G R A D I E N T

TRENDS

Risk Science & Application

Spring 2002

Overview: Indoor Air Quality

Building engineers, facilities managers, public health experts, and regulators are facing a plethora of indoor air quality challenges.

With the ongoing cleanup of asbestos and other particulate debris in office buildings and apartments surrounding the World Trade Center, as well as the recent anthrax scare, indoor air quality has finally become the hot topic that many claim it should be. However, a quick review of other data – arguably just as alarming – makes it a puzzle as to why it has taken this long for indoor air pollution to enter the mainstream. For instance, radon gas, which the U.S. EPA reports may be present at elevated levels in one out of every 15 U.S. homes, is estimated to be the second-leading cause of lung cancer deaths. Moreover, according to the American Lung Association, over 300 people die every year from indoor exposure to carbon monoxide released from residential combustion appliances (*e.g.*, furnaces, ranges, water heaters, space heaters). Finally, volatile organic compounds (VOCs), such as formaldehyde and toluene, can have concentrations tens of times higher indoors than they are outdoors due to off-gassing from building materials.

> *It is now widely recognized that the rise in indoor air complaints coincides with the 1970s energy crisis when buildings were made tighter…*

Indoor air quality problems are thus not a recent phenomena. In fact, since the early 1970s, the National Institute for Occupational Safety and Health (NIOSH) has completed over 1,500 human health evaluations (HHEs) in indoor environments. It is now widely recognized that the rise in indoor air complaints coincides with the 1970s energy crisis when buildings were made tighter and indoor air exchange with outdoor air was minimized in order to conserve fossil fuel. In

continued on pg. 2

I N S I D E

Letter to our Readers

May 2002

Dear Colleague,

Spring may turn our thoughts to the outdoors, but the indoor environment increasingly holds sway in the news. Lower Manhattan's fight to return to normalcy includes the need to assure that indoor air is healthy. Anthrax and mold vie for our attention as the new indoor threats. In light of this growing area, this issue of *Trends* focuses on indoor air quality issues – their causes and their assessment.

Contributors to this issue include Dr. Christopher Long, a Gradient environmental scientist with indoor air expertise, Ms. Cathy Petito Boyce, a Gradient exposure assessment expert, and Dr. Lorenz Rhomberg, Gradient Principal and nationally-recognized expert in quantitative risk assessment methodologies. Joining them is Mr. Michael Last, an attorney at the law firm Rackemann, Sawyer & Brewster in Boston, who specializes in environmental law, and provides legal perspectives on indoor air quality issues.

On an unrelated note, many of you should have recently received a letter explaining that the bankruptcy of the IT Group does not affect us. We'd like to take one more opportunity here to assure you that our firm is in no way related to IT's Chapter 11 filing, and that we are in sound financial condition. The confusion arose because IT retained a shell corporation called "Gradient" after our management purchased our firm from IT. Our firm, "GradCo, LLC d/b/a Gradient Corporation," is thriving and plans to be here for a long time!

Yours truly,

Neil Shifrin, Ph.D.
President

Trends is a free publication of Gradient Corporation, a national leader in risk assessment and negotiation of risk-based remediation. If you have a colleague who would benefit from this publication, please contact Alison F. Barlow at (617) 395-5000 or email us at *trends@gradientcorp.com.*

Gradient
CORPORATION

Overview: Indoor Air Quality

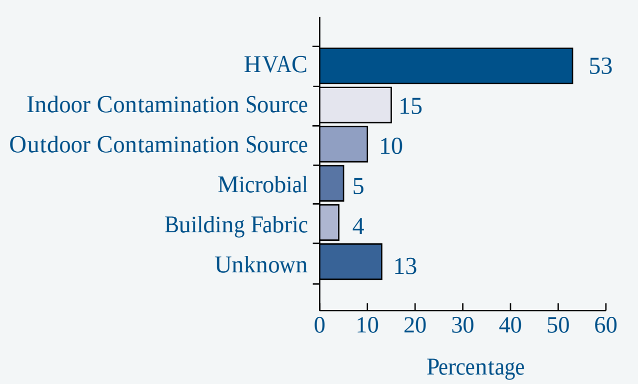
continued from pg. 1

addition, over the years, synthetic building materials and furnishings have gained greater use, as have chemically-formulated personal care products, pesticides, and household cleaners. Tighter buildings have also resulted in greater moisture retention, which favors mold growth.

