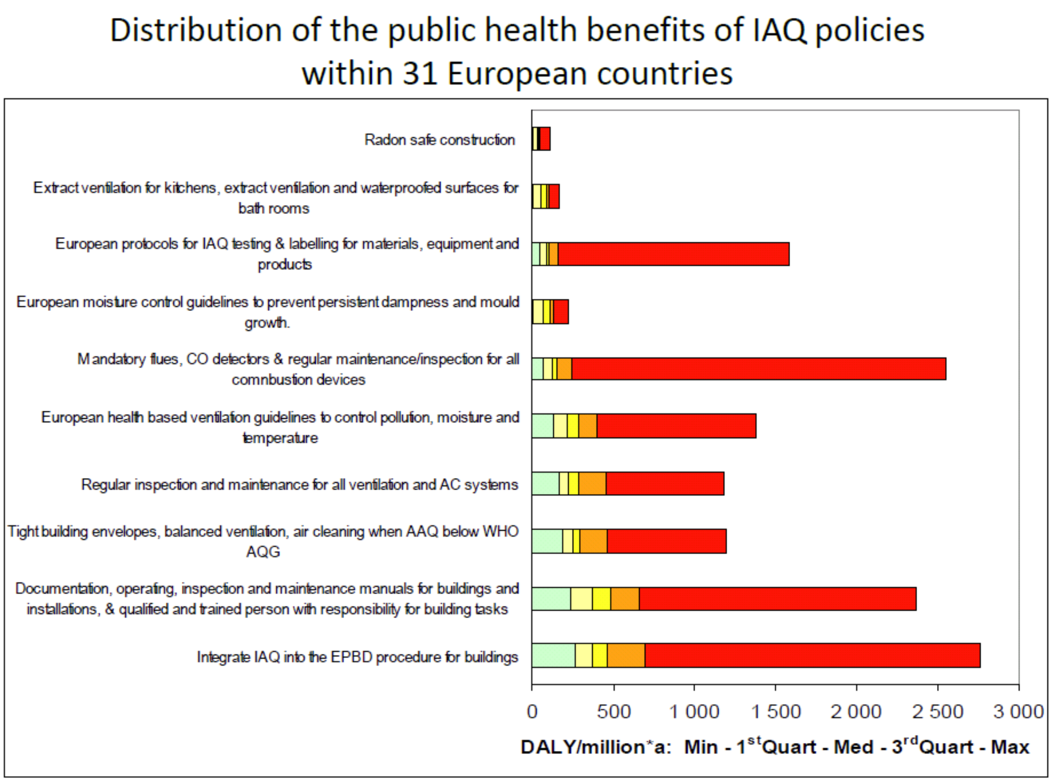

Figure Jantunen-1.

Search for additional evaluative information

A web-based search for studies documenting the effectiveness of emissions testing under LEED or GreenGuard was made using Web of Science, as follows:

all databases, year 2000-2010: 'Topic Search', for keywords: =(LEED OR GreenGuard OR 'Green Guard') AND TS=('indoor air' OR 'indoor env*') AND TS=(health OR productivity OR occupant* OR 'field study') . The search produced 9 hits, 3 of them an article on occupant self-reported productivity with no reference to IAQ or emissions. The other 6 were not relevant to the relation between emissions testing, IAQ, and occupant responses.

European Commission Joint Research Centre, ISPRA

The following text presents an analysis of the potential efficacy of emissions testing in terms of DALYs saved by a 10% reduction in the risks presented by exposure to emissions from products and materials found indoors. [Excerpt from Invitation to Harmonised Framework on indoor material labelling schemes: challenge with a global perspective. 7-8 June 2010, Ispra]

> "Emissions from construction products can constitute a significant source of indoor pollution. Recently the DG RTD[10] funded EnVIE[11] co-ordination action on indoor air quality and health effects estimated that, substantial short to medium term benefits at low cost can be expected from harmonised testing and labeling of all building materials, equipment and consumer products (i.e., 10% of the estimated risk reduction potential in EU-27 corresponds to 30000 DALYs/y). Currently, a number of national and industry focused labeling schemes for low emitting products exist in Europe and worldwide and each has its own specific requirements for testing and criteria for product evaluation. This results in significant costs to industries wishing to provide low emitting products in different European markets and is potentially confusing for consumers wishing to make informed choices among a variety of available products in the market."

