BC Green Building Code
Background Research

Materials Emissions & Indoor Air Quality

October 2007

Note: The following research paper on materials emissions and indoor air quality was prepared independently by Light House Sustainable Building Centre. The paper provides a review of the current literature and background information that the province will consider during the development of Green Building requirements now and in the future. The provincial government does not necessarily endorse the information or share the views expressed in this paper.

Summary:

This paper provides an overview of the major known indoor air pollutants, the associated health concerns, and possible costs due to death, medical treatments and lost productivity. The paper reviews the wide range of testing, rating and labelling systems currently in use, and finds that the data necessary for establishing clear scientific standards is often lacking.

The science on materials emissions and the complex factors that can influence indoor air quality is in its infancy. Factors include not only building materials, building design and ventilation—elements that could fall within the purview of building regulation—but also post-occupancy factors associated with furnishings, cleaning agents and life-style practices. There is also a general lack of economic analysis on this topic, both on the economic impacts of poor indoor home environments, and on the costs and benefits of potential regulatory approaches.

The paper concludes that deciding between different policy approaches to reduce exposure to indoor pollutants is an exceptionally complex task. Options range from waiting until more definitive information is available to enacting regulatory standards, with many variations in between.

Most Canadian jurisdictions do not have specific legislation to deal with indoor air quality issues. Health Canada guidelines, ASHRAE standards, and CSA standards are noted as potentially useful tools for policy makers.

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light house
Sustainable Building Centre

1575 Johnston Street
Vancouver, BC
V6H 3R9
(604) 682.5960
www.sustainablebuildingcentre.com

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Introduction

The purpose of the following document is to provide technical research summaries that will inform the development of specific code provisions in areas of material emissions and indoor air quality. The document therefore comprises literature review and excerpts from relevant technical sources, supported by commentary from Light House, in order to offer guidance and background to the Province of BC's development of a proposed Green Building code for BC.

The document was completed by Light House with technical support from Julie Hardy, Environmental Consultant, Environmental Home Solutions.

[This section includes excerpts from the following sources:

CDC Fact Sheet: Actual Causes of Death in the United States, 2000. Centers for Disease Control and Prevention. Atlanta, Georgia. March 15, 2004.

Abu-Shalback, L. The impact of IAQ. Appliance. 57(6) pg. 53. June 1, 2000.

Health Canada. Environmental and Workplace Health. Air Quality. http://www.hc-sc.gc.ca/ewh-semt/air/index_e.html. Accessed August 2007.

Burnett, J. Niu, J.L. "Setting up the Criteria and Credit-Awarding Scheme for Building Interior Material Selection to Achieve Better Indoor Air Quality." Environment International. 2001; 26: 573-580.]

More than 10 years have passed since the US Environmental Protection Agency (EPA) ranked indoor air pollution as one of the top five environmental threats to public health and one of the largest remaining health risks in the United States. According to the Centers for Disease Control and Prevention (CDC), the most common actual causes of death in the US in 2000 were tobacco (435,000), microbial agents (such as influenza and pneumonia, 75,000), and toxic agents (such as pollutants and asbestos, 55,000) (1). Also, the American College of Allergy, Asthma and Immunology in 2000 noted that 50 percent of all illnesses are either caused or aggravated by poor indoor air quality (IAQ) (2).

Interior building materials can represent a significant source of indoor air pollution. Material emission rates, and the number of compounds emitted, vary considerably from product to product, and even within the same material category (3). In 2004 the National Research Council (NRC) began research to assess the health risks from organic chemicals in indoor air with the intention of creating a list of target contaminants, acceptable concentrations for each, and a checklist for managing them (4). More recently, Health Canada announced plans to develop a priority list of indoor contaminants that will be national in scope and require government action. The federal government will utilise legislative authorities to gather information on contaminants that affect indoor air quality, which will then be used to guide decisions on the development of guidelines and product regulations. Consultation on the list of priority contaminants began in the spring of this year. (5)

The building industry has conventionally addressed indoor air pollution through ventilation rates. In the past these were calculated based on a building's occupancy, which was then expanded to include pollutant sources from both the building and its occupants. In the past decade, however, the argument has arisen that if, during a building's design, a material is known to be a significant source of emissions, which would require increased ventilation rates, it would be more economical to specify an alternative material. (3) As high ventilation rates translate to increased energy use and costs, source control by means of interior building material selection holds the most promise for further investigation and action.

Definitions, Concepts, & Benefits

[This section includes excerpts from the following sources:

Burnett, J. Niu, J.L. "Setting up the Criteria and Credit-Awarding Scheme for Building Interior Material Selection to Achieve Better Indoor Air Quality." Environment International. 2001; 26: 573-580.

Felicia Wu, David Jacobs, Clifford Mitchell, David Miller, and Meryl H. Karo.

"Improving Indoor Environmental Quality for Public Health: Impediments and Policy Recommendations." Environmental Health Perspectives.   June 2007; 115 (6): 953-957.]

There are few building materials, except for glass and stainless steel, which are emission-free. These materials, along with some other 'natural' materials are generally classified as low-emission materials (3). The majority of indoor building products add various quantities of polluting emissions—radon, volatile organic compounds (VOCs), and Polybrominated diphenyl ethers (PBDE)—to the indoor environment. While the total amount of indoor emissions is much less than that found outdoors, once emitted, indoor pollutants are diluted much more slowly than outdoor concentrations. British Columbians, like people from other industrialized nations, spend most of their time indoors. This makes it much more likely that people will be exposed to pollutants emitted indoors than those emitted outdoors.

There is considerable evidence to suggest that indoor contaminants pose significant public health risks, particularly among children and the poor (6). The term "Sick Building Syndrome" (SBS) has been frequently used to describe the IAQ-related complaints by office workers, and is characterized by a rapid disappearance of symptoms—headaches, nausea, fatigue, etc—after leaving the building, There is also growing concerns about the long-term health effects of some indoor pollutants, even if present only at very low levels.

Major Indoor Air Pollutants and Their Health Concerns

[This section includes excerpts from the following sources:

Burnett, J. Niu, J.L. "Setting up the Criteria and Credit-Awarding Scheme for Building Interior Material Selection to Achieve Better Indoor Air Quality." Environment International. 2001; 26: 573-580.

California Air Resources Board. "Report to the California Legislature: Indoor Air Pollution in California." February, 2005.

Shaw, C.Y. Won, D. Reardon, J. National Research Council Canada. "Managing Volatile Organic Compounds and Indoor Air Quality in Office Buildings – An Engineering Approach." March 2005.]

The following is a brief review of the pollutants associated with indoor building materials and their respective health concerns. Table 1 is a summary of these findings.

Asbestos

The only material banned for building use, asbestos was traditionally used in buildings as fire and heat-resistant materials. As the use of asbestos has been banned in most countries including Canada, exposure occurs only in old buildings when fibres become airbourne due to deterioration or its removal from the applied surface. (3)

Lung cancer is the predominant asbestos-related disease, accounting for the majority of deaths from asbestos exposure. Due to the success of remediation efforts, asbestos concentrations are generally quite low in most buildings today. Non-occupational exposures, therefore, are generally low compared to occupational ones. (7)

Endocrine Disruptors

Endocrine disrupters are substances that alter the normal function(s) of the endocrine systems of animals and humans, adversely affecting growth, development or reproduction. Public attention has been drawn to endocrine disrupters that mimic or block the natural effects of estrogens, but they can also affect male sex hormones, development and behavior. Substances that cause endocrine disruption include both natural and synthetic chemicals.

The air and dust inside homes are likely to contain a wide variety of chemicals, many of which are identified as endocrine disrupting substances. Polybrominated diphenyl ethers (PBDE), a group of chemical endocrine disrupters, are added to plastics and textiles to meet fire safety regulations. Phthalates, another group of chemicals that have been implicated as endocrine disrupters, are used to create flexible plastic products such as vinyl upholstery, shower curtains, and garden hoses. (7)

Formaldehyde

A suspected carcinogen, formaldehyde is a pungent smelling gas emitted from numerous indoor sources. While many materials and products emit formaldehyde, emissions studies have shown that building materials, particularly composite wood products, are likely the greatest contributors to indoor levels of formaldehyde. Technically a VOC, formaldehyde is often treated separately because it is not detected by the gas chromatographic methods commonly used to measure other VOCs. (7)

Formaldehyde is an upper respiratory tract irritant that produces eye, nose, and throat irritation. Indoor formaldehyde concentrations typically exceed outdoor levels due to the many indoor sources. Indoor and urban ambient levels also typically exceed California's Office of Environmental Health Hazard Assessment (OEHHA) Chronic Reference Exposure Level (REL) of 2.4 parts per billion (ppb), which is based on irritant effects on the mucous membranes of the upper airways and eyes. Nearly all indoor environments also exceed their one-in-a-million cancer risk level. Formaldehyde emissions are greatest when building materials are new, and take years to completely off-gas. (7)

Lead

Lead is a toxic metal that has been used in paints, pipes, and ceramic glazes, and to a lesser extent, in caulk. Lead poses a major hazard to children, with long term, exposure leading to brain damage, decreased growth, hyperactivity, and impaired hearing, and reproductive.

Eliminated from paints and gasoline, by many countries, the major indoor building sources of lead today include old paint in homes built before 1978, lead pipes installed before the 1930s, and lead solder in copper piping installed before 1987. Activities that disturb lead-based paint, such as remodeling, can release large amounts of lead-bearing particles into the air, which may later settle in dust. The simple deterioration of lead paint can accumulate in house dust. (7)

Volatile Organic Compounds

Volatile organic compound (VOC) is a generic term to describe thousands of compounds with widely varying physical, chemical, and toxicological properties. Concentrations of many VOCs are consistently higher indoors (up to ten times higher) than outdoors, and are emitted by a wide array of products including paints and lacquers, paint strippers, and wood preservatives (7). Testing for the presence of 66 different VOCs, air samples taken in 24 Canadian workplaces and 25 Canadian houses (Tsuchiya and Kanabus-kaminska, 1990) found 34 different VOCs in the former and 56 in the latter. (8)

A report prepared by the National Research Council Canada states that there appears to be "no well-established evidence linking a large number of individual VOCs found in the indoor air to health concerns, particularly for occupants with normal health." However, the report goes on to acknowledge that some VOCs detected in indoor air are recognized carcinogens and that there are reports of exposure to VOCs resulting in symptoms varying from headache, nausea, dizziness to eye, skin, and throat irritations. The odour associated with some VOCs may also cause complaints. (8)

Radon

A naturally-occurring, radioactive gas that comes from soil, radon is also released from any earth crust-derived building material enriched with uranium-238: bricks and concrete used in the foundation or walls. Radon itself is relatively harmless, but its decay products can accumulate in the lung and cause cancer. (7)

Table 1: Sources and Potential Health Effects of Indoor Material Emissions

POLLUTANT	MAJOR INDOOR SOURCES	POTENTIAL HEALTH EFFECTS ASSOCIATED WITH ONE OR MORE OF THE POLLUTANTS LISTED*
Asbestos	Building materials in older homes released during renovation, naturally occurring in some soils	Lung cancer, asbestosis, mesothelioma
Endocrine Disruptors (phthalates; DDT, chlordane, heptachlor, *o*phenylphenol, PBDEs)	Plastics, pesticides, flame retardants	Mimic or block natural effects of hormones (estrogen and others); developmental abnormalities
Formaldehyde, Other Aldehydes	Composite wood products such as plywood and particleboard, furnishings, wallpaper, durable press fabrics, paints, combustion appliances, tobacco smoke	Cancer, eye, nose, and throat irritation, headache, allergic reactions, aggravated asthma, decreased lung function
Lead	Lead paint chips, contaminated soil	Learning impairment
Organic Chemicals (benzene, chloroform, paradichlorobenzene, methylene chloride, perchloroethylene, phthalates, styrene, others)	Solvents; glues, cleaning agents, pesticides, building materials, paints, treated water, moth repellents; drycleaned clothing, air fresheners	Cancer; eye, nose, throat irritation, aggravated asthma, decreased lung function; headaches, at high levels: loss of coordination, damage to liver, kidney and brain
Radon	Uranium-bearing soil under buildings, ground-water, construction materials	Lung cancer (especially in smokers)

* Note that when multiple pollutants are listed in a group, each pollutant may not cause all of the health effects listed in the third column.