Indoor air quality poses a unique set of challenges to building engineers, facilities managers, and public health experts. The bar chart shows that there are a variety of common sources of indoor air problems, some related to building factors such as heating, ventilation, and air-conditioning systems (HVAC), others to chemical and biological contamination, and finally others that remain unknown. Poor indoor air quality can elicit a variety of symptoms ranging from respiratory ailments such as asthmatic wheezing and chronic lung disease to non-specific symptoms such as headache, fatigue, and general discomfort. Individual sensitivities can vary considerably and multiple pollutants and/or building factors may contribute to symptoms, making it difficult for investigators to pinpoint specific causative agents. This is especially true for so-called "sick buildings," where individuals experience acute health effects that are associated with their time spent indoors, but no specific illnesses or causes can be identified. Furthermore, there are a number of different kinds of indoor environments – offices, homes, and schools – each with unique characteristics and problems.

In the absence of a specific mandate to regulate indoor air, the EPA has traditionally focused on outdoor air pollutants. For example, the EPA recently proposed a new stringent standard for outdoor fine particulate matter (*i.e.*, $PM_{2.5}$), despite study findings that have shown that indoor sources such as cooking and cleaning activities can dominate total personal exposures. The Occupational Safety and Health Administration (OSHA) enforces workplace standards for indoor air, but their impact on overall indoor air quality has been limited. There are signs, however, that indoor air quality may be becoming a higher priority of regulatory agencies. For instance, state and local governments have begun to promulgate indoor air quality regulations, such as those dealing with public smoking. And, in its January 2001 Corrective Action Reforms to the Resource Conservation and Recovery Act (RCRA), the EPA specifically addressed indoor air quality, requiring control of indoor human exposures from constituents volatilized from groundwater plumes.

MAJOR SOURCES OF IAQ PROBLEMS



Breakdown of primary building air quality problems identified during NIOSH indoor air quality investigations between 1971 and 1988 (Crandall and Sieber, 1996).

With advances in measurement techniques and exposure assessment, substantial progress has been made in the recognition of indoor air problems. There may still be debate about the aspects of indoor air quality that can cause human health effects, but the potential health implications of indoor air exposures are well-acknowledged, given that people spend approximately 90% of their time indoors. With sophisticated instrumentation, extremely low levels of indoor pollutants can now be measured. Experience with airborne biological outbreaks such as Legionnaires' Disease has led to a better understanding of HVAC systems and the importance of their correct use, inspection, and maintenance. It is now understood that improper ventilation can not only promote biological growth, but can also allow indoor pollutant concentrations to build up to toxic levels.

Because we are predominantly an indoor society, indoor air quality will likely continue to grow as a public health issue. Fortunately, the tools for diagnosing and eliminating most of these problems are growing as well.

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For Additional Information:

Crandall, M.S. and W.K. Sieber. 1996. The National Institute for Occupational Safety and Health indoor environmental evaluation experience. Part one: Building environmental evaluations. *Appl. Occup. Environ. Hyg*. 11(6):533-539.

Long, C.M., H.H. Suh, and P. Koutrakis. 2000. Characterization of indoor particle sources using continuous mass and size monitors. *J. Air & Waste Manage. Assoc.* 50(7):1236-1250.

U.S. EPA. 1995. The Inside Story: A Guide to Indoor Air Quality. EPA/402/K-93/007. April.