CONCLUSION

Emissions testing, labeling, and certification are gaining market penetration and adoption throughout the developed and in limited portions of the developing world. The major barriers to more effective implementation include the absence of widely-accepted, health-based target concentrations for indoor air pollutants of concern. Furthermore, there is very limited understanding of the health and comfort effects of exposure to the complex mixtures found in indoor environments.

Available data from prevalent practices for testing emissions limit the understanding that can be gained from such testing due to the increasingly common practice of delegating the determination of pass-fail to the laboratories that perform the emissions test. More complete reporting of emissions test results would enable both researchers and manufacturers alike to engage in an on-going process of product improvement that was not limited to the criteria for the particular certification or label.

There are numerous technical issues related to the testing itself that also need to be addressed as testing and certification or labeling based on test results becomes more commonplace. These are discussed below.

[10] European Union Directorate General Research and Technological Development

[11] EnVIE – "Behind closed doors: air quality in buildings." EnVIE is a European Co-ordination Action interfacing science and policy making in the field of indoor air quality. EnVIE is collecting and interpreting scientific knowledge from on-going research, in particular from EU funded projects and Joint Reserch Center activities, to elaborate policy relevant recommendations based on a better understanding of the health impacts of indoor air quality.

RECOMMENDATIONS FOR FURTHER RESEARCH

Example Issues to Target for Resolution

The following are 4 examples of problems related to the issues needing resolution that could be targeted for resolution. All these issues are important. They are placed in approximate order of the feasibility and complexity of their resolution, though opinions may differ about that.

Problem 1: Testing of Wet Products

Description of the Problem

Application of wet products (e.g. paints, adhesives, sealants, and caulks) is highly variable, depending on the substrate, the application tools, and the applicator as well as environmental conditions like (e.g., air movement, temperature and humidity). The total quantity applied can vary significantly as a function of coating thickness. Some of this variability can be addressed in testing by standardized procedures such as weighing the substrate before and after application of the product to the test specimen using a micro balance. However even then, there is no assurance that an evenly applied coating has been attained. It is also challenging to represent the high variability of field applications in the testing process.

In the case of adhesives, the emissions in field applications will also depend strongly on the characteristics of the material applied over them and the amount of time between application of the adhesive and of its coating.

One remedy for this in wet-applied products is to base labeling and certification on bulk content and modeling rather than on emissions testing. This needs to be explored through research, but it is a theoretically plausible approach. It also has the benefit of providing information for potential worst case exposure scenarios for wet products which are inherently very high during the first few hours after application when chamber testing is difficult due to the high rate of emission of solvent (water or other solvent material).

Unresolved Issue Needing Resolution: Composition Testing

- Define the circumstances, if any, in which composition limits rather than emission limits are acceptable for indoor air quality product assessments.
- Establish a general agreement for chemicals warranting a composition prohibitions.
- Define a standardized methods for measuring chemical composition for indoor air (vs outdoor air) quality purposes and the extent to which chemical speciation is required.
- Define acceptable chemical composition limits based on health impact of assumed or estimated emissions or exposures (based on diverse scenarios for various applications()
- Determine whether it is cost effective to develop models that estimate emissions from chemical composition with sufficient accuracy for specific product classes, and if so, encourage development of such models.
- Define the specific product emission models to be allowed, and circumstances for their use, in lieu of product emission testing.
- Define exposure scenarios relevant to each product class or type.

What Could Be Done

- Convene a technical workshop of indoor air scientists to develop an agreed approach to testing/modeling and evaluating wet product emissions.