Source: California Air Resources Board. "Report to the California Legislature: Indoor Air Pollution in California." February, 2005

Examples of Building Materials that May Have an Impact on IAQ

Table 2: Building Materials and Their Associated Pollutants

BUILDING MATERIALS	ASSOCIATED POLLUTANTS
Shell and façade construction	Asbestos may be found in cement roofing, shingles and siding.
Insulation	Formaldehyde may be found in foam and fiberglass insulation. Fibers, including fiberglass or asbestos, also may be found in insulation.
Wood	Formaldehyde may be found in some plywood and particleboards.
PVC	Polyvinyl chloride is by far the most common plastic used in construction. In 1992, 6.3 billion pounds of this resin were used. Polyvinyl chloride also is commonly used in flooring.
Concrete	Concrete sub flooring in a finished building may be uneven and require applications of floor leveler before the interior floor material is applied. These products may contain odorous chemicals such as phenol and phenoxyethanol. In other cases, floor sealants were placed directly on the concrete, either as finish paint or as a moisture seal. These sealants typically have very high VOC emissions. Though concrete is usually one of the best materials for people who are chemically sensitive, occasionally chemicals such as fungicides, germicides and insecticides are added, which could possibly off gas into the building.
Paneling	Aldehydes, such as formaldehyde, may be found in decorative paneling made of pressed wood products. The manufacturing of plastic paneling typically results in solvents being trapped in the plastic. In addition, heptachlor, a pesticide added to prevent mold growth, has been detected in these materials
Paints, coatings, sealants, adhesives	These are used to bond, seal, coat or finish building materials and may be significant sources of VOCs, solvents and odors.
Wallboard or drywall	These materials can contain formaldehyde and other aldehydes. They also can be the source of odors. These materials are very adsorptive and can collect chemical odors and fumes from other sources such as paints and adhesives.
Roofing	Flat roofs require applications of asphalt and tar that contain VOCs and are a significant source of odors. Some membrane roofing systems used on shopping malls and commercial office buildings can off gas formaldehyde, VOCs, ammonia and amines. Emissions from these materials can infiltrate the building through open crack and crevices.

Source: *Aerias: Air Quality Sciences. IAQ Resource Center. www.aerias.org. Accessed 2007.*

Costs of Indoor Air Pollution

[This section includes excerpts from the following sources:.

California Air Resources Board. "Report to the California Legislature: Indoor Air Pollution in California." February, 2005.

Aerias: Air Quality Sciences. IAQ Resource Center. www.aerias.org. Accessed 2007.

Felicia Wu, David Jacobs, Clifford Mitchell, David Miller, and Meryl H. Karo. "Improving Indoor Environmental Quality for Public Health: Impediments and Policy Recommendations." Environmental Health Perspectives. June 2007; 115 (6): 953-957.]

There are limited quantitative estimates on the costs of indoor pollution, and those available are for a few specific indoor air pollutants that have been well studied, such as environmental tobacco smoke and radon. However, there is no dearth of information on the effects indoor air pollution can have on human health, wellness, and productivity. The California Air Resources Board reports that poor indoor air can result in large costs on society, both economic and personal, including the loss of human life and increased medical costs due to cancer treatments, hospitalizations, chronic respiratory disease, and emergency room visits. Student absenteeism, reduced worker productivity, and associated costs also result from indoor air pollution. (7)

Premature Death

According to the 2005 *Report to the California Legislature: Indoor Air Pollution in California*. There are approximately 230 excess cancer cases due to VOCs in California each year. Considered a conservative estimate relative to the total cancer burden from indoor carcinogens, nearly half of these VOC-related cancer cases are estimated to result in premature death. Actual premature death rates, however, could be higher than one-half given that the cancers caused by these air pollutants typically result in lung, organ, or blood cancers, which are more difficult to detect and treat. (7)

Medical Costs

Illness and disease caused by indoor air pollution include the production of new asthma cases, exacerbation of preexisting asthma symptoms, development of other respiratory diseases and symptoms, and the onset or aggravation of allergies. The cost for these illnesses and diseases was estimated for California, using methods including looking at medical, work-related, and education-related costs, as well as the willingness of individuals to pay to avoid the anxiety, pain, suffering, and other health risks. For VOC-related cancer alone, the total cost for medical treatment was estimated to be $11 million. These medical costs also do not include the indirect costs of reduced productivity of individuals and employees. (7)

In the US, an estimated 20.3 million Americans have asthma, including 6.3 million children (9). The World Health Organization reported in 2000 that between 100 million and 150 million people around the world — roughly the equivalent of the population of the Russian Federation — have asthma and this number is increasing. Worldwide, deaths from asthma have reached more than 180,000 annually. In the US, the number of people with asthma has increased by more than 60 percent since 1980 (9). In the US, asthma accounts for an estimated 14.5 million lost workdays annually for people over 18 years of age. The annual direct health care costs of asthma are approximately $9.4 billion; indirect costs (such as lost productivity) add another $4.6 billion, for a total of $14 billion dollars. In addition, in 2000, there were nearly 2 million emergency room visits and nearly 500,000 hospitalizations, at a cost of almost $2 billion, causing 14 million school days to be missed each year. (6)

Productivity Losses

The impacts of indoor air pollution also affect the quality of a person's life in terms of reduced or limited activities, limited employment opportunities, and reduced productivity. Sick building syndrome (SBS) is a collection of non-specific symptoms such as eye, nose, skin, and throat irritation; headache; fatigue; and skin rash that have no known cause. A number of indoor building conditions—inadequate building ventilation, elevated levels of VOCs, and other environmental stressors—have been implicated as potential causes. (7)

The annual economic costs of common respiratory illnesses (reported in 1996 US dollars) are 180 million lost workdays; 120 million additional days of restricted activity; approximately $36 billion ($140 per person) in health care costs and approximately $70 billion ($270 per person) total cost. (9)

Benefits of Improved IAQ

[This section includes excerpts from the following sources:.

California Air Resources Board. "Report to the California Legislature: Indoor Air Pollution in California." February, 2005.

Felicia Wu, David Jacobs, Clifford Mitchell, David Miller, and Meryl H. Karo. "Improving Indoor Environmental Quality for Public Health: Impediments and Policy Recommendations." Environmental Health Perspectives. June 2007; 115 (6): 953-957.]

A 2005 NRC publication on managing IAQ in office buildings reports there is strong theoretical evidence indicating that improvements to indoor environments can result in significant improvements to health and productivity. In the US, the potential annual savings plus productivity gains are estimated between $30 and $170 billion, with benefits outweighing costs by a factor of 18 to 47 (10). Recent experiments in office buildings have demonstrated that office worker performance could be significantly increased over the short term by either increasing ventilation rates or removing common indoor sources of air pollution, such as floor coverings and used supply air filters (7).

An example of how the removal of indoor toxins can have significant results is the remediation of U.S. homes with lead-based paint and the impacts on children's health. As a result of careful legislation, regulation, education, research, and enforcement, children's blood lead levels have decreased dramatically since the 1970s. In 2000, the U.S. Department of Housing and Urban Development (HUD) and the U.S. EPA estimated the cost of reducing blood lead levels from exposure to lead-based paint would be $2.4 billion over 10 years. These costs, however, were far below the annual monetized benefits, anticipating a 2.2–4.7 point increase in IQ per child affected, of $110 billion–$319 billion (6).

Key Issues

Identifying Material Emissions

[This section includes excerpts from the following source: Burnett, J. Niu, J.L. "Setting up the Criteria and Credit-Awarding Scheme for Building Interior Material Selection to Achieve Better Indoor Air Quality." Environment International. 2001; 26: 573-580.]

Typically, the emission rate of a material drops in relation to the time it is exposed to the air. This reduction of emission rate over time is called the rate of decay. This rate can vary considerably from material to material. For example, emissions from 'wet' products such as paint and adhesives tend to have high decay rates, while formaldehyde from wood products and radon from concrete can remain at the same level for years. In many countries, there are specific regulations limiting or banning emissions from pollutants with confirmed health effects, such as asbestos, formaldehyde, and radon. However, even though VOCs constitute the majority of indoor air contaminants, there is still no recognized indoor air standard for these compounds. (3)

Labelling Systems

[This section includes excerpts from the following sources:

Charles, K., Magee, R.J., Won, D., Lusztyk, E. National Research Council Canada. "Indoor Air Quality Guidelines and Standards." March 2005.

Integrated Waste Management Board. Building Materials Emissions Study. November 2003.]

In the past 25-30 years, a wide variety of organisations have developed criteria for specific building materials and products, in order to help consumers choose those that emit lower levels of VOCs. The total number of labeling systems has become quite large, with individual systems adopted by many different countries. Appendix A offers a brief description of several of the report presents twelve of the most well known, and most-widely used of these labeling schemes. (10)

Labelling schemes for low-VOC emitting products show considerable variety in terms of materials/products, chemical substances (criteria), levels of criteria, and testing methods. This may imply that there is not much consensus in deriving the schemes. The necessity of more standardized testing methods and criteria becomes obvious to maximize the effectiveness of such schemes.

Some of the results reported by independent studies are inconsistent with those reported by industry supported product certification programs, such as Carpet and Rug Institute's Green Label testing program for carpets and paint manufacturers' low- or no-VOC labels. These inconsistencies may be attributed to (a) the differences in the sampling and analytical techniques employed by these programs and those used in this study; or (b) to the definitions upon which these labels are based. Other researchers have reported similar discrepancies between their findings and those of industry-supported programs. (11)

Material Safety and Data Sheets

[This section includes excerpts from the following source: Canada Mortgage and Housing Corporation. Building Materials for the Environmentally Sensitive. 1997.]

Material Safety Data Sheets (MDS Sheets) can be utilized to monitor the chemical composition of materials that are being considered in the design concept. Monitoring the chemical composition of materials can reduce the VOC load within a building and be incorporated into a VOC budget type of system.

Although workplace information provided by Material Safety Data Sheets (MSDS) is available for commercial products, consumer products are essentially exempt from this process due to proprietary or trade secret exemptions. As a result, consumers, builders and professionals have great difficulty in obtaining product information. The CMHC published guide "Building Materials for the Environmentally Sensitive" notes that the chemical composition of most products is proprietary and the exact formulation not often complete in MSDS. (12)

Untested Compounds

[This section includes excerpts from the following source: Healthy Building Network. "Improving Indoor Air Quality with the California 01350 Specification." June 2007.]

A range of VOC issues remain inadequately unaddressed by any IAQ program.
The California OEHHA CREL State covers 80 chemicals. This does not mean that any of another thousand plus compounds that IAQ testing might uncover are with out health effects. It only means that the state has not studied them and set a CREL level yet. Thousands of volatile organic compounds remain very poorly understood for their effect individually or in combination and must be approached with caution. Some systems address this through setting a limit on the total volatile organic compounds (TVOC). There is no health basis research on which to set such limit so it is of limited meaning. GreenGuard has recently proposed addressing it through an approach that takes the lesser of 1/2 of the CREL or 1/100 of the ACGIH's TLVs in its Children and School Standard. (13)

Health Care and other Sensitive Settings

[This section includes excerpts from the following source: Healthy Building Network. "Improving Indoor Air Quality with the California 01350 Specification." June 2007.]

In healthcare facilities, the air change rates are likely to be twice or more those in the offices and schools for which many protocols have been evaluated. This could result in a lower bar being set for products in a healthcare facility under this as emissions will be flushed out faster and hence not concentrate at the same rate. However these facilities have immune suppressed and otherwise highly sensitive populations that may require a higher standard of care. This trade off be considered in applying standards to healthcare. (13)

Cancer Effects

[This section includes excerpts from the following source: Healthy Building Network. "Improving Indoor Air Quality with the California 01350 Specification." June 2007.]

The CA Office of Environmental Health Hazard Assessment (OEHHA) Chronic Reference Exposure Limit (CREL) list is based on chronic health effects, including reproductive issues. There is no equivalent to the CREL for carcinogenic effects. The specification requires reporting of chemicals known to be carcinogens. Except for adhesives, is up to the owner to make precautionary judgments and determine when to screen out a product. Likewise, even with chronic effects, there are many chemicals that have not yet been studied to determine appropriate exposure limits and synergistic effects between chemicals. (13)

Life Cycle Emissions Impacts

[This section includes excerpts from the following source: Healthy Building Network. "Improving Indoor Air Quality with the California 01350 Specification." June 2007.]

Standards and guidelines generally only address the emissions from the product when installed in a building, not emissions from the manufacture and disposal ends of the lifecycle. Some materials, such as PVC, may have more significant emission impacts at other stages of their lifecycle and warrant screening for these hazards too in healthy building specifications.

IAQ Emissions and Long Term Testing

[This section includes excerpts from the following source: Healthy Building Network. "Improving Indoor Air Quality with the California 01350 Specification." June 2007.]