Modeling Indoor Exposures

When modeling exposures to substances in indoor environments, special features of both the exposed individual and the exposure environment should be considered.

As interest in indoor air quality issues continues to mount, the need to accurately evaluate human exposures in the indoor environment grows accordingly. There are basically six main factors that influence the magnitude and extent of exposures to substances in the environment. The first four categories of factors characterize the exposed individual (*i.e.*, human factors), while the last two categories describe the environment in which the exposure occurs (*i.e.*, environmental factors). To ensure well-grounded exposure estimates for indoor environments, the following critical aspects of each of these six categories should be considered:

> *Parameters applied in exposure models should reflect actual activity pattern data, which can be highly situation-specific…*

Human Factors

Physical and Physiological Factors – This category includes parameters such as body weight and absorption factors. Values applicable to a particular exposure analysis may vary depending on the specific activities that are undertaken. For example, the types of clothing worn indoors and the activities involved influence the amount of skin that is exposed in an indoor scenario.

Intake Rates and Related Factors – Differences in the types of activities and the conditions encountered affect intake rates for indoor scenarios. For example, some indoor activities are lower intensity (*e.g.*, sleeping), resulting in lower inhalation rates relative to activities that may occur outdoors. By contrast, other activities may occur at a greater intensity indoors, *e.g.*, data suggest that young children engage in more hand-to-mouth contacts indoors, which may enhance their incidental ingestion exposures to interior dust.

Behavioral Factors Related to Activity Patterns – Activity patterns are highly dependent on the exposure environment. Data sources such as the U.S. EPA's National Human Activity Pattern Survey provide information on the amount of time individuals spend engaged in specific activities (*e.g.*, showering or using certain consumer products), at specific locations (*e.g.*, in the basement), and in proximity to various exposure sources (*e.g.*, near sources of excessive dust). The accompanying graphic illustrates typical locations where young children and adults spend their time indoors in a residence. Parameters applied in exposure models should reflect actual activity pattern data, which can be highly situation-specific, reflecting differences in climate, residential setting (*e.g.*, urban *vs.* rural), personal traits (*e.g.*, age and health), and personal habits.

Demographic Factors – Sociodemographic factors that can influence indoor exposure potential include gender and age, socioeconomic status, and residence location and characteristics. For example, young children residing in older houses may have a greater potential for exposure to leaded paint.

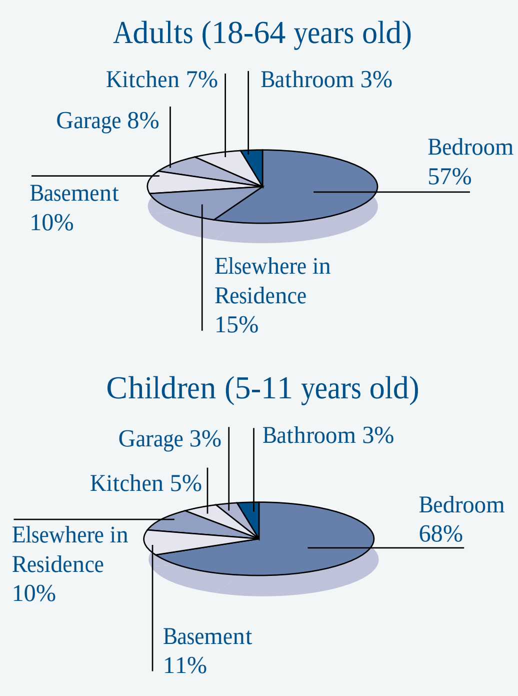
Environmental Factors

Environmental Modeling Factors – Building characteristics can influence the transport of substances between the indoor and outdoor environments and within the indoor environment. Relevant data include information from studies of test houses, such as those maintained by the EPA and the Canadian Center for Housing Technology.