- Convene a scientific panel on the analysis of wet product contents and emissions
- Convene a meeting of stakeholders to endorse an approach to evaluating wet products based on the recommendations of the scientific panel.
- Develop protocol in concert with technical panel and stakeholders for testing/labeling wet products (possibly through ASTM)
- Develop guideline in the use of emissions data from wet products.

Problem 2: Accounting for Product or Specimen Variability

Description of Problem:

Single Test: Most certifications and labeling programs are based on one test a year. The products covered by that single test are represented by a single sample even though there are a variety of different versions, models, etc. of the product. Variations occur from batch to batch, day to day, plant to plant, and over longer periods of time.

Paints: Variations in paint by addition of color are not evaluated in most labeling programs. The basic paint is tested without pigment, yet the pigments themselves may be of concern.

Natural ingredient/composite wood products: Products made from “natural ingredients,” especially composite wood products, other composites made of cellulose fibers, or natural rubbers and other materials may have natural variations with significant impacts on emissions from these natural components as well as from other components in the finished product. This is an especially important problem because of the high emission rates of formaldehyde and several other VOCs of health significance from composite wood products and because of the widespread use of these products in large quantities in enclosed spaces. The trailers for victims of Hurricane Katrina illustrate this latter point..

Unresolved Issue Needing Resolution: Sample Selection and Handling

Standardize methods of sample selection, number of samples, handling of samples, and frequency of sample selection/testing for different types of products

Problem 3: Dealing with Cleaning Products and Air Fresheners

Description of the problem

VOC emissions from cleaning products are dependent on a number of factors including cleaning product composition, volatile constituent of cleaning products, product usage pattern (timing and frequency, ventilation regime, relationship to occupancy, etc.), and application and use practices (e.g., type of applicator such as mop, rag, sponge, etc., polish, wiping off excess, etc.)

All of these factors are highly variable from product to product and even within a single product type or class and application. Therefore, the type of variability that characterizes wet-applied architectural coatings is even more significant for cleaning products, where the variability in exposures can be very large.

Cleaning and maintenance product as part of building material evaluation: The total life cycle emissions from building materials should ideally include the emissions of products used to clean and maintain that material. For example, wet cleaning of carpets can result in elevated concentrations of chemicals adsorbed on carpet surfaces and also contribute to mold growth, while regular cleaning and coating (polish, wax, sealants) of hard surface floors can produce emissions far in excess of those coming from the floor itself. For example, the mass of volatile components emitted from the cleaning and maintenance products can exceed the mass of the volatile components of the vinyl floor tile in two years of regular maintenance. Thus, it is important to incorporate an evaluation manufacturers' recommended cleaning and maintenance practices in the evaluation of potential emissions and selection of materials for indoor use.

Interactions between cleaning product behavior and applicator behavior: When one integrates over the complex and dynamic emissions that occur AND the nature of application (floor mop vs. scrub vs. spray) and indoor conditions (air exchange, mixing, etc.), it may not always be reasonable to assume that the often-used well-mixed assumption will yield reasonable estimates of exposure concentration. It would be good to get to a point where we can characterize events as being "simple" (meaning ... go ahead and assume the well-mixed model), and complex (better do real measurements or more sophisticated modeling).

Indoor Air Chemistry: A further complication is the reactions of the ingredients of many cleaning products, especially those considered to be "green", with oxidants commonly found indoors. For example, terpenes can react rapidly with ozone in indoor air generating many secondary pollutants, including TACs such as formaldehyde. Furthermore, ozone–terpene reactions produce the hydroxyl radical, which reacts rapidly with organics, leading to the formation of other potentially toxic air pollutants. Indoor reactive chemistry involving the nitrate radical and cleaning-product constituents is also of concern, since it produces organic nitrates as well as some of the same oxidation products generated by ozone and hydroxyl radicals

A California Air Resources Board study on the reactions of cleaning products with oxidants found in indoor air revealed that the cleaning products now considered "green" are among those most likely to react with ozone, for example, to form more toxic and irritating products (Nazaroff et al, 2006). Some of the most common (popular, widely-used) green cleaning products contain citrus- or pine -derived solvent substitutes that are very likely to react in the presence of oxidants. Even at fairly low (but common) indoor concentrations of ozone, sufficient ozone is present to initiate these reactions and result in worse exposures than to the products from which they were formed. There are a variety of other indoor air chemistry issues that arise in the consideration of cleaning products.