Emissions of VOCs tend to be strongest early in the life of the product and diminish over time – meaning that emission testing in the first few weeks is the most important indicator of potential health impact. Some other compounds – e.g., SVOCs (semi-volatile organic compounds) such as phthalate plasticizers from PVC, halogenated flame-retardants, such as PBDEs and perfluorocarbons – may not emit from products until some time has passed after installation, with emissions increasing rather than decreasing with time, then remaining stable for long periods. More long-term studies are needed to understand this phenomenon. Other heavy metal additives like lead, mercury may dust off of products over time as well. (13)

Education

Education of the general public as well as such key individuals as teachers, office workers, members of the building industry, health professionals, government officials, labour union leaders, and the media is an important element of a program to reduce indoor air pollution because personal behaviour as well as public regulation is involved.

Many people do not understand how the interrelationship of numerous factors can contribute to poor IAQ, including those cited above as well as building occupant activities. Further, many do not realize that they can take a proactive role in preventing IAQ problems. Learning what to do to prevent IAQ problems and then doing it is an important part of any IAQ strategy or program. Instruction in the correct use and maintenance of products, substitution of non-polluting products, and recommended levels and frequency of ventilation can reduce indoor air pollution.

Assessing Building Material Emissions and IAQ

[This section includes excerpts from the following sources:

Shaw, C.Y. Won, D. Reardon, J. National Research Council Canada. "Managing Volatile Organic Compounds and Indoor Air Quality in Office Buildings – An Engineering Approach." March 2005.

United States Environmental Protection Agency. Indoor Air Management. Indoor Air Quality Modeling. http://www.epa.gov/appcdwww/iemb/model.htm

United States Environmental Protection Agency. "Compendium of Methods for the Determination of Air Pollutants in Indoor Air." May 1990.

James, B. Public Works and Government Services Canada, Office of Greening Government Operations. Indoor Air Quality. "Commissioning For Good Indoor Air Quality in New and Renovated Office Space." August 2005. http://www.pwgsc.gc.ca/greening/text/publications/newreno-e.html

Canadian Mortgage Housing Corporation (CMHC). "Evaluation of Pollutant Source Strengths and Control Strategies in Conventional and R-2000 Houses." 1997.]

According to the Institute for Research in Construction (IRC), building materials can emit hundreds of chemicals, making comprehensive identification and testing impractical. Emission assessment has therefore been aimed at target pollutants and VOCs whose greater abundance made analysis relatively easy. Some of the disadvantages to this include:

- The most abundant chemicals are not necessarily compounds with the highest health concerns
- Lab analysis may be difficult if no calibration standard exist for the compound
- Lack of data on the characteristics of the compound makes it difficult to positively identify it.

The IRC target VOC (list of 90 compounds) criteria include:

1. Known or suspected to have health or irritation concerns
2. Known to be emitted from the building materials
3. Often found in indoor air
4. Suitable for sorbent sampling and analysis with GC/MS or carbonyl analysis with HPLC

The IRC's Target VOC list was derived mostly from the European Committee, 1997 TVOC analysis for IAQ investigations. Other standards and guidelines that were consulted for Target List VOCs included:

- Japanese Indoor Air Standards
- Health Canada Priority Substances Lists – CEPA
- Health Canada Domestic Substances List (DSL)
- California Proposition 65

- US 2001 CERCLA Comprehensive Environmental Response, Compensation, and Liability Act – Priority List of Hazardous Substances [ASTDR 2003]
- US EPA Hazardous Air Pollutants (HAPs)
- WHO 1999 Air Pollutants with Health Endpoints
- California Chronic Reference Exposure Level (CREL)
- US EPA Voluntary Children's Chemical Evaluation Program (VCCEP)
- US NIOSH Method 2549 (List of 42 common VOCs)

NIOSH also has an extensive list of methods for testing single VOC compounds, including formaldehyde, and labs often develop protocol based on these. This becomes particularly important when concerns arise about a particular building material and testing for specific compounds is required. Other testing methods have been developed in line with the US Department of Labor's Occupational Safety and Health Administration (OSHA), ASTM International, and some Worker Compensation Boards. PASS or FAIL criteria for VOCs or any compound requires consideration of the laboratory's detection limits as well as percent error of the analytical results.

Testing should be done prior to occupancy and furnishing of a building in order to correctly assess the source of VOCs. Furnishings, office station furniture and cleaning products can add VOCs to the indoor environment. (8)

Sink effects

The sink effect is the capability of building materials and furnishings to adsorb VOCs from the air and re-emit them into the air later; therefore affecting the IAQ predictions and measurements. Sink effect should be incorporated into IAQ analysis as it is possible to lower sink effects if you allow off-gassing of material prior to the installation of materials that have a tendency to absorb chemicals, such as carpets.

IAQ Modeling

Empirical source models

Used for the prediction of long-term emissions characteristic of a specific sample, using short-term measurement data or a snapshot analysis from chamber testing without any consideration of physical phenomena. The models are generally based on short term testing (72hrs) and will have a tendency to under- or over-predict long term emissions. See Appendix D for further discussion on the American Society for Testing and Materials (ASTM) standards and chamber testing.

Mass transfer source models

Models that simulate the emission process from building material to the air (one for dry and one for wet materials).

Sink Models

The sink models help to predict the rate of adsorption of VOCs into interior building materials and furnishings such as vinyl floor tile, painted gypsum wallboard, ceiling tile and carpet. Research suggest that further work is needed to investigate sink effects and, particularly, the relationship between the strength of the sink effect and the physical and chemical properties of individual VOCs.

Room simulation models

Material Emission Database and Indoor Air Quality simulation program (MEDB-IAQ). Emissions modeling help builders make informed choices for building materials and to have a better overall understanding of parameters that affect IAQ. MEDB-IAQ is a material emission database and a single-zone IAQ simulation software. The database includes 60 commonly used building materials in Canada and emission characteristics of 90 target VOCs.

Natural Resources Canada IA-QUEST

Version 1.1: IAQ Emission simulation Tool allows users to conduct a simulation to assess the VOC emission impact of selected materials based on the amount of materials used and Ventilation rates. It also offers a database of measured emission characteristics for various building materials, and the properties and health effects, if any of the modeled chemicals

Phase II program allows the user to pre-determine whether his choices of materials will meet specific air quality guidelines and/or how long it will take for the concentration to fall below that guideline.

US EPA IAQ Modeling: RISK

http://www.epa.gov/appcdwww/iemb/model.htm

The model uses data on source emissions, room-to-room air flows, air exchange with the outdoors, and indoor sinks to predict concentration/time profiles for all rooms. The concentration/time profiles are then combined with individual activity patterns to estimate exposure. The model allows analysis of the effects of air cleaners located in either/or both the central air circulating system or individual rooms on IAQ and exposure. The model allows simulation of a wide range of sources including long-term steady-state sources, on/off sources, and decaying sources. Several sources are allowed in each room. The model allows the analysis of the effects of sinks and sink reemissions on IAQ. (20)

IAQX 1.0 – Simulation Tool kit

IAQX stands for Simulation Tool Kit for Indoor Air Quality and Inhalation Exposure. It complements and supplements existing IAQ simulation programs (such as RISK) and is designed mainly for advanced users. IAQX version 1.0 consists of five stand-alone simulation programs.

IAQ Modeling in BC

According to a leading commercial IAQ specialist, there is currently no demand for IAQ modeling here in BC. IAQ models serve a purpose when designing the interior home to help choose products that will create the least off-gassing problems.

Post Construction Assessment and Monitoring

IAQ issues depend on a number of environmental factors and sink characteristics. IAQ = Thermal comfort + ventilation + indoor contaminants + materials emissions.

Things to consider when air sampling:

- Location of sample area to obtain adequate representation of all areas
- Indoor testing to be done between 4 and 7 feet to represent breathing zones
- Comparison of indoor samples to outdoor sample

According to the US EPA Compendium of Methods for the Determination of Air Pollutants in Indoor Air, test the following compounds to ensure that they meet the maximum concentration criteria of IAQ Pollutants (21):

PM10 – 50ug/m3
Formaldehyde – 50 ppb
TVOC – 500 ug/m3
CO – 9ppm
4-PC – 6.5 ug/m3

PWGSC study

The PWGSC Commissioning for Good Indoor Air Quality in New and Renovated Office Space - Post Construction and Pre-Occupancy noted the following (22):
http://www.pwgsc.gc.ca/greening/text/publications/newreno-e.html

- Arrange to sample airborne total volatile organic compound levels (TVOC's) after new carpet or vinyl flooring has been laid, when new furniture is in place, and if there is complaint of odours from the occupied space.
- PWGSC has found 1 mg/m3 of total volatile organic compounds to be a useful guideline.
- PWGSC has found it unproductive to identify each individual VOC in this instance because the source is known (fit-up activities and emissions from new materials). If total volatile organic concentrations are found to be above the guideline in the occupied areas, exhaust air from the construction site will need to be increased, and leaks from the work area into the office area need to be located and sealed.
- When the fit-up of the new space is completed, and before the occupants move in, check the airborne particulate levels in the new space, the TVOC levels, and formaldehyde.

- If particulates, TVOC's, or formaldehyde levels are elevated, delay the move, increase the air exchanges, run the HVAC system longer, repeat cleaning (for airborne particulate), and monitor again.

CMHC Study - Pollutant Source Strengths and Control Strategies

A study conducted in 1997 by Canadian Mortgage Housing Corporation (CMHC) entitled "Evaluation of Pollutant Source Strengths and Control Strategies in Conventional and R-2000 Houses" evaluated air quality in five conventionally built houses and one R-2000 house. The study reaffirmed that reducing the use of pollutants, during construction and after moving in, is the primary solution for healthy indoor air quality.

Volatile Organic Compounds were analyzed in the home before occupancy, one month later and after six months. At pre-occupancy, almost 100% of the VOC levels were the result of off-gassing from new building materials, finishes, and furnishings. At one month after occupancy, the VOC concentrations increased as a result of the occupant's activities. Sources of occupant-generated VOCs included furniture, paints, cooking, smoking and showering. At six months, only 20% of the VOC concentrations were the result of off-gassing from building materials - mostly formaldehyde. Materials such as carpets and latex painted trims can act as formaldehyde sinks that can become low-level sources for years. Formaldehyde emissions were low at pre-occupancy and did not decrease with time over 6 months. (14)

Overview of Standards & Building Rating Systems

[This section includes excerpts from the following source: Aerias: Air Quality Sciences. IAQ Resource Center. www.aerias.org. Accessed August 2007.

Although there are no currently defined federal regulations covering indoor air quality (IAQ), there are a number of standards and guidelines recommended by international health associations, industry organizations, state governments, and private programs and researchers. The US Environmental Protection Agency (EPA) has certain IAQ requirements for its own facilities, both in allowable emissions from products and final acceptance for pollutant air concentrations in newly constructed buildings.

A federal regulation has been proposed in the US, and numerous programs exist to control pollutant emissions from materials and furnishings used in buildings. The current GREENGUARD Environmental Institute has been established to control emission levels and pollutant contributions from construction materials and furnishings in buildings.

In addition, ASHRAE/ANSI Standard 62-2001, Ventilation for Acceptable Indoor Air Quailty, the American Society of Heating, Refrigerating and Air-Conditioning Engineers ventilation standard, ensures adequate and effective ventilation to buildings. Ventilation and pollutant source control have been recognized as the primary ways to control indoor air quality in buildings. Currently, these programs are voluntary, but use of these controls is very effective in minimizing pollutant levels and odors in buildings. (9)

Standards and Guidelines for Common Indoor Contaminants

[This section includes excerpts from the following source: Charles, K., Magee, R.J., Won, D., Lusztyk, E. National Research Council Canada. "Indoor Air Quality Guidelines and Standards." March 2005.]

There is a wide range of IAQ standards and guidelines. This observation is more pronounced with guidelines relating to indoor air pollutants in both types of substances and levels of each substance. An order of magnitude of difference is not unusual even among the standard and guideline values for industrial settings (OSHA, MAK, NIOSH, and ACGIH), which have a longer history of establishment. For example, in the case of formaldehyde, there are 7 different allowable concentrations from the various standards. (10)

NAAQS/EPA – 0.4 ppm
OSHA – 0.75 ppm
MAK – 0.3
Canadian HC – 0.1 over the long term
WHO/Europe – 0.0851
NIOSH – 0.016
ACGIH 0.3 Ceiling
COSHR – same as ACGIH

HK – 0.024

The most stringent is NIOSH at 0.016 ppm. Further research would be required to investigate how each of these guidelines and standards were achieved and which standard is the most applicable here in BC.

It should also be noted that many of the standards have been adopted for exposure in a working environment where industrial workers have access to Personal Protection Equipment.   Office workers are exposed to a broad spectrum of contaminants at low concentrations for generally 40+ hours per week. ASHRAE Standard 62-1989 recommends using one tenth of ACGIH limits for compounds for which comfort guidelines do not exist.