Factors Related to Exposure Sources – Indoor exposure sources may exist due to indoor activities (*e.g.*, showering or use

continued on pg. 5

Percent of Total Indoor Residential Time Spent in Various Locations



Charts reflect 50th percentile values from EPA (1997).

Toxic Mold Litigation Mushrooms

Regulatory pressure and third party litigation are outpacing science in this rapidly growing area.

In one of the fastest growing areas in tort and insurance litigation, plaintiffs are blaming respiratory problems, asthma, irritation, rashes, allergic reactions, and even liver and nervous system damage on toxins produced by molds growing on wallboard and other cellulose-rich materials affected by water leaks in homes and workplaces. The mold issue leapt to prominence in 1994 when eight Cleveland babies were treated for unusual bleeding from the lungs, a cluster that was blamed on the mold *Stachybotrys chartarum* (also known as *Stachybotrys atra*) growing in their homes. It's not only run-down properties that are involved; a recent Texas verdict awarded $32 million in remedial costs, punitive damages, and attorneys' fees to raze and reconstruct a mansion affected with mold hidden inside the walls of its 22 rooms.

A recent Texas verdict awarded $32 million…to raze and reconstruct a mansion affected with mold hidden inside the walls of its 22 rooms.

In spite of such cases, however, the ability of mold growth in buildings to cause serious human health effects is not well established scientifically, and many experts are quite skeptical (Hagmann, 2000; Hamilton, 2001). The Centers for Disease Control (CDC), whose 1994 report on the Cleveland babies initially blamed molds, recently published findings from two expert panels that found "serious shortcomings" in the initial investigation. One panel concluded that "this hypothesis is not scientifically proven…[and] may not even be strongly supported by the available evidence, both epidemiologic and biologic" (CDC, 1999).

Although there are a number of mold species that may produce toxins, the recent focus has been on *Stachybotrys chartarum*. This "black mold" can grow hidden inside walls on wood and wallboard that are chronically damp. The fungus produces several toxins called trichothecenes that, when purified and given at substantial exposures, are strong suppressors of protein synthesis and can modulate immune responses, which can lead to serious toxicity in experimental animals. What is unclear, however, is how volatilization of the toxins or release of spores (which are not easily airborne) into indoor air can lead to exposures large enough to cause any marked effects.

Assessing actual human uptake of spores or toxins (as opposed to mere presence of mold in walls) is one big challenge (Dillon *et al*., 1999), but another is that different strains of *Stachybotrys chartarum* have different levels of trichothecene production (with some strains having essentially none), and for a given strain, the toxin and spore production varies with environmental conditions. No standards or regulations currently exist to define acceptable levels of mold exposure, although a new California law mandates development of standards by July 2003 (Wolfson and Eversole, 2002).

Defining a basis for standards will be challenging. The epidemiologic evidence is scant and plagued by ill-defined exposures and disease states. The available animal data show effects only at rather high exposures when purified toxins or concentrated spores are artificially injected or instilled; and, no one has produced experimental airborne concentrations high enough to study naturally inhaled mold spores or volatilized trichothecenes at levels needed to produce observable toxicity. Nonetheless, a spate of case reports and complaints of allegedly mold-caused health effects keep the question in flux.

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Centers for Disease Control. 1994. Acute pulmonary hemorrhage/ hemosiderosis among infants – Cleveland, January 1993-November 1994. *MMWR* 43:881-883.

Centers for Disease Control. 1999. Report of Members of the CDC External Expert Panel on Acute Idiopathic Pulmonary Hemorrhage in Infants: A Synthesis. December 1999. Available at http://www.cdc.gov/od/ads/pulhem_inf.htm

Dillon H.K., J. D. Miller, W.G. Sorenson, J. Douwes, and R.R. Jacobs. 1999. Review of methods applicable to the assessment of mold exposures in children. *Environ. Health Perspect.* 107(Suppl. 3):473-480.

Hagmann, M. 2000. A mold's toxic legacy revisited. *Science* 288:243-4.

