AIR QUALITY SCIENCES

IAQ and Sensitive Population Groups

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Indoor Air Quality & Sensitive Population Groups

Grappling with why some people are more sensitive to indoor air contaminants than others can be as elusive as a wispy cloud evaporating in the bright sunlight. For certain segments of the population, however, there is discernable evidence that poor indoor air quality (IAQ) is a significant risk factor for serious and sometimes life threatening health effects, including cancer, infections and respiratory, endocrine and developmental problems. These "sensitive" population groups include children, older adults and people with chronic illnesses or suppressed immune systems from drug therapies, fatigue or stress. Consequently, special attention must be paid to the indoor environments in which these people spend their time. This report provides an overview of which indoor air contaminants are of most concern and the health effects associated with them, who is at risk and what type of indoor environments are most impacted. The technology and strategies to provide healthy indoor environments for people who are especially vulnerable to indoor air pollution are widely available to homeowners, building owners, school administrators and facility managers.

Indoor Air: Host to Wide Variety of Contaminants

Indoor air is an intriguing, complex environment that contains a myriad of visible and invisible contaminants. These contaminants generally fall in one of two categories: particulates or gases, vapors and odors. The following provides a brief description of each category and the health problems associated with them.

Particulates: Size Is Everything

Particulates are particles that are small enough to suspend in the air. Suspended inorganic particles, such as metals (lead, mercury); dust; pollen; asbestos and other fibers; car, bus and truck exhaust; or environmental tobacco smoke and other types of smoke, are often referred to as *aerosols*. Suspended organic compounds and small living organisms, such as bacteria and viruses; mold spores and pieces of mold colonies; dust mite feces and body fragments; cockroach body parts; and dander from cats, dogs and other mammals, are called *bioaerosols* (McDonald and Ouyang 2000). Allergens, associated with grasses, pollen, dogs, cats, dust mites, cockroaches and mice to name a few common examples, also fall into this category. Particles can range in size from very small (0.001 µm to 10 µm), which can remain in the air for a long time, up to relatively large (100 µm), which quickly settle out of calm air (ALA Special Report on Air Cleaners).

Inhaling particulates can cause eye, nose and throat irritation and increase the risk for respiratory infections. Healthcare professionals are especially concerned about the long-term effects of inhaling fine particles (less than 2.5 µm – also referred to as $PM_{2.5}$ or fine PM), because they can travel deep into the lungs where they can remain embedded for years or be absorbed into the bloodstream. Inhalation of fine PM have been linked to increases in respiratory health problems such as asthma, bronchitis, pneumonia and emphysema; hospitalization for heart or lung disease; and even premature death.

The results of numerous studies have demonstrated a correlation between adverse health effects, including premature death, and the level of fine PM. In response, the United States Environmental Protection Agency (US EPA) has established an aggressive program and standards to reduce fine PM levels in outdoor air. These same concerns also apply to indoor air, especially in schools where children spend many hours each day. For more information and a comprehensive review of these studies, see Dockery et al 1993; Moolgavkar, Dockery and Pope 1994; Godleski et al 2000; US EPA Provisional Assessment of Recent Studies on Health Effects of Particulate Matter 2006; and the US EPA website on particulate matter, **www.epa.gov/oar/particlepollution**.

Healthcare professionals are not as concerned about larger particles (greater than 10 µm), because they get caught in the nose and throat and are cleared from the respiratory tract by coughing or swallowing (ALA Special Report on Air Cleaners).

Gases, Vapors and Odors: What You Can't See Can Hurt You

The types of gases or vapors most often found in indoor environments include combustion byproducts, such as carbon monoxide, nitrogen oxides, carbon dioxide, and polycyclic aromatic hydrocarbons (PAHs); pet, human and cooking odors; environmental tobacco smoke (ETS); volatile organic compounds (VOCs); microbial VOCs; and mycotoxins. Many of these substances also produce odors, some of which are pleasant while others can be distracting and irritating.

Among the most prevalent of all indoor air constituents are volatile organic compounds (VOCs), with as many as 100 to 1,000 different VOCs in the air where people can easily inhale them. Some VOCs can cause eye, nose and throat irritation; cough; headache; general flu-like illnesses; skin irritation; and some can cause cancer. Others produce odors that may be objectionable. Complicating matters is the potential for interactions of VOCs with other chemical compounds to form additional compound that also may be a threat. As a result, even though the concentrations of individual VOCs may be well below odor thresholds or known toxic levels, their occurrence in complex mixtures may lead to perceived poor IAQ or irritation among those exposed.

Moisture also is a vapor that must be monitored, as too much moisture can support indoor mold growth. Some types of mold also emit VOCs, known as microbial VOCs or MVOCs, which are responsible for the characteristic musty, earthy odors associated with mold. People who are sensitive to MVOCs may experience eye, nose and throat irritation. A wide variety of molds also can produce mycotoxins at various times during their lifecycles. Building occupants can experience potentially serious health problems if they are exposed to high levels of these compounds, but this is rare in most indoor environments.

Although becoming a lesser issue in public buildings, environmental tobacco smoke (ETS) is still found in many homes. Environmental tobacco smoke alone contains more than 4,700 airborne substances, including gases and particles from incompletely burned tobacco, of which 243 are known carcinogens. Exposure to passive smoke is well documented as a major risk factor for respiratory problems and cancer.