Special problems with chemical analysis of cleaning products: Some of the glycol ethers and terpene alcohols are very sticky (quite polar) and can be missed by routine analytical methods. In the past, common terpenoids such as a-terpineol and linalool have been overlooked because of inappropriate analytical procedures.

What needs to be accomplished

- Characterize the factors that affect emission behavior of cleaning products to better model that behavior for use in certification and labeling programs
- Determine significance of emissions from cleaning and maintenance (periodically-renewable surface coatings) in terms of life cycle emissions associated with specific products
- Characterize indoor air chemical reactions with chemicals in and emitted from cleaning products.
- Define protocols for testing and evaluating cleaning product emissions and performance
- Define labeling requirements for cleaning products.

Possible approaches to address cleaning product emissions testing, certification, and labeling

- Convene a technical workshop of indoor air scientists to develop an agreed approach to modeling cleaning product emissions.
- Since the mass emitted from a product cannot exceed the mass originally contained in it, it is reasonable to use modeling in worst case and typical scenarios to obtain a first order estimate the

potential emissions. Some emissions testing and modeling work has been done that can give general guidance and advice. But more detailed knowledge of the very broad range of specific products in commerce is required. Such a meeting should also be used to identify and prioritize a research agenda to resolve important questions.

- Convene a scientific panel on the analysis of cleaning product contents and emissions
- Convene a meeting of stakeholders to endorse an approach to evaluating cleaning products based on the recommendations of the scientific panel.
- Convene a technical panel on the analysis of cleaning product contents and emissions
- Develop protocol guidelines in concert with technical panel and stakeholders for testing/labeling cleaning products (possibly through ASTM)
- Develop guidelines for the use of emissions data from cleaning products.

Problem 4: Establishing Common Standardized Concentration Limits

Description of the Problem

Chemical exposure limit values are necessarily the basis for any testing used for labeling, listing of approved products (CHPS, GreenGuard, Floorscore, CRI Green Label, etc.). The values that are used have not all been developed using the same criteria, either empirically-based or theoretically based. For Example:

1. Threshold limit values (TLVs) based on irritation are generally based on data gathered in industrial contexts where a small number of subjects is exposed to a single known irritant as part of the occupational workplace setting. Self-selection is a characteristic of the populations that are studied since individuals with low tolerance for the chemical agents studied would tend to select themselves out of the workplace population. Furthermore, the published documentation of the ACGIH TLVs shows that for many of the chemicals, a significant number of the subjects did experience irritation even thought the TLV is described as protective against irritation. In many cases, the TLV was set at the measured level regardless of the fraction of the study population that reported irritation during exposure. Approximately half the adopted TLVs are based on irritation.
2. The chronic reference exposure levels (CRELs) adopted by the California Office of Environmental Health Hazard Assessment (OEHHA) are based on 1/10 of the lowest no observed adverse effect level (NOAEL) and are intended to protect sensitive populations.
3. NIOSH adopts criteria for pollutant exposure generally based on health although some of its criteria state that the criterion is based on the lowest practical level for measurement by industrial hygiene techniques. In many cases, NIOSH criteria are considerably lower than OSHA or ACGIH TLVs and permitted exposure levels (PELS).
4. The World Health Organization (WHO) Regional Office for Europe has included indoor air exposure in its Air Quality Guidelines for Europe, but the values are a compromise between outdoor and indoor exposures. These guidelines have been revised and are published as Air Quality Guidelines by WHO International in Geneva. The Regional Office for Europe has now published guidelines for Dampness and Mold and will begin development of guidelines for Indoor Air early next year.
5. The European Community produced a thorough review of key indoor air pollutants with extensive documentation of the data sources. The "Critical Appraisal of the Setting and Implementation of Indoor Exposure Limits in the EU, INDEX," was completed in 2005 and will be reviewed and revised beginning in October 2008 to establish guideline values.