Hamilton, A. 2001. Beware: Toxic mold. *Time*, June 24.

Wolfson, P.S. and S.S. Eversole. 2002. Toxic Torts: An overview of legal, regulatory developments prompted by mold. *Toxics Law* 17(8):183.

By The Way...

The 106th Congress enacted a law (P.L.106-554, H.R. 5658) requiring Office of Management and Budget (OMB) to issue guidelines to ensure and maximize the quality, objectivity, and integrity of data disseminated by federal agencies. In turn, OMB has mandated federal agencies such as the EPA to implement data quality guidelines by October 1, 2002 (FR 67(2), 369-378[2002]). These guidelines could have far-reaching consequences on environmental regulations, standards, and supporting data such as databases for risks (*e.g.*, IRIS).

What's New at Gradient

Gradient Welcomes A. Wallace Hayes, Ph.D., DABT

Dr. A. Wallace Hayes has joined Gradient as a Principal and will direct Gradient's Product Safety practice out of the Cambridge, MA office. Dr. Hayes is an expert in toxicology and product safety, and has over 30 years experience. He earned his Ph.D. in biochemistry and M.S. in physiology from Auburn University, and A.B. in chemistry at Emory University.

Gradient Wins Awards

Gradient Corporation presented 11 posters at the 2002 Society of Toxicology Meeting, and three won awards for best posters in risk assessment. All posters were designed by our in-house graphics artist, Theresa Forgach. The winning posters were:

E.M. Dubé, C.P. Boyce, B.D. Beck, and **S. Schettler.** "Evaluation of Human Health Risks from Exposures to Arsenic Complex Associated with CCA-Treated Wood."

L.R. Rhomberg, S. Baird, J. Evans, P. Williams, and A. Wilson. "Quantifying Uncertainty in Human Reproductive Risk Projected from Rat Inhalation Studies on Ethylene Oxide: A Framework Based on Data-Based Statistical Distributions of Extrapolation Factors."

K.W. Chan, **L.A. Beyer,** and **B.D. Beck.** "Assessment of Benzene Carcinogenic Potential in Humans."

Upcoming Presentations

Amherst, MA. June 11-13, 2002. C.S. Wells. "Risk Modeling Implications of Mechanistic Difference Between Low and High Dose Effects of Arsenic." International Conference on Non-Linear Dose-Response Relationships in Biology, Toxicology and Medicine.

San Diego, CA. July 15-18, 2002. C.P. Boyce. "Comparison of Approaches for Quantifying Incidental Ingestion of Arsenic from Treated Wood and Other Materials." Fifth International Conference on Arsenic Exposure and Health Effects.

Recent Articles

Long, C.M., H.H. Suh, P.J. Catalano, and P. Koutrakis. 2001. "Using time – and size-resolved particulate data to quantify indoor penetration and deposition behavior." *Environmental Science and Technology* 35(10):2089-2099.

Price, B., C.J. Borgert, **C. Wells,** and G.S. Simo. 2002. "Assessing toxicity of mixtures: the search for economical study designs." *Human and Ecological Risk Assessment* 8(2):305-326.

Mattuck, R., B. Beck, T. Bowers, and J. Cohen. 2001. "Recent trends in childhood blood lead levels." *Archives of Environmental Health* 56(6):536-541.

Modeling Indoor Exposures

continued from pg. 3

of certain consumer products) or building characteristics (*e.g.*, releases from building structural components). Indoor exposures also can occur when substances are transported from outdoor sources into a building (*e.g.*, when soil is tracked into buildings or gases volatilize from underlying soil or groundwater). The nature of the exposure analysis will determine whether exposures from these sources need to be evaluated separately or in combination.