Acceptable office IAQ, as defined by the Canadian Standards Association (CSA) and the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE), is air in which there are no known contaminants at harmful concentrations and with which a substantial majority (i.e. 80% or more) of the people exposed do not express dissatisfaction. Generally accepted industry standards include ASHRAE ventilation and thermal comfort standards.

Ventilation Standards

[This section includes excerpts from the following source: Charles, K., Magee, R.J., Won, D., Lusztyk, E. National Research Council Canada. "Indoor Air Quality Guidelines and Standards." March 2005.]

Indoor air quality is closely related to ventilation. Assuming outdoor air is less contaminated than indoor air, fresh outdoor air replaces indoor air through ventilation, thus removing and diluting contaminants generated indoors. Standardization of ventilation requirements has a long history, dating back to as early as the 18th century. The guidelines specify ventilation rates that are linked to the minimum acceptable pollutant concentrations. For many years, ventilation standards and guidelines were based on the metabolic CO2 concentration. The recent ventilation guidelines take into account both occupant generated contaminants (e.g., CO2 or odours) and non-occupant sources (e.g., VOCs from building materials and furnishings). (10)

ASHRAE Standard 62 (2001)

[This section includes excerpts from the following source: American Society of Heating, Refrigerating and Air Conditioning Engineers. ASHRAE Standard: Ventilation for Acceptable Indoor Air Quality. 2001.]

ASHRAE guidelines are not specific to building materials, nor are there any sections that specifically address this topic. ASHRAE define indoor air quality as "…determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction." ASHRAE conforms to the health effects of chemical and biological substances per ACGIH, American Conference of Governmental Industrial Hygienists.
ACGIH threshold level values (TLV's) for indoor pollutants "…are referenced in other western nations' standards, including Canada, Western Europe, Australia." (26)

Though not specific to building materials, the following sections are applicable to the discussion of indoor air pollutants:

- Table B-1: STANDARDS APPLICABLE IN THE UNITED STATES FOR COMMON INDOOR AIR POLLUTANTS, listed by pollutant e.g. asbestos, CO, formaldehyde, lead, particulates, radon, SO2, and a few more.
- Table B-2: GUIDELINES USED IN THE UNITED STATES FOR COMMON INDOOR AIR POLLUTANTS, same as above
- ASHRAE standard 62-2001, Addendum 62n. - Table 6-2: Minimum ventilation rates in indoor breathing zones. Note: table is a 2-page table with overview of physical ventilation requirements of different room types (per their intended purpose).

IAQ in Green Building Rating Systems

Table 3 outlines how several green building rating systems address IAQ in their requirements.

TABLE 3: IAQ STANDARDS IN GREEN BUILDING RATING SYSTEMS

RATING SYSTEM	JURISDICTION	CREDIT REQUIREMENTS	STRATEGIES	WEBSITE
The Building Research Environmental Assessment Method (BREEAM)	U.K.	Health and Wellbeing	Where cooling towers/evaporative condensers are designed to allow ease of access for cleaning, maintenance and replacement of parts or no cooling towers/evaporative condensers are specified.	http://www.breeam.org/pdf/EcoHomes2005DevSheetsV1.pdf
			Where hot and cold water systems have been designed or actions taken to minimise risks of Legionellosis.	
			Where air intakes serving occupied areas avoid major sources of external pollution.	
		Materials	Where there is no asbestos in the structure, services, lifts, etc. of new buildings; Or for existing buildings where an asbestos survey has been carried out and all asbestos either removed or contained and identified within a H&S plan.	
		EQ required credits	Environmental Tobacco Smoke Control Minimum IAQ Performance	http://www.cagbc.org/uploads/FINAL_LEED%20CANADA-NC%201.0_Green%20Building%20Rating%20System.pdf
		EQ Credit 3.1: Construction IAQ Management Plan: During Construction	Adopt an IAQ management plan to protect the HVAC system during construction, control pollutant sources and interrupt contamination pathways. Sequence the installation of materials to avoid contamination of absorptive materials such as insulation, carpeting, ceiling tile and gypsum wallboard.	
		EQ Credit 3.2: Construction IAQ Management Plan: Before Occupancy	Prior to occupancy, perform a building flush-out or test the air contaminant levels in the building. The flush-out is often used where occupancy is not required immediately upon substantial completion of construction. IAQ testing can minimize schedule impacts but may be more costly.	
		EQ Credit 4.1: Low-Emitting Materials: Adhesives & Sealants	Specify low-VOC materials in construction documents. Ensure that VOC limits are clearly stated in each section of the specifications where adhesives and sealants are addressed. Common products to evaluate include: general construction adhesives, flooring adhesives, fire-stopping sealants, caulking, duct sealants, plumbing adhesives, and cove base adhesives.	
		EQ Credit 4.2: Low-Emitting Materials: Paints & Coatings	Specify low-VOC paints and coatings in construction documents. Ensure that VOC limits are clearly stated in each section of the specifications where paints and coatings are addressed. Track the VOC content of all interior paints and coatings during construction.	
		EQ Credit 4.3: Low-Emitting Materials: Carpet Systems	Clearly specify requirements for product testing and/or certification in the construction documents. Select products that are either certified under the Green Label Plus program or for which testing has been done by qualified independent laboratories in accordance with the appropriate requirements. The Green Label Plus program for carpets and its associated VOC emission criteria in micrograms per square meter per hour, along with information on testing method and sample collection developed by the Carpet & Rug Institute (CRI) in coordination with California's Sustainable Building Task Force and the California Department of Health Services (DHS), are described in Section 9, Acceptable Emissions Testing for Carpet, DHS Standard Practice A/DHS/EHLB/R-174, dated 07/15/04.	
		EQ Credit 4.4: Low-Emitting Materials: Composite Wood & Agrifiber Products	Specify wood and agrifiber products that contain no added urea-formaldehyde resins. Specify laminating adhesives for field and shop applied assemblies that contain no added ureaformaldehyde resins.	

Policy Options & Regulations

Deciding between the different policy approaches available for reducing human exposures to indoor pollutants is an exceptionally complex task. These options can range from waiting until more definitive information is available to enacting regulatory standards, with many variations in between.

Approaches to Reducing Indoor Material Emissions

[This section includes excerpts from the following source: Shaw, C.Y. Won, D. Reardon, J. National Research Council Canada. "Managing Volatile Organic Compounds and Indoor Air Quality in Office Buildings – An Engineering Approach." March 2005.]

The best solution to minimize VOC effects in buildings is to develop a proactive plan that focuses on eliminating VOC sources rather than treating the symptoms. Two measures that have been successfully used to reduce VOC concentrations in the indoor air are the use of low-emitting materials/products and the venting of airborne contaminants associated with renovation and installation activities directly outside. Other approaches include the utilization of air cleaners, and where possible containing emissions through the use of sealants. (8)

Source Control and Chemical Component Restriction

[This section includes excerpts from the following sources:

Shaw, C.Y. Won, D. Reardon, J. National Research Council Canada. "Managing Volatile Organic Compounds and Indoor Air Quality in Office Buildings – An Engineering Approach." March 2005.

Burnett, J. Niu, J.L. "Setting up the Criteria and Credit-Awarding Scheme for Building Interior Material Selection to Achieve Better Indoor Air Quality." Environment International. 2001; 26: 573-580.

Canada Green Building Council. "LEED Green Building Rating System: For New Construction & Major Renovations" (LEED Canada-NC Version 1.0). December 2004.]

Source control using low emission building materials followed by ventilation has been considered as one of the most effective strategies for controlling VOCs indoors.

The best way to identify low-emitting material/products would be to require all potential suppliers to submit their material/products samples to the same laboratory for testing. Given that hundreds of materials used in buildings, testing all potential material sample may not always be practical. A more feasible approach might involve potential suppliers submitting emission test reports or similar information such as Material Safety Data Sheets (MSDS). (8)

Product selection can be made using certification, standards and Material Safety Data Sheet. The following are some examples:

- Scientific Certification Systems – Indoor Advantage and FloorScore
- Carpet & Rug institute – Green Label Plus Carpet
- Green Guide for Health Care
- Green Seal Certified Products

- CHPS (Collaborative for High Performance Schools) Low-Emitting Materials criteria
- Institute for Market Transformation to Sustainability – Textile and Flooring stds
- California's reference Specifications - section 01350

Rate of decay, the reduction in rate of emission rate over time, should be taken into consideration when setting up source control strategies. Wet products like paints and adhesives have high decay rate. Formaldehyde from wood products and radon from concrete can remain at same level for years. (3)

As an example of source control, LEED offers points for the following:

- Sequence construction activities so that materials are kept dry and those that absorb contaminants are installed after other materials have off-gassed their contaminants to reduce the sink effect.
- VOC content of adhesives, sealants and sealant primers used must be less than the VOC content limits of the State of California's South Coast Air Quality Management District (SCAQMD)
- VOC emissions from paints must not exceed the Green Seal Standard GS-11 and SCAQMD
- Carpet systems must meet or exceed the requirements of the CRI Green Label IAQ test program.
- Composite Wood and Laminate Adhesives must contain no urea-formaldehyde.

LEED-CI references the GREENGUARD Indoor Air Quality Certified® Products as a requirement for low-emitting furniture. (23)

Ventilation Improvements

[This section includes excerpts from the following sources: Shaw, C.Y. Won, D. Reardon, J. National Research Council Canada. "Managing Volatile Organic Compounds and Indoor Air Quality in Office Buildings – An Engineering Approach." March 2005.

California Interagency Working Group on Indoor Air Quality. Indoor "Air Quality Info Sheet: Advisory on Relocatable and Renovated Classrooms." 1996.]

Increased ventilation prior to occupancy of a building may help to expedite evaporation of VOCs, however it is unclear if it would have any significant effects over the long-term.

Installation and renovation activities lead to a significant increase in the VOC levels indoors. Studies indicate that VOC levels are highest immediately following the installation of products then decrease sharply with time becoming relatively stable after 7-10 days (15). Because this increase is temporary, special measures can be used to minimize the effect including makeshift exhaust systems such as open windows, portable exhaust fans, and smoke shafts. Operating the building's HVAC system at increased ventilation rates for one to two weeks following installation and renovation activities should help alleviate higher than normal emission loads. (8)

While a multidisciplinary group of European scientists recommended increasing the ventilation rate per person to 30L/s, NRC experimental study indicated that increasing the ventilation rate is not effective. Firstly, source control, then ventilation.

Building Flush-out and Bake-out

Did not identify any standardized procedures for flush-outs except from LEED and the following comments from the California Interagency Working Group on Indoor Air Quality (24).

"Flush-out" not "Bake-out"

Building "bake-outs", i.e., when temperatures are increased up to 100F in order to "artificially age" building materials, are not recommended. Their effectiveness has not been proven, and they may in fact damage parts of the HVAC system or building components.

"Flush-out" all newly constructed, remodeled, or acquired classrooms.

Prior to use of any new relocatable units by staff or students, operate HVAC systems at their maximum outdoor air intake rate continuously for several days. Similarly, provide maximum flush-out by HVAC (or open windows) for newly renovated classrooms and offices. Start this "flush-out" as soon as the HVAC system is operational, and continue after furniture installation. During this period, do not recirculate return air.

Continue "flush-out" ventilation during periods of first use

Efforts to minimize exposures to school children and staff should continue in the weeks following project completion. Emissions of VOCs from building materials still pose problems during this time, when they are at their highest. This is done by delaying occupancy in renovated rooms and portable classroom for several weeks, and utilizing maximum outdoor air ("flush-out") ventilation during these periods and for the first weeks of use. Flush out periods of 1-2 weeks are recommend, although longer periods may be required. For the first days to weeks of occupant use, continue to operate HVAC systems at the maximum outdoor air setting. Finally, monitor occupants' comfort, and follow-up complaints to identify problems early.

http://irc.nrc-cnrc.gc.ca/pubs/fulltext/prac/nrcc39862.php - offers practical guidelines for determining the length of the flushing cycle of an HVAC system on computer simulations of contaminant movement in buildings and on experience in managing buildings.

Air Cleaners

[This section includes excerpts from the following source: California Air Resources Board. “Report to the California Legislature: Indoor Air Pollution in California.” February, 2005.]