The lack of a single consistent set of exposure concentration limits in the U.S. is a very large weakness for the U.S. emission testing/labeling activities. Should EPA be able to lead an effort to establish a standardized set of limits, it would be the single most important contribution that EPA could make to the emissions testing, certification and labeling industry. It is also a contribution that is uniquely EPA's to make.

What EPA could do

- EPA IED may advocate the establishment of a set of standardized procedures for adopting limit values to be used in certification and labeling programs. To do so, it will be important to account for the sources of uncertainty in the data used to establish the criteria, in the principles applied in the adoption of "safety factors" and to the application of the values to emissions testing results or modeled concentrations.
- 2.EPA's IED together with the OPPT may use one of the several methods available in the relevant literature, e.g., that used in the Hodgson and Levin, Classification of measured indoor volatile organic compounds based on noncancer health and comfort (2003), shown inf Figure HAL-1; the AgBB approach as presented in this paper; or the approach of Nielsen et al, (1998). The approach used by Hodgson and Levin (2003) is shown diagrammatically in Figure HAL-1. The approach taken by the European Union as described in the document The INDEX Project: Critical Appraisal of the Setting and Implementation of Indoor Exposure Limits in the EU can also be considered. This document contains risk assessments of chemicals and will attempt be revised to establish indoor air exposure concentration limits next year.
- EPA could convene a workshop or conference to achieve agreement among stakeholders as to the appropriate methods for establishing limit values and also to agree on a process for selecting interim guideline values to be used in emissions testing, certification and labeling programs.
- Another option would be for EPA to fund the National Research Council for an independent analysis and make recommendations for indoor exposure concentration limits for the U,S.