Who Is Most At Risk

Children At Greater Risk Than Adults

Children are more vulnerable to exposure and face greater environmental health risks to indoor pollutants than adults. Their organs and immune and neurological systems are still developing, and because of their lower body weight, they breathe in a relatively greater volume of air than adults. This results in a higher body burden of air pollutants for the same amount of exposure. A recent study, for example, found that children exposed to high levels of VOCs were four times more likely to develop asthma than adults (Rumchev et al 2004).

Other studies also have found an association between VOCs and asthma in children. A California Air Resources Board's (CARB) report noted: "Delfino (2002) published a review of the epidemiological evidence for links between air toxics and asthma [in which he] cites Swedish studies that showed that self-reported asthma prevalence in school children increased with increasing VOC levels, and asthmatic adult symptoms occurred in association with toluene, C_8-aromatics, terpenes, formaldehyde and limonene." The report qualified Delfino by stating that he did not directly associate these findings with schools and that he cautioned that effects may be influenced or a result of other causal agents (CARB 2005). See *A Closer Look at Specific Environments* below for a list of the most prevalent VOCs found in schools.

A growing number of scientists also are concerned that exposure to very small traces of VOCs and some industrial chemicals in homes and schools may have profound impacts on fetuses, newborns and children, including disruptions to the endocrine system (hormones), gene activation and brain development. An especially striking finding is some chemicals may have health impacts at extremely low levels, which are not seen at higher

levels. Minute levels of phthalates, for example, which are used to make toys, building materials, drug capsules, cosmetics and perfumes, have been linked to sperm damage in men and genital changes, asthma and allergies in children (Waldman 2005).

Researchers at the University of London suspected that small amounts of some environmental chemicals might have a dramatic effect on hormone levels. They tested the hormonal strength of 11 common chemicals, known to mimic estrogen. Alone, each chemical was very weak, but when low doses were mixed with natural estrogen, the strength of estrogen doubled (Waldman 2005, Rajapakse et al 2002). High levels of estrogen are associated with some forms of cancer and developmental problems during puberty. For more information about results of studies linking environmental contaminants to illnesses, see Cohen 2006.

At this time, research in this area is still new, and as yet results do not present a clear picture. One study of particular note, the National Children's Study, sponsored by the US EPA and the Centers for Disease Control and Prevention (CDC), is in progress with results expected in 2010. By the time the study is completed, about 100,000 children at various ages from birth to puberty will have participated. Among the primary goals is to investigate the associations between exposures to environmental pollutants, such as VOCs among others, and health problems, especially asthma, autism, attention deficit disorder and alterations at puberty caused by hormonal disruptions and other neurobehavioral and neurocognitive disorders (Özkaynak et al 2005). See Table 1 for the number of children living in the US with high-risk medical conditions, as reported by the CDC's National Health Interview Survey.

Older Adults Also At Greater Risk

At the other end of the age spectrum, older people also are at a greater risk for adverse health effects from exposure to indoor air pollutants. One factor is as people age their immune systems become less effective. As a result, autoimmune disorders and cancer become more common. Among the reasons for this is various components of the immune system respond more slowly to antigens (foreign substances that cause the immune system to react) and there are fewer lymphocytes (white blood cells) capable of responding to new antigens. Thus, when older people encounter a new antigen, the body is less able to recognize and defend against it (Merck Manuals 2003).

In addition to autoimmune diseases, older people have a greater risk for developing cardiovascular and respiratory diseases. This increase in risk is due in part to the aging process, which weakens various bodily systems. Genetics, exposure to environmental pollutants and lifestyle choices also play a part. Cardiovascular disease (CVD), including heart attack and stroke, remains the number one cause of death in the US, causing more than 36 percent of all deaths. The lifetime risk of developing coronary heart disease after 40 years of age is 49 percent for men and 32 percent for women (American Heart Association 2008).

Older patients, people with underlying heart or lung disease, lower socioeconomic populations and diabetes may be at increased risk. Epidemiological studies conducted worldwide have shown a consistent, increased risk for cardiovascular events, including heart and stroke deaths, in relation to short- and long-term exposure to concentrations of pollution, especially particulate matter (Brook et al 2004). Results from other studies have demonstrated that exposure to indoor air pollutants, such as VOCs from household products, may not only increase the risk in older people of developing asthma and chronic obstructive pulmonary disease (COPD), which includes chronic bronchitis and emphysema, but also neurologic and cognitive effects, motor dysfunction and loss of visual acuity (Farrow et al). See Table 2 for the number of adults living in the US with high-risk medical conditions, as reported by the CDC's National Health Interview Survey.

Chronic Diseases Take Their Toll At Any Age

Today, chronic diseases, such as allergies, asthma, CVD (primarily heart disease and stroke), cancer and diabetes, are among the most prevalent of all health problems. In 2005, 133 million people, almost one-half of all Americans lived with at least one chronic condition. Chronic diseases also account for 70 percent of all deaths in the US (CDC 2008). Building related symptoms (BRS) and building related illnesses have been identified as frequent contributors to short-term and chronic illnesses. This is consistent with analyses that find that in the US people spend on average about 90 percent of their time indoors and that many common materials emit chemical compounds, such as VOCs and semi-volatile organic compounds (SVOCs), and harbor infectious molds, fungi and bacteria. For people confined indoors due to illness, the consequences can be more severe than for