Air cleaning devices are available in a variety of types and sizes. Most air cleaners remove particles, a few remove gases, and some perform both removal processes. Air cleaners can remove particles from the air using a mechanical or physical barrier, or through an electronic device. Air cleaners that remove gases and odors are less common, and relatively more expensive to purchase and maintain. Gaseous pollutants are typically trapped or destroyed as the air is drawn through materials such as activated charcoal or alumina coated with potassium permanganate. However, the filter material can become quickly overloaded and may need to be replaced often. (7)

Air cleaning devices usually come as portable, stand-alone appliances, or as filters or cleaners in a central air system. Portable air cleaners are sometimes practical for rooms in existing homes where addition of a central air cleaner is too costly. Proper size, installation, and maintenance are critical for portable air cleaners to be effective. Test standards for particle removal by air cleaning devices have been developed by trade and engineering groups. (7)

The effectiveness of some portable air cleaners in removing particles is rated in terms of pollutant removal efficiency or clean air delivery rate (CADR), measured in cubic feet per minute (cfm). The CADR equals the airflow (cfm) multiplied by the efficiency of particle removal; a larger CADR is better. The CADR ratings are given separately for the removal of dust, pollen, and environmental tobacco smoke. Standards for gas removal have not been developed. (7)

Portable air cleaning devices have limited utility, are often not very effective, and can incur high-energy costs relative to the benefit gained. However, air cleaners may be useful for controlling airborne particles for some individuals with special sensitivities, such as those with asthma or allergies who use them in their bedrooms at night. (7)

Based on the limited scientific evidence that is currently available, the health benefits of air cleaners are not clear. Generally, it is more effective to prevent emissions rather than to try to remove them from the air once they are there. (7)

For new homes or major remodels, "whole-house" or "fresh-air" ventilation systems that include some type of air cleaning device can be installed. Installed costs depend on the system size and the type of air cleaning device. Fresh-air ventilation systems are recommended in new, tightly built energy-efficient houses and for situations where the outdoor air is a major source of indoor pollution. (7)

Some air cleaning devices emit ozone, either purposely or as a by-product of the particleremoval technology used in the device. Those that generate ozone by design are often called ‘ozone generators”. ESPs, ionizers, and hybrid models often emit ozone as an unintentional byproduct. While just a few studies have examined the health risk from the use of ionizers and electrostatic precipitators, research has shown that the use of ozone generators can result in harmful levels of indoor ozone. (7)

Containment

Use of effective coating may be an option for some products that are not readily available without VOCs. For example, to prevent formaldehyde off-gassing from composite wood products.

Regulatory Tools

[This section includes excerpts from the following sources: Healthy Building Network. "Improving Indoor Air Quality with the California 01350 Specification." June 2007.

Canadian Mortgage Housing Corporation (CMHC). "Evaluation of Pollutant Source Strengths and Control Strategies in Conventional and R-2000 Houses." 1997.]

Indoor Air Quality Management Plans

The Indoor Air Quality Building Education and Assessment Model (I-BEAM)

Material Screening Policy

Material screening policy might include:

- No PVC (polyvinyl chloride, vinyl)
- Low or no VOCs (volatile organic compounds)
    1) CA 01350 compliant
    2) No added formaldehyde
- No phthalates or heavy metals (lead, mercury, cadmium, organotins)
- No HFRs (PBDEs, BFRs & other halogenated flame retardants)
- No PFCs (perfluorocarbons, PFOA, Teflon & other treatments) (13)

Economic and Financial Tools

Green Building Tax Credit

Give financial help in designing a "green" building that avoids using carpet, paints or other interior materials that can release harmful chemicals. For example, the legislation provides a credit per square foot of interior work builders who meet energy goals and use non-toxic materials in construction.

Information-Based Tools

Right-to-know Labelling

Enact comprehensive right-to-know legislation that mandates a system of labeling of household furnishings (furniture, carpets, drapes, etc.) and home products, combustion appliances, office supplies, art and hobby supplies, and building materials to warn consumers of the potential health effects from their improper use. (15)

Successful product labeling programs in Europe and California suggest that clear disclosure of product constituents and other environmental indicators influences consumer purchasing behaviour, leads to product improvements and may have a positive impact on the indoor environment. (15)

Voluntary Certification Systems

U.S. EPA's Energy Star Plus Indoor Air
Enterprise Foundation's Green Communities Program

Monitoring Programs

Provincial monitoring programs. Citizens need an agency to turn to when they feel that their home or office has a contamination problem. Municipal and Provincial programs can best respond to these concerns with mobile monitoring equipment.

Policies & Regulations in Other Jurisdictions

[This section includes excerpts from the following sources: California Air Resources Board. "Report to the California Legislature: Indoor Air Pollution in California." February, 2005.

Canadian Centre for Occupational Health and Safety. www.ccohs.ca. Accessed August 2007.]

Despite the ubiquitous presence of toxic pollutants in the indoor environment, there are no government air quality regulations that are intended to protect the general public in residences, schools, or public buildings. Workplace regulations address indoor air quality, but they are designed for 8-hour exposures of healthy adults, and are not designed to be protective for longer periods nor for some of the more sensitive subgroups of the population, such as children and the elderly. Ambient air quality standards are focused on outdoor air quality, and are not designed to protect indoor air quality. Other regulations, such as California's Proposition 65, and AB 13, which prohibits cigarette smoking in workplaces, are applicable to indoor air quality only in a limited way and do not prevent indoor emissions and exposures. (7)

There are a few examples of government regulations for emissions from specific sources of indoor pollutants that are intended to protect the general public in indoor environments. In addition, a variety of government agencies and private organizations have established voluntary guidelines and practices that can be applied to indoor environments to assist in the assessment and control of health hazards from air pollutants. (7)

Most Canadian jurisdictions do not have specific legislation that deals with indoor air quality issues. In the absence of such legislation, the "general duty clause" applies. This clause, common to all Canadian occupational health and safety legislation, states that an employer must provide a safe and healthy workplace. Thus, making sure the air is of good quality is the employer's duty. (17)

Several organizations* have published recommended guidelines for indoor air quality:

- Health Canada has prepared a number of publications such as Indoor air quality in office buildings: A technical guide and Dampness, Mold and Indoor Air.
- In the United States, the Occupational Safety and Health Administration (OSHA) has proposed "Indoor Air Quality Standards". For more information, please see OSHA Technical Links page on Indoor Air Quality. (17)

In addition, IAQ is implied in most building codes as design and operation criteria. Building codes in Canada and the U.S. generally refer to the American Society of Heating, Refrigerating, and Air Conditioning Engineers* (ASHRAE) Standard 62 "Ventilation for Acceptable Indoor Air Quality" (1989 or 1999 version may be cited), CSA International* Standard Z204-94 "Guideline for Managing Indoor Air Quality in Office Buildings", or other acceptable standards. (17)

Washington

[This section includes excerpts from the following source: Aerias: Air Quality Sciences. IAQ Resource Center. www.aerias.org. Accessed 2007.]

In the late 1980s, the State of Washington pioneered a strategy to reduce levels of pollutants in the indoor environment. In 1990 the state's Department of General Administration created the Assessment Program for Indoor Air Quality, also known as the "East Campus Plus IAQ Program" and included the program's guidelines in the state's design and construction specifications. Design specifications addressed ventilation, pollutant emissions, lighting, and other elements. The program was designed to control IAQ problems in state office buildings, and included a requirement that all materials used in construction, such as finishing and furnishings of new office buildings, must comply with the program's pollution specifications for formaldehyde, VOCs and particulates. (9)

Low-Emitting Specifications

For pollutant source control, the specifications required the use of "low-emitting" construction materials, interior finishes and furnishings in the construction and furnishing of the building. Pollutant specifications were made for general construction materials, systems office furniture, seating, and carpet. Contaminant specifications required that each product not contribute more than the following levels of pollutants to the building air:

*0.05 ppm (50 ppb) or 61 µg/m3 of formaldehyde
*500 µg/m3 total volatile organic compounds) (TVOC)
*50 µg/m3 of particles
*Carpet only, 0.001 ppm (1 ppb or 6 µg/m3) of 4-phenylcyclohexene (4-PC)

Additionally, those individual volatile organic compounds (VOCs) found to be emitted by the products and known to be carcinogens, mutagens, reproductive toxins, or compounds that emit greater than 1/10th of the threshold limit values (TLVs) had to be reported, along with their levels. Manufacturers were given the opportunity to remove these from their products or to ensure that levels were below health concerns. (9)

Product Emissions Testing

In order to meet these specifications, manufacturers were required to test their products' emissions using environmental chamber methodology following the testing guidelines of ASTM D-5116 and EPA Report 6000/8-89-074 (ASTM, 1990; EPA, 1989). Using specific building assumptions supplied by the state, a computer exposure model was used for predictions of the contaminated concentrations that would result in the building for use of the specified product. Product compliance sheets were required from the manufacturers indicating product compliance or non-compliance with the pollutant specifications. If a product required a period of conditioning or "airing-out" before it could meet the specification, the manufacturer was asked to supply this information. It was necessary for all products to meet these specifications within 30 days after installation. (9)

Today, the State of Washington product specifications are included in many state and building project requirements. To find out if a product meets these specifications, products are tested for their chemical and particle emissions following ASTM D 5116. The results are then entered into an exposure model, which helps predict indoor air concentrations in buildings based on these emissions data. The GREENGUARD Environmental Institute, a third party independent organization that certifies low-emitting materials, tests products using stringent environmental chamber techniques to ensure they meet these low-emitting specifications. (9)

California

[This section includes excerpts from the following sources: California Air Resources Board. "Report to the California Legislature: Indoor Air Pollution in California." February, 2005.

Healthy Building Network. "Improving Indoor Air Quality with the California 01350 Specification." June 2007.]

In 1986, California voters approved Proposition 65, the Safe Drinking Water and Toxic Enforcement Act of 1986, an initiative to address concerns about exposure to toxic chemicals. Proposition 65 requires the State to publish a list of chemicals known to cause cancer, birth defects, or other reproductive harm. The list includes approximately 750 chemicals, many of which are additives or ingredients in pesticides, common household products, food, drugs, dyes, solvents, building materials, and other sources found indoors. Businesses are required to provide a "clear and reasonable" warning when their products or actions may result in a release of chemicals above a specified threshold level, so that members of the public are aware they may be exposed to harmful chemicals. Warnings have evolved to include labeling of consumer products, posting signs at the workplace or on new housing, and publishing notices in a newspaper. OEHHA develops numerical guidance levels, known as "safe harbor" levels, for determining whether a warning is necessary. Proposition 65 pollutants and safe harbor levels are available on the OEHHA website at http://oehha.ca.gov/prop65.html. (7)

California 01350 is a Special Environmental Requirements standard specification developed by the State of California to cover key environmental performance issues related to the selection and handling of building materials. It represents a significant step forward in specification to evaluate and reduce the impact of building materials on indoor air quality and health in buildings and could become a major driving force for better products and healthier buildings as its use spreads. (13)

New York

[This section includes excerpts from the following source: Aerias: Air Quality Sciences. IAQ Resource Center. www.aerias.org. Accessed 2007.]

To help make it easier for building owners and tenants to "go green" in the state of New York, the Green Building Tax Credit was signed into law in May 2000. The tax credit provides $25 million from 2001 to 2009 in income and franchise tax credits to encourage building owners and tenants to produce energy-conserving and environmentally friendly buildings and spaces.

One of the goals of this legislation is to give financial help in designing a "green" building that avoids using carpet, paints or other interior materials that can release harmful chemicals. For example, the legislation provides a credit of five percent of the cost of a project-up to $3.75 per square foot for interior work and $7.50 per square foot for exterior work-to builders who meet energy goals and use non-toxic materials in construction. To qualify, a building must meet requirements for energy use, indoor air quality, waste disposal and water use. There is also a credit equivalent to 10 percent of the cost of new air-conditioning equipment that uses refrigerants that do not harm the ozone layer. (9)

Germany

Formaldehyde emissions from wood-based products as well as emissions of other carcinogenic VOCs from building materials are regulated. (16)

UK

[This section includes excerpts from the following source: Judd, C., Bleicher, D. "Energy Efficiency Meets Indoor Air Quality." Modern Building Services. March 2006.]

The main thinking behind the forthcoming amendments to the Building Regulations is to reduce the energy consumption of buildings while ensuring sufficient ventilation is provided. This will improve air quality in buildings and reduce the risk of condensation forming and mould being able to grow. The new regulations are being introduced to show that good air quality does not come at an increased cost. (25)

There are currently two Part L Approved Documents: L1 for dwellings and L2 for non-dwellings. From April there will be four: L1A for new dwellings; L1B for work in existing dwellings; L2A for new non-dwellings and L2B for work in existing non-dwellings. Approved Document F will also be updated. (25)

Approved Document L is all about getting the industry to minimise the annual energy cost of a building at the design stage. Approved Document F is about ensuring healthy indoor environments by reducing the levels of pollutants and mould growth. (25)

Achieving good air quality in an office environment is an important issue. This is because the work force is a company's biggest asset and keeping them comfortable in their work environment is beneficial to all concerned. The amendments to Approved Document F and Approved Document L of the Building Regulations have been produced to address the issues involved in achieving good indoor air quality and are expected to come into force from 6 April 2006. (25)

An overview of these two documents can be found in Appendix C.