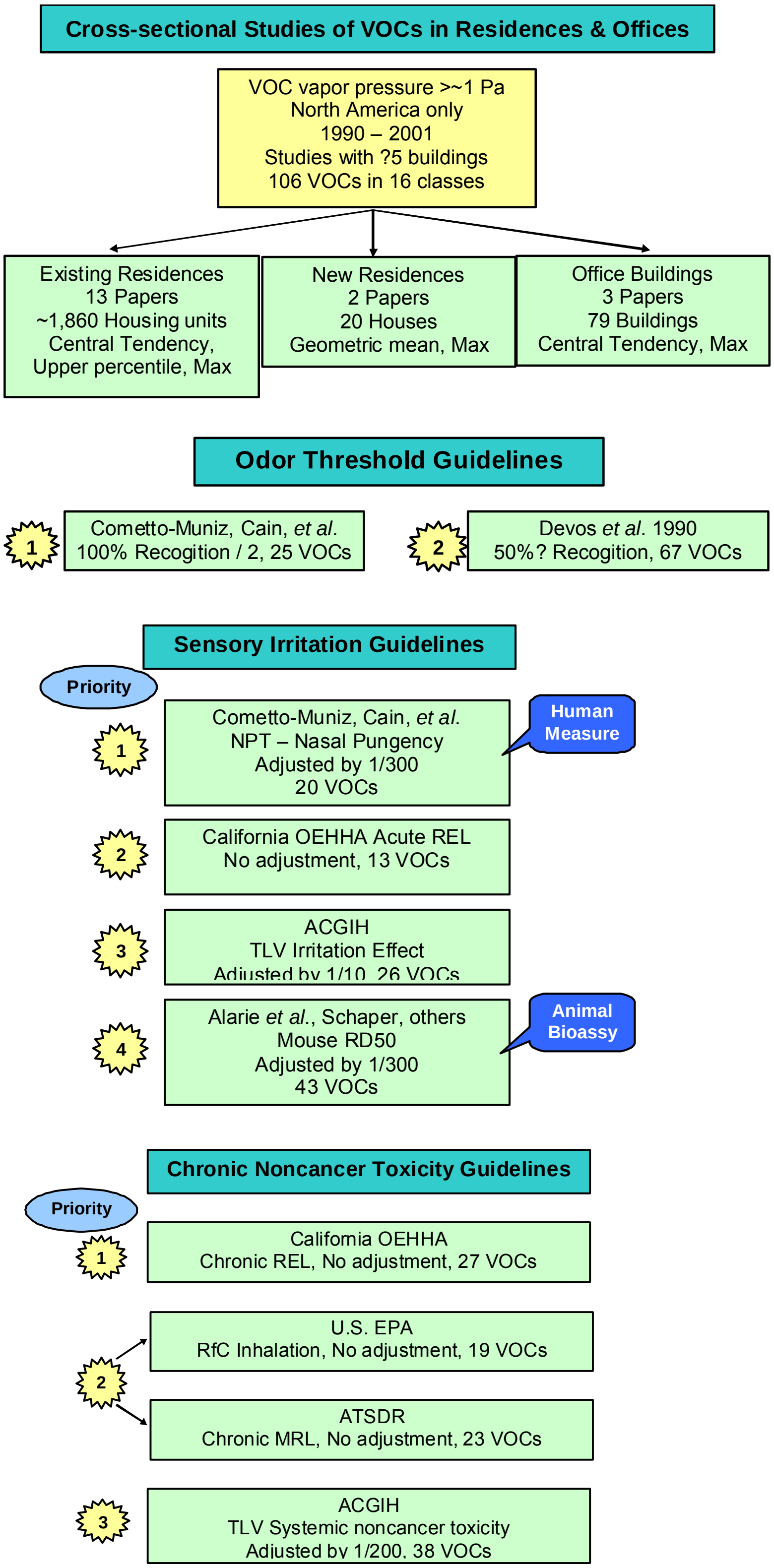
Cross-sectional Studies of VOCs in Residences & Offices
VOC vapor pressure >~1 Pa
North America only
1990 – 2001
Studies with ?5 buildings
106 VOCs in 16 classes
Existing Residences
13 Papers
~1,860 Housing units
Central Tendency,
Upper percentile, Max
New Residences
2 Papers
20 Houses
Geometric mean, Max
Office Buildings
3 Papers
79 Buildings
Central Tendency, Max
Odor Threshold Guidelines
1
Cometto-Muniz, Cain, et al.
100% Recogition / 2, 25 VOCs
2
Devos et al. 1990
50%? Recognition, 67 VOCs
Sensory Irritation Guidelines
Priority
1
Cometto-Muniz, Cain, et al.
NPT – Nasal Pungency
Adjusted by 1/300
20 VOCs
Human Measure
2
California OEHHA Acute REL
No adjustment, 13 VOCs
3
ACGIH
TLV Irritation Effect
Adjusted by 1/10, 26 VOCs
4
Alarie et al., Schaper, others
Mouse RD50
Adjusted by 1/300
43 VOCs
Animal Bioassy
Chronic Noncancer Toxicity Guidelines
Priority
1
California OEHHA
Chronic REL, No adjustment, 27 VOCs
2
U.S. EPA
RfC Inhalation, No adjustment, 19 VOCs
ATSDR
Chronic MRL, No adjustment, 23 VOCs
3
ACGIH
TLV Systemic noncancer toxicity
Adjusted by 1/200, 38 VOCs

Figure HAL-1. Process used in Hodgson and Levin (2003) to establish target concentrations

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APPENDIX 1

Emissions Testing And Labeling Programs and Schemes in EU, USA, China, Korea:

(Source JRC Harmonization Workshop, June 9-10, 2010: LIST OF INVITEES (version 8, 30 April 2010)
.