When evaluating indoor exposures, choices for each necessary modeling parameter depend on the specific substances and exposure scenarios under consideration, the degree of complexity desired in the evaluation (*e.g.*, a simple screening analysis *vs.* a detailed microenvironmental model), and the modeling framework being applied (*e.g.*, a deterministic analysis *vs.* a probabilistic analysis). Regulatory requirements also affect modeling choices. For example, the Food Quality Protection Act requires consideration of aggregate and cumulative exposure (*i.e.*, combining exposures occurring *via* different exposure pathways or different chemicals with similar toxicological effects or endpoints).

While any exposure modeling should be designed to ensure that it is technically sound and will achieve the desired goals, modeling of the indoor environment presents a number of unique challenges.

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For Additional Information:

Petito Boyce, C., and M.R. Garry. 2002. Review of information resources to support human exposure assessment models. Scheduled for publication in August 2002 issue of *Human and Ecological Risk Assessment.*

U.S. EPA. 1997. *Exposure Factors Handbook*. Office of Research and Development. Washington, D.C. EPA/600/P-95/002Fa-c. August.

Guest Editorial: IAQ – Legally Coming of Age

Indoor air quality issues are impacting a wide range of parties involved in building design, construction, and maintenance.

After a surprisingly long gestation period, indoor air quality (IAQ) concerns are garnering more attention in courts across America. While asbestos-related litigation has been actively pursued for well over 15 years, other IAQ concerns have received significantly less attention. This situation is rapidly changing. The forces behind the change, which is manifesting itself in the form of high stakes personal injury and property damage lawsuits, include the following:

> *The lesson to be learned from this "coming of age" of IAQ concerns is that preventive programs must be implemented to address IAQ problems.*

- Increased awareness of the dangers of indoor air contaminants, including mold.
- Increased susceptibility to adverse IAQ impacts, as evidenced by the increase in persons having asthmatic or allergic conditions.
- Significant new case law decisions and damage awards, particularly relating to so-called "toxic mold."
- New IAQ legislation and regulation such as a recent enactment in California mandating the development of mold standards and appropriate disclosures.

From a legal perspective, IAQ issues are notable because they impact a broad range of interests, including developers, building owners and managers, architects, engineers, building material suppliers, contractors, construction managers, insurers, and bonding companies. Likewise, diverse types of properties may be affected, including residential, commercial, and industrial.

Liability for IAQ problems includes negligence, penalties for regulatory violations and contractual liability created under leases, purchase and sale agreements, architects/engineers, and construction contracts. Indeed, of particular note in the last two years are courts' and juries' willingness to award significant damages on account of demonstrated IAQ problems involving mold. For example, in Texas, a homeowner was awarded $32 million, including $12 million in punitive damages, while in California a jury awarded a plaintiff $18 million, all but $500,000 of which was punitive damages. Although the California award was reduced to $3 million on appeal, it still represents a significantly adverse outcome. Moreover, these awards have spurred a flood of class action lawsuits alleging injury due to mold exposure.

The lesson to be learned from this "coming of age" of IAQ concerns is that preventive programs must be implemented to address IAQ problems. Such programs involve education and training regarding sound construction and building management techniques, including appropriate handling and protection of building materials during construction; optimal design and installation of vapor barriers, ventilation, and water proofing, and effective operation and maintenance of critical building systems, notably HVAC systems.

Fortunately, there are a number of collaborative approaches being undertaken to foster better IAQ management and problem prevention. One such approach has been initiated in California as the Healthy Indoor Environment Program (HIEP). HIEP is bringing together building material suppliers, contractors, architects/engineers, building owners and operators, and insurers in order to develop and disseminate information regarding best practices for IAQ problem prevention, identification, and remediation. Such efforts will hopefully be successful in incorporating sound science into good building practices and will serve to stem the oncoming tide of IAQ litigation.

Michael P. Last, Esq.
Rackemann, Sawyer & Brewster

In the next issue:

Overview: Land Disposal of Non-Hazardous Materials

Biosolids Management

A Look at Deep Well Injection

Guest Editorial: Regulatory Strategies for Non-Hazardous Materials

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