Table 4: Green Building Programs						
Jurisdiction	**Program**	**Compliance**	**Regulatory/Assessment Tools**	**Website**	**Comments**	**Success?**
Portland, Oregon	Green Building Policy	The City of Portland has recently updated its initial green policy which presently requires a minimum of LEED® Gold for all new publicly-funded projects. Private sector projects are voluntary and the City provides support – through both outreach, education and research as well as facilitating the approvals process.	The Portland LEED® Supplement localizes LEED® requirements and identifies both local and state codes that go beyond LEED® standards as well as additional green building strategies that are regionally significant. LEED® "Gold" level is mandatory for all new public projects, but projects are encouraged to go as high as possible. All projects must be certified by LEED®. • Retrofits must achieve LEED®-EB Silver (Existing Buildings) • All tenant improvements in City-leased facilities must achieve LEED®-CI Silver or greater and/or Grated Tenant Improvement Guide certification. • The Portland Development Commission is to adopt LEED® Silver standard for all private sector development in excess of 10,000 S.F that receive at least $200,000 (or 10%) of funding through PDC or other public agencies • Compliance is voluntary for private development (the City provides leadership and guidance to the private sector) o All private sector development that meets LEED® Silver standard will receive special technical assistance from the Development Services Department ("process management" program).	http://www.portlandonline.com/osd/index.cfm?c=41481	Green building needs to be a part of a larger policy discussion (i.e. includes impact on infrastructure) in order to see the greatest impacts. Need coordination among departments. There is very little autonomy in the State Building Code. Barriers with the Code make it more difficult to implement green building initiatives (i.e. State Plumbing Code prevents grey water reuse). Applications must go through an exemptions process which is time consuming. Codes cannot keep up with technological advancements.	This has stimulated extensive private sector initiatives. Currently, green building has occurred primarily in the private sector and Portland boasts the most number of LEED® projects in the US. The majority of green development has occurred in the private sector (voluntarily), as the City has not undertaken a lot of capital projects.
San Mateo County, California	RecycleWorks	voluntary	Their Green Building Program now includes a set of voluntary guidelines (the Green Building Guideline), educational initiatives, LEED requirements for public buildings, and free technical assistance. The program is paid for by landfill tipping fee surcharges.The Green Building Guideline includes a list of green building goals, and strategies for achieving the goals. Each strategy and its intent are defined, and suggestions are provided for implementation. The strategies are summarized in a 75-item checklist. Technical support and educational programs complement the guideline.In 2001, the County of San Mateo adopted a policy that requires all County buildings greater than 5,000 square feet be built to achieve LEED certification.	http://www.recycleworks.org/reuse_center.html	The Green Building Program itself does not monitor environmental performance but it does utilize the annual "Indicators for a Sustainable San Mateo County" report to determine which areas of the program need greater attention.• A $7/ton tipping fee helps in part to fund the green building program.• The County does not provide any incentives, but there are utilities offering fundingfor increased efficiency measures.	

Santa Monica , California		mandatory and voluntary elements	All public buildings must achieve a LEED Silver certification, and all buildings are encouraged to achieve a LEED certification. The State of California has a state-wide Building Code, and a state-wide Energy Efficiency Standard (Title 24) but municipalities can modify these to set higher performance requirements.• Santa Monica has modified both of these sets of regulations in the areas of green development and energy efficiency. Upgrades were selected to maximize impact on the Program's environmental drivers while adding no more than a 3% cost premium to a building built under the state regulations.• So far the mandatory upgrades apply only to multi-unit residential and commercial buildings. They will soon introduce them to single family detached housing.	http://santa-monica.org/epd/	Santa Monica has modified the state building code and energy code to set higher performance standards. The city has modified these regulations in the areas of green development and energy efficiency. So far the mandatory upgrades only apply to multi-unit residential and commercial buildings. However, they are planning to soon introduce them to single family detached housing. This modified code achieves buildings that are about "halfway to LEED Silver"	In order to encourage private builders to build green, the city offers incentives ranging between $20,000 and $35,000, but no developer has taken advantage of these incentives. The city will soon be offering expedited permit approvals at the suggestion of developers, which is expected to be more effective. Since the program's last major revision in 2002, 686 buildings have been constructed to green building guideline standards. This has resulted in an estimated reduction in carbon dioxide emissions of 11,000 tonnes. Furthermore, in 2003, 6.25% of all new construction in the city was LEED certified or better.
Boulder, Colarado	Green Points Program	mandatory	The Green Points Program defines nine categories of green options, plus "innovation". The nine core categories are: • Construction, Demolition and the use of Recycled Materials; • Land Use and Water Conservation; • Framing; • Plumbing; • Electrical; • Windows and Insulation; Heating, • Ventilation, and Air Conditioning; and **• Solar, Indoor Air Quality and Interior Finishes.**	http://www.bouldercolorado.gov/index.php?option=com_content&task=view&id=208&Itemid=489		
Austin, Texas	City of Austin Green Building Program	voluntary	It includes its own measurement system, educational resources, rebate programs and a consulting program for builders. The Residential Green Building Program rates new and renovated houses on a scale of 1 to 5 stars: the more stars there are, the more green features in the home. Homes are rated in six areas: • Energy efficiency; • Testing; • Water efficiency; • Materials efficiency; • Health and Safety; and • Community Additionally, the program offers resources to builders and citizens, which include: educational resources, consulting services and a directory of green building professionals.	http://www.austinenergy.com/Energy%20Efficiency/Programs/Green%20Building/index.htm	The City of Austin also has a Commercial Green Building Program and a Multi-family Green Building Program, that both have similar rating systems to the Residential Green Building Program.	

New York,New York	High Performance Building Guidelines	The Guidelines are mandatory for the development/ retrofit of all public buildings that are the responsibility of the Department of Design & Construction	The Guidelines relate to/reference LEED® but LEED® certification is not required	http://www.ci.nyc.ny.us/html/ddc/html/ddcgreen/	Officials strongly favour moving towards integration with LEED® since this is a standard that is used everywhere (common and generally accepted language). It also has a training aspect and third party verification, although this is difficult for individual organizations to keep up with changes, need for revisions, upgrading of skills etc; all of this is incorporated as part of LEED®.	
State of Minnesota	Sustainable Building Guidelines	mandatory requirement for any state-funded facility.	There is correspondence to LEED® although there is no requirement to attain LEED® certification. The Building Guidelines exceed LEED® standards in many areas with energy efficiency being a prime example (i.e. under the Building Guidelines, buildings must exceed the state energy code by at least 30%).	http://www.msbg.umn.edu/	Reaction from the development community indicates that the mandatory requirement of the new Building Guidelines has created more interest in sustainable building as compared with the previous voluntary Guide. Where the Guideline has succeeded in generating interest within the broader development community, the development community is likely to seek LEED® certification due to its high profile and wide reach in the market.	There was initial resistance from the contractors/agencies which has subsided over the past few years. Green building practices that were initially considered radical are now viewed as mainstream and many of the strategies embedded in the Building Guidelines are widely acknowledged In the future, there may be consideration for developing a Minnesota version of LEED® by integrating the State Guidelines with LEED®.
District of Columbia	Green Building Act of 2006	mandatory	It requires either LEED "certification" or "silver" status depending on the type of project. New construction or substantial improvements must submit a green building checklist as part of the building permit application. The checklist will document the elements of green building that are to be integrated into the project. Within two years of receiving the certificate of occupancy, these projects must be "verified" as having met or exceeded the applicable green building requirements.	http://www.bdlaw.com/assets/attachments/DC_Green_Building_Bill.pdf	The new green building standards will be mandatory in the District by 2009 for private construction projects that are 50,000 square feet or larger. Public projects may have to comply with standards as early as 2008.	

Chicago	Chicago Green Building Program	volunary	• The Green Building Best Practices Guide: identifies green building best practices for homeowners, developers, designers and facility managers. • The Chicago Standard: recommends the use of LEED for new buildings and identifies the 46 credits and prerequisites deemed to be most beneficial to the city.	http://egov.cityofchicago.org/city/webportal/portalEntityHomeAction.do?entityName=Chicago+Center+for+Green+Technology&entityNameEnumValue=161	The City of Chicago has excelled at marketing itself as a leader in green development, which is notable considering that the percentage of green building is far less than 1% of the annual construction in Chicago, and no mandatory green building standards exist	
UK	On 13 December 2006, the Code for Sustainable Homes - a new national standard for sustainable design and construction of new homes was launched.	Since April 2007 new home developers in England can choose to be assessed against the Code. In the short-term, Code compliance is voluntary but the Government is considering making assessment under Code standards mandatory in the future.	Assessment procedures will be similar to BRE's EcoHomes System which depends on a network of specifically trained and accredited independent assessors. BRE will retrain and accredit assessors for the new Code. Code assessors will conduct initial design stage assessments, recommend a sustainability rating, and issue an interim Code certificate. They will perform a post-completion check to verify the rating before a final Code certificate of compliance is issued.	http://www.planningportal.gov.uk/england/professionals/en/1115314116927.html	The Code is closely linked to Building Regulations, which are the minimum building standards required by law. Minimum standards for Code compliance have been set above the requirements of Building Regulations. It is intended that the Code will signal the future direction of Building Regulations in relation to carbon emissions from, and energy use in homes, providing greater regulatory certainty for the homebuilding industry	
Ucluelet, BC		mandatory	the first municipality in the province to require all new multi-family residential, hotel, condominium, and commercial developments to at least meet silver standards under the Leadership in Energy and Environmental Design (LEED) program.	http://www.westcoaster.ca/modules/AMS/article.php?storyid=2500	planner Felice Mazzoni told council the requirement for LEED standard would have to be approved by the provincial government.	

BC Transferability

Stakeholder barriers to IAQ Regulatons

[This section includes excerpts from the following source: Felicia Wu, David Jacobs, Clifford Mitchell, David Miller, and Meryl H. Karo. "Improving Indoor Environmental Quality for Public Health: Impediments and Policy Recommendations." Environmental Health Perspectives. June 2007; 115 (6): 953-957.]

Scientific data is needed in most cases to establish appropriate guidelines, but finding such data for many indoor pollutants is difficult. The lack of biomarkers of exposure for many contaminants makes setting scientific standards difficult. Current science is still in its infancy in the indoor environment/healthy homes area because these questions largely have been overlooked with scant resources committed to policy-relevant research. There is also a relative lack of economic analysis regarding the impact of diseases and lost productivity associated with poor indoor home environments. Without such compelling statistics, there is no political motivation to develop new regulations on IEQ. When policies have been based on scientific findings, the substantial benefits of making such investments have become more transparent and progress adopting them as standard operating costs has been possible. But in cases where science is wanting, we often lack standards that homeowners, building managers, and governments will implement with confidence. (6)

The costs of not creating healthy houses, buildings, and communities are rarely identified or understood. These costs are real but are often overlooked or ignored because they are shifted to the health care sector of the economy, where they appear as more expensive medical care (Jacobs 2005). Consequently, investments in healthy homes are unlike other home improvements because they are not reflected in the market price of the structure. That makes health investments appear to be unwise on the part of the homeowner because unlike other home improvement or maintenance investments, they cannot be recovered when the house is sold. Until health investments are identified in the economic value of buildings, integrating health into routine maintenance, finance, regulatory, and rehabilitation systems will continue to pose a policy challenge for all levels of government. Consequently, the health aspects of housing and indoor environments are generally an afterthought at best, and at worst appear as a burden on affordability or as an "extra" first cost. (6)

Manufacturer Resistance

In General

[This section includes excerpts from the following source: Healthy Building Network. "Improving Indoor Air Quality with the California 01350 Specification." June 2007.]

An increasing number of manufacturers are reformulating their products to bring their emissions down below 01350 mandated levels. As it is adopted more widely by other major buyers, such as educational institutions and healthcare organizations, we can expect this market transformation to pick up steam throughout the interior finish market.

The 01350 standard raises the bar on indoor air quality in important ways. It brings some of the best and current research to bear on the impact of product emissions on chronic health problems. It is customized to the individual building project, but is pretty straightforward. The equation for modeling the concentration is not complex to apply. One test may cost a manufacturer a couple of thousand dollars but can be applied by the lab or the architect or engineer to a wide variety of building projects at little additional cost. CRI, SCS and the State of California have now established modeling scenarios to allow testing of materials for a generic classroom or office building, allowing pre-screening of materials without new modeling for every project.