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APPENDIX 2.
EcoLabels related to buildings in North America

Source: EcoLabels web page accessed 5 September 2010 at
http://www.ecolabelindex.com/ecolabels/?st=region,north-america;category,buildings

Earth Advantage
New & remodeled homes certified as Earth Advantage ensures that the highest standards of energy efficiency, indoor air quality, resource efficiency and environmental responsibility are being met.
Built Green
Built Green promotes and recognize environmentally responsible residential home construction and renovation with four standards or labels. Rating levels are linked to the labels. Members and home buyers have the flexibility of choosing their level of participation, thereby offering broader appeal. Bronze represents the minimum of achievement level, Silver is the next level, and Gold is the third ...
Green Globes
The Green Globes assessment and rating system for buildings.
R-2000
R-2000 is a voluntary, perfomance-based standard for new homes, which goes beyond building codes. The technical requirements involve three main areas of construction: energy performance, indoor air quality and environmental responsibility. R-2000 homes must operate within a specific energy budget, based on the characteristics of the home and the climate conditions where it's built. Typically, R-2000 …
WaterSense
Products bearing the WaterSense label are generally 20% more water-efficient than similar products in the marketplace and must be independently tested before qualifying for the label.
LEED Accredited Professional
LEED Professional Accreditation distinguishes building professionals with the knowledge and skills to successfully steward the LEED certification process.LEED Accredited Professionals (LEED APs) have demonstrated a thorough understanding of green building practices and principles and the LEED Rating System.
LEED Project Certification
LEED certification provides independent, third-party verification that a building project meets the highest green building and performance measures. All certified projects receive a LEED plaque, which is the nationally recognized symbol demonstrating that a building is environmentally responsible, profitable and a healthy place to live and work.
GreenCircle
GreenCircle™ Certified GreenCircle Certified provides independent certification of green and sustainable aspects of products, manufacturing operations and claims. By issuing a GreenCircle Certification, GreenCircle Certified demonstrates that it has evaluated and verified the information provided by the manufacturer and that the manufacturer is capable of, and consistently produces, a product …
Greenstar Certified
Purpose of the label is to promote the production and use of products that maximize sustainability, protect the environment and protect human health. Currently certifies cleaning products.
LEED Green Building Rating System
The Leadership in Energy and Environmental Design (LEED) Green Building Rating System™ encourages and accelerates global adoption of sustainable green building and development practices through the creation and implementation of universally understood and accepted tools and performance criteria.

CHPS - Collaborative for High Perfromance Schools
CHPS is leading a national movement to improve student performance and the entire educational experience by building the best possible schools. CHPS develops tools that help make schools energy, water and material efficient, well-lit, thermally comfortable, acoustically sound, safe, healthy and easy to operate. Resources offered by CHPS include a six-volume best practices manual, training and conferences, …

Green Shield Certified
An independent, non-profit certification program that promotes practitioners of effective, prevention-based pest control while minimizing the need to use pesticides. Evaluates and certifies both pest control professionals and buildings and facilities that meet high standards of Integrated Pest Management (IPM).

EnerGuide for New Houses
Shows information about your home's energy use. The program is designed to help new home builders plan and build energy efficient, cost-effective homes. Scoring systems rates homes from 0 (lowest) to 100 (highest).

Green Flag Program
The Green Flag Program promotes student leadership and activism for the creation of safer and healthier school environments. The Program assists schools to achieve environmental success in the following four issue areas. - Reduce, Reuse, Recycle- Indoor Air Quality- Integrated Pest Management- and Non-Toxic Products.

IPM Star
The Integrated Pest Management (IPM) Star Certification Program recognizes IPM practitioners who meet a high standard for IPM in schools, childcare centers and school-age programs. IPM STAR certification is a voluntary step that clearly establishes your IPM competence in a way that is readily recognized by others both in and outside of your community.

Certified Envirodesic
The Envirodesic certification mark is licensed to qualified builders, manufacturers and service-providers whose buildings, products and services meet stringent standards for healthy environments.

Envirostars
EnviroStars is an environmental certification program designed to address hazardous wastes being generated by small businesses in Washington State. EnviroStars is limited to companies generating small quantities of hazardous waste -less than 220 pounds per month, and who and accumulate no more than 2,200 pounds of hazardous waste on site at any time.