As written, the standard can be a living document. As the research improves and the impact of additional chemicals is better understood, they are being added to the CA state lists and reflected in the results without requiring further update of the specification. If they do complete testing up front, however, manufacturers will not need to be continually retesting there products but can just apply the results of their tests to the updated lists. It is important, however, that manufacturers retest their products whenever formulations are substantially changed. It is also important that specifiers refer to 01350 in the individual sections that apply. (13)

Example: Paint

[This section includes excerpts from the following source: State and Territorial Air Pollution Program Administrators (STAPPA). Association of Local Air Pollution Control Officials (ALAPCO). "Regulating Air Emissions From Paint: A Model Rule for State & Local Air Agencies. October 2000.]

Some have argued that the consumer market in California is much larger than in other states, creating a greater volume of sales that helps to balance the cost of reformulation. They are concerned that because a lower volume of coatings is sold in many other states, reformulating to meet the VOC limits is economically infeasible, and would force manufacturers to charge much higher prices than the market will support. There are several responses to this argument. First, paints and architectural coatings, are one of the most widely used consumer and commercial product categories producing significant VOC emissions. The universal need for paints, particularly of the flat and non-flat varieties, creates a stable and extensive market for these products throughout the nation. Additionally, many manufacturers that market their coatings nationally currently possess the technologies needed to produce the compliant coatings. Finally, the SCM was found to be cost effective in terms of dollars spent per pound of VOC reduced. The average cost effectiveness, weighted by emissions reductions across all the proposed limits, was estimated to be about $3.20 per pound of VOC reduced, not only well within the typical range of existing CARB control measures and district rules,21 but also within the range of most state and local agencies. (18)

Example: Wood Products

[This section includes excerpts from the following source: California Air Resources Board. "Report to the California Legislature: Indoor Air Pollution in California." February, 2005.]

After numerous lawsuits in the 1970s and 1980s, the composite wood industry developed voluntary emission standards for medium density fiberboard (MDF) and particleboard. A comparison of emission rates from Pickrell *et al.* (1983) and Kelly *et al.* (1999) showed that the emission rates from current composite wood products averaged 49% lower than the emissions in the early 1980s. Industry data provided to ARB by the Composite Panel Association indicate that emissions of particleboard have decreased by 80% in this time frame. In response to an ARB survey, members of the composite wood industry responding to the survey (53%) indicated 100% of their particleboard meets the HUD large chamber test concentration of 0.3 ppm (this chamber concentration is not equivalent to the concentration that would be expected in a home). Of the products Kelly *et al.* (1999) tested, all of the bare MDF products and most of the particleboard samples were below the industry limits. (7)

Occupant Behavior

[This section includes excerpts from the following source: Canadian Mortgage Housing Corporation (CMHC). "Evaluation of Pollutant Source Strengths and Control Strategies in Conventional and R-2000 Houses." 1997.]

CMHC Study - Pollutant Source Strengths and Control Strategies

A study conducted in 1997 by Canadian Mortgage Housing Corporation (CMHC) entitled "Evaluation of Pollutant Source Strengths and Control Strategies in Conventional and R-2000 Houses" evaluated air quality in five conventionally built houses and one R-2000 house. Volatile Organic Compounds were analyzed in the home before occupancy, one month later and after six months. At pre-occupancy, almost 100% of the VOC levels were the result of off-gassing from new building materials, finishes, and furnishings.

At one month after occupancy, the VOC concentrations increased as a result of the occupant's activities. Sources of occupant-generated VOCs included furniture, paints, cooking, smoking and showering. At six months, only 20% of the VOC concentrations were the result of off-gassing from building materials - mostly formaldehyde.

On the problems of indoor environmental quality is that it involves multiple stakeholders who lack both the motivation and the proper information necessary to make changes. The combination of inaction at both the individual and societal levels makes healthy indoor environments difficult to achieve. Even if regulatory decision makers, architects, and engineers could be convinced to provide high-quality homes to all, indoor environments could still be poor if the building dwellers did not know how to take proper care of their homes (14).

Technical barriers to IAQ Regulations

Material Testing Limitations

SCAQMD Rule #1168 http://www.aqmd.gov/rules/reg/reg11/r1168.pdf
According to SCAQMD Rule 102 VOCs are defined as "any volatile compound of carbon, excluding methane, CO, CO2, carbonic acid, metallic carbides or carbonates, ammonium carbonate and exempt compounds. Exempt compounds include HCFC, acetone, ethane, and dichloromethane to name but a few.

VOC limit in grams per litre for various compounds – Laboratories will use different standards for calibration of Total VOCs. A clear definition of VOCs and methods to be used should be prescribed in the BC Building Code to ensure standardization.

Product Availability

[This section includes excerpts from the following source: Integrated Waste Management Board. Building Materials Emissions Study. November 2003.]

Low-emitting, sustainable building materials are available within each of the categories Studied. (11)

Appropriate Alternatives

Manufacturers strive to produce products that meet consumers’ needs and can be used safely; however, VOCs are often required in the manufacture of products to impart desired properties for a given application. This results in trade-offs: proper use of some cleaning products, for example, can remove biological contaminants and some allergens and asthma triggers in the indoor environment, yet occupants sensitive to the odor and irritant effects of the VOC components may be affected. (7)

One study found that VOC limits were exceeded more or less equally by both standard and alternative products. Most products exceeded the Section 01350 limits for only one chemical. (11)

Energy Efficiency

Balancing energy efficiency requirements with indoor air quality support the argument for a material selection approach.

Homes that are built to conserve energy or that are built to be "tight" can be more likely to have indoor air quality problems than homes that are kept "leaky", because air pollution from indoor activities and materials does not get adequately flushed out of the home. Also, in a home that is left intentionally leaky, there is no way to control the air that enters through cracks and other openings.

Appendix A: IAQ Labelling Programs

Source: Charles, K., Magee, R.J., Won, D., Lusztyk, E. National Research Council Canada. “Indoor Air Quality Guidelines and Standards.” March 2005.

Environmental Choice Eco-Logo (Canada)
http://www.environmentalchoice.ca
The Canadian Environmental Choice Label Program was one of the original labeling systems, preceded only by Germany’s Blue Angel program. It was developed in 1988 by Environment Canada, and is administered by TerraChoice Environmental Services. The labeling program is much broader than just emissions testing and includes many environmental management requirements. Example:

- Adhesives: no use in manufacture of aromatic or halogenated solvents, formaldehyde,borax, Hg, PB, Cd, Cr; detailed instructions for safe (health) application and disposal; VOC content < 5% by weight.

Green Label (USA)
http://www.carpet-rug.com/index.cfm
Industry-designed and administered. Developed in 1992 by the Carpet and Rug Institute (the national trade association of carpet and rug industry) in consultation with US EPA. The program specifies maximum emission rates for 4-PC, formaldehyde, styrene and TVOC following small emission chamber trials conducted by a single commercial lab.

Green Label Plus (USA)
http://www.carpet-rug.com/index
This is a revised version of the Green Label program developed to satisfy California's CHPS Criteria. Every carpet receiving Green Label Plus certification has been tested for emission levels for all chemicals as required by Section 01350, plus six additional chemicals for a total of 13 chemicals:

Green Seal (USA)
www.greenseal.org
Developed by independent non-profit organization of the same name. Based on ISO 14020 and ISO 14024, and US EPA, and global ecolabelling network. Guiding principles and procedures are from Type I Environmental labelling (ISO 14024). Example criteria:

- Paints – should not contain any of the following ingedients – methylene chloride, 1,1,1-trichloroethane, benzene, toluene (methylbenzene), ethylbenzene, vinyl chloride, naphthalene, 1,2-dichlorobenzene, di (2-ethylhexyl) phthalate, butyl benzyl phthalate, din-butyl phthalate, di-n-octyl phthalate, diethyl phthalate, dimethyl phthalate, isophorone,antimony, cadmium, hexavalent chromium, lead, mercury, formaldehyde, methyl ethyl ketone, methyl isobutyl ketone, acrolein, acrylonitrile.

Green Guard (USA)
http://www.greenguard.org
Developed from AQSpec List, which was first initiated in 1996. Product-by-product specifications for emissions of formaldehyde, VOC, respirable particles, ozone, and

other pollutants using small environmental chambers. Tested to see if they meet “acceptable IAQ pollutant guidelines and standards” within a 5-day period of unpackaging. Examples:

- Construction materials, furnishings and office furniture must meet the low pollutant of the State of Washington’s IAQ program, OSHA’s formaldehyde rule, US EPA’s office furniture specifications, US EPA’s national ambient air quality standards, and 1/10 of all regulated chemical exposure limits established by OSHA.

Environmentally Preferable Product (USA)
http://www.scscertified.com/epp
Managed by Scientific Certification Systems (SCS). EPP Certification is based upon a full Lifecycle Impact Assessment (LCIA). To achieve certification, part of the evaluation protocol requires that calculated model building concentrations (school classroom and office space) for chemicals emitted by the product must conform to the following:

- Formaldehyde – Less than or equal to16.5 ug/m3; and
- All other organic chemicals – Less than or equal to 1/2 the established Chronic Reference Level as listed in the latest edition of the Cal/EPA OEHHA list of chemicals with noncancer chronic Reference Exposure Levels (RELs). The current version of this list is accessible at http://www.oehha.ca.gov/air/chronic_rels/AllChrels.html

Blue Angel (Germany)
www.blauer-engel.de/englisch/
The first environmental label, created in 1977, now used by about 710 companies for ~3,800 products in ~80 product categories. The label is the property of the Federal Ministry of the Environment, Nature Protection and Nuclear Safety. It is sponsored and administered by the Federal Environmental Agency and the quality assurance and product labelling institute RAL Deutsches Institut für Gütesicherung und Kennzeichnung e.V. All technical demands placed on products and services for the award of the Environmental Label are decided by an independent Environmental Label jury. Emission data assessed after 28 days of chamber testing.

EMICODE (Germany)
http://www.emicode.com
A group of German manufacturers of flooring installation products founded the “Gemeinschaft Emissionskontrollierter Verlegewerkstoffe e.V." (GEV), or translated “Association for the Control of Emissions in Products for Flooring Installation ”. The EMICODE ® system is based on defined analytical test chamber procedures and strict classification criteria. These criteria have been defined by the Technical Council of the GEV with the professional support of the environmental institute Miljö-Chemie, the Carpet Research Institute (TFI) and the Association for Environmentally-Friendly Carpets (GuT).

GuT (Germany)
http://193.201.162.104/
The Association of Environmentally-Friendly Carpets was established in 1990. A new evaluation scheme, instituted in Jan.2004, is based on the ECA-18-system and is

compatible with other systems such as the procedure suggested by AgBB (Ausschuss zur gesundheitlichen Bewertung von Bauprodukten = Committee for Health-related Evaluation of Building Products) for the evaluation of building products used for large indoor areas. Emissions testing is now conducted after 72 hours, and uses the LCI (Lowest Concentration of Interest) table published by AgBB. Prohibits carcinogens vs. EU list Classes 1 and 2.

Finnish M-1, M-2 (Finland)
http://www.rts.fi/english.htm
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. In May 2000 the system changed its name into emission classification of building materials. Classifications are granted by the Building Information Foundation (RTS), a private foundation with representatives from 43 Finnish building organisations, and Finland's leading information service for the building and construction sector. Carcinogens are identified vs. IARC.

Indoor Climate Label (Denmark and Norway)
www.dsic.org
The scheme was developed by the Danish Society of Indoor Climate in 1995 on the initiative of The Danish Ministry of Housing. Normative bodies for the system are the Danish Society of Indoor Climate and the Norwegian Forum of Indoor Climate Labelling. Chemical and sensory odour emission testing in cells or conventional chambers for 28 days is required. Results are converted to indoor air concentrations in a standard room. All products are declared with an “indoor-relevant time-value”, which is based on of the time it takes the most slowly emitting individual substances to fall below their odour and irritation thresholds. Assessment protocols for the following product-areas have been developed:

- Wall and ceiling systems
- Carpets
- Interior doors and folding partitions
- Windows and exterior doors
- Resilient floors, wood-based floors and laminated floors
- Oils for wood-based floors
- Kitchen, bath and wardrobe cabinets
- Interior building paint
- Furniture

Nordic Swan (Scandinavia)
http://www.svanen.nu/Eng/default.asp
The Nordic Swan labelling system was developed in 1989 by the Nordic Council of Ministers and administered by the Nordic Ecolabelling Board. It is a voluntary program intended to enable consumers to select products that are the least harmful to the environment. Lifecycle assessment criteria are developed on a product-by-product basis. Chemical emissions impacting indoor air are assessed based on 28-day chamber tests. Examples of emissions criteria include:

- Plywood: Formaldehyde emission: ≤ 0.125 mg/m2 at 28 days
- Adhesives: TVOC: < 0.2 mg/m2h (as toluene equivalent)

Appendix B: Sample IAQ Codes

Program	Materials Regulated (if specified)	Pollutants Regulated (if specified)	Regulation / Code
California Health & Safety Code 105405		VOCs	Requires the Department of Health Services, through its Indoor Air Quality Program, to develop nonbinding guidelines for the reduction of exposure to volatile organic compounds from construction materials in newly constructed or remodeled office buildings.
California Public Resources Code § 42645			Requires the state to establish a program to provide grants to school districts and schools to promote educational programs on source reduction and recycling. Provides that one of the criteria for awarding a grant is the extent to which the applicant has demonstrated a commitment to using environmentally preferable products (EPP) in the construction or modernization of public school facilities, and defines EPP to include the promotion of healthy indoor environments for children.
California Public Resources Code §§ 25911--25912	Insulation	Urea-formaldehyde	Authorizes the state to adopt regulations pertaining to urea-formaldehyde foam insulation, as necessary to protect public health and safety. Regulations adopted under the law (20 Cal. Code Regs. §§1551--1553 and 26 Cal. Code Regs. §§ 20-1551--1553) prohibit the sale of urea-formaldehyde foam insulation within the state. Provides for an exemption if manufacturers obtain certification of compliance with specific standards relating to, e.g., composition, corrosiveness, and safety information.
Maine Executive Order 8 FY 04/05			Promotes health and environmental considerations in building design, construction and operation by requiring all new or renovated state buildings to incorporate the LEED™ guidelines developed by the United States Green Building Council, which include certain mandatory minimum IAQ practices and a variety of optional practices, such as use of low-emitting building materials.

Minnesota Statutes Ann. § 144.495		Formaldehyde	Authorizes the Commissioner of Health to adopt different building materials product standards than those prescribed in Minn. Stat. Ann. § 325F.181, to ensure that indoor air levels of formaldehyde do not exceed 0.4 parts per million. Regulations adopted under the law (Minn. Rules 4620.1800) require that formaldehyde levels not exceed 0.4 parts per million in newly-constructed homes at the time of sale, and also prohibits the installation of urea formaldehyde foam insulation from causing the concentration of formaldehyde in indoor air to exceed 0.4 parts per million.
Minnesota Statutes Ann. §§ 325F.18, 325F.181, 325F.23	All products containing formaldehyde	Formaldehyde	Requires manufacturers and users of building materials that contain urea-formaldehyde to disclose information on the health risks associated with formaldehyde through a written disclosure form or through product labeling. Requires compliance with federal formaldehyde product standards, certification, and labeling requirements for particleboard and plywood, as well as for medium density fiberboard, used in newly constructed housing. Requires labeling of insulation products.
New Jersey Executive Order No. 24 (2002)			Requires that all new school designs incorporate the LEED™ guidelines developed by the United States Green Building Council, which contains certain mandatory minimum IAQ practices and a variety of optional practices, such as use of low-emitting materials.
Nevada Statutes § 338.187			Requires that, effective July 2007, public buildings sponsored or constructed by the state meet the standards of the LEED™ guidelines developed by the United States Green Building Council, which include certain mandatory minimum IAQ practices and a variety of optional practices, such as use of low-emitting building materials, or meet an equivalent standard adopted by the state. Also requires the state to designate as green building demonstration projects at least two state construction projects each biennium.
New York Executive Order 111 (2001)			Requires that new state buildings incorporate, to the maximum extent practicable, state green building guidelines (see N.Y. Tax Law § 19) and the LEED™ guidelines developed by the United States Green Building Council, which include certain mandatory minimum IAQ practices and a variety of optional practices, such as use of low-emitting building materials.

Texas Education Code § 42.352			Authorizes the state Board of Education to establish standards addressing the adequacy of Texas public school facilities. Regulations adopted under the law (19 Texas Admin. Code §61.1036) establish a variety of requirements for state-funded school construction and renovation projects, as well as the recommendation that schools consider the use of designs, methods and materials that will reduce the potential for IAQ problems. Rules further recommend that districts use the state's voluntary IAQ guidelines and the EPA's IAQ Tools for Schools program, and that they consult with a qualified IAQ specialist during the design process.
Vermont Public Act 125 (H.B. 192)			Requires the Department of Health and the Department of Buildings and General Services to create and maintain a website to serve as a clearinghouse for information on environmental health in schools, including information on common materials and practices that may compromise indoor air quality; preventative maintenance options; a list of nontoxic or least-toxic supplies, equipment, materials, and a list of environmental health criteria that schools may use in determining which materials to purchase or use. Also requires the departments to: help schools identify and address potential sources of environmental pollution; organize annual training workshops for various school personnel; assist schools in establishing comprehensive environmental health programs; and report annually to the state legislature on the extent of indoor air and hazardous exposure problems in schools. Further requires the departments to develop and distribute a model school environmental health policy to all schools.
Revised Code of Washington § 19.2			Mandates the development of state requirements for maintaining indoor air quality in newly constructed residences. Provides that these requirements must establish standards for indoor pollutant source control, including minimizing the entry of radon gas into homes through appropriate foundation construction measures. Regulations adopted under the law adopt the state Ventilation and Indoor Air Quality Code, which addresses a variety of IAQ issues in new home construction, including mechanical ventilation, formaldehyde in building materials, and solid-fuel burning appliances.

Revised Code of Washington § 4.24.560			Establishes a defense in a civil lawsuit brought against a builder for damages for injury caused by indoor air pollutants in a residential structure. Defense applies if builder complied in good faith with: building product safety standards, including labeling; restrictions on use of building materials known or believed to contain substances that contribute to indoor air pollution; and ventilation and radon-resistant construction requirements contained in state law.
Revised Code of Washington §§ 39.35D.010--.800, 39.04.330			Green Building Council, which include certain mandatory minimum IAQ practices and a variety of optional practices, such as use of low-emitting building materials. Requires that school construction projects receiving state funding be designed and built to meet either the LEED™ silver standard or the Washington Sustainable Schools protocol, which contains additional required IAQ practices, as well as optional practices. Requires state to issue guidelines for verifying compliance with the standards. Also requires the state to amend fee schedules for A/E services to accommodate the new design requirements. Exempts affordable housing projects but requires state to implement a sustainable building program for such projects.

Source: Environmental Law Institute. "Environmental Law Institute Database of State Indoor Air Quality Laws." March 2007.

Appendix C: Amendments to the UK's Building Regulations

Approved Document F

Approved Document F 2006 gives three ways of complying with the new regulations.

1. Specified ventilation rates. This is a performance-based method based on specified extract rates from rooms such as toilets and print rooms, and a fresh air supply rate of 10 l/s/person to office areas. The 2002 Approved Document specified a rate of 8 l/s/person, but many designers have been specifying higher fresh-air ventilation rates for some time and so complementing the new regulations.

2. System guidance. This is a prescriptive method that gives guidance for natural- and mechanical-ventilation systems. Either way, the same ventilation rates apply as for the performance-based method outlined above. Some of this guidance is contained within the Approved Document, for example on controls and locations of ventilators. Second-tier documents are relied on for further guidance, including the following.

- CIBSE AM13: Mixed Mode Ventilation
- CIBSE AM10: Natural Ventilation
- CIBSE Guides A and B2

3. Performance criteria. This is also a performance-based regulation, as the name suggests. It details the following list of criteria that should be met.

- Air supply of 10 l/s/person
- No visible mould
- Nitrogen-dioxide limits
- Carbon-monoxide limits
- Total-volatile-organic-compound (TVOC) limits
- Ozone limits

There is little guidance on how these criteria can be met, but all can be measured in some form. The measured levels of the pollutants listed above can be compared against the Workplace Exposure Limits (WEL) detailed in EH40 2005 produced by the HSE. These parameters are all key indicators of the air quality.

Approved Document L

A brief overview of the amendments to the Approved Document L is as follows.

- Dedicated Approved Documents have been produced for work in existing buildings.
- Mandatory airtightness testing.

• Predicting annual carbon-dioxide emissions, taking into account the measured airtightness.
• Targets for carbon-dioxide emissions are 20 to 28% tighter than the 2002 Building Regulations.

The measured ventilation rate into a building is only accurate if there are no holes in the external envelope of the building. If the building meets the airtightness regulations, the measured ventilation rate will be accurate, and air quality can be more easily controlled. Also, leaky buildings lose more conditioned air due to infiltration and so use more energy to maintain the internal environment. Mandatory airtightness testing will ensure that new and refurbished buildings will conform to the regulations and be more energy efficient. It is also important that the overall carbon-dioxide emissions produced in the manufacture of all the building components and the construction process are reduced to the new regulations, which are stricter than the previous regulations.

Appendix D: ASTM standards and Chamber Tests

The following ASTM method should be reviewed for evaluation of each IAQ models:

ASTM D5157-97(2003)e1 Standard Guide for Statistical Evaluation of Indoor Air Quality Models

> "This guide provides quantitative and qualitative tools for evaluation of indoor air quality (IAQ) models. These tools include methods for assessing overall model performance as well as identifying specific areas of deficiency. Guidance is also provided in choosing data sets for model evaluation and in applying and interpreting the evaluation tools. The focus of the guide is on end results (that is, the accuracy of indoor concentrations predicted by a model), rather than operational details such as the ease of model implementation or the time required for model calculations to be performed.
>
> Although IAQ models have been used for some time, there is little guidance in the technical literature on the evaluation of such models. Evaluation principles and tools in this guide are drawn from past efforts related to outdoor air quality or meteorological models, which have objectives similar to those for IAQ models and a history of evaluation literature.1 Some limited experience exists in the use of these tools for evaluation of IAQ models."

Chamber Tests

Chamber tests – concentration of exhaust air over time.

ASTM (1998), Standard Practice for Determination of Volatile Organic Compounds (Excluding Formaldehyde) Emissions from Wood-Based Panels Using Small Environmental Chambers Under Defined Test Conditions, ASTM Standard D6330-98, American Society for Testing and Materials, West Conshohocken, PA.

> "The practice measures the volatile organic compounds (VOC), excluding formaldehyde, emitted from manufactured wood-based panels. A pre-screening analysis is used to identify the VOCs emitted from the panel. Emission factors (that is, emission rates per unit surface area) for the VOCs of interest are then determined by measuring the concentrations in a small environmental test chamber containing a specimen. The test chamber is ventilated at a constant air change rate under the standard environmental conditions. For formaldehyde determination, see Test Method D 6007.
>
> They shall not be used to predict the emission rates over longer periods of time (that is, more than one month) or under different environmental conditions."

ASTM (2007), Standard Practice for Full-Scale Chamber Determination of Volatile Organic Emissions from Indoor Materials/Products, ASTM Standard D6670-01, American Society for Testing and Materials, West Conshohocken, PA.

> "This practice is intended for determining volatile organic compound (VOC) emissions from materials and products (building materials, material systems, furniture, consumer products, etc.) and equipment (printers, photocopiers, air cleaners, etc.) under environmental and product usage conditions that are typical of those found in office and residential buildings."

ASTM, Standard Guide for Small-Scale Environmental Chamber Determinations of Organic Emissions from Indoor Materials/Products (the foundation standard for all material emissions testing), ASTM Standard D5116-06, American Society for Testing and Materials, West Conshohocken, PA.

> "The use of small environmental test chambers to characterize the organic emissions of indoor materials and products is still evolving. Modifications and variations in equipment, testing procedures, and data analysis are made as the work in the area progresses. For several indoor materials, more detailed ASTM

standards for emissions testing have now been developed. Where more detailed ASTM standard practices or methods exist, they supersede this guide and should be used in its place.

Normally, only samples of larger materials (for example, carpet) are tested.

The techniques described are useful for both routine product testing by manufacturers and testing laboratories and for more rigorous evaluation by indoor air quality (IAQ) researchers."

Other Methods for review for the BC Green Building Code

ASTM D5197-03 Standard Test Method for Determination of Formaldehyde and Other Carbonyl Compounds in Air (Active Sampler Methodology)

ASTM D5466-01(2007) Standard Test Method for Determination of Volatile Organic Chemicals in Atmospheres (Canister Sampling Methodology)

ASTM D5791-95(2006) Standard Guide for Using Probability Sampling Methods in Studies of Indoor Air Quality in Buildings

ASTM D6803-02(2007) Standard Practice for Testing and Sampling of Volatile Organic Compounds (Including Carbonyl Compounds) Emitted from Paint Using Small Environmental Chambers

Proposed New Standards for Air Quality continue to be developed in response to IAQ in buildings by ASTM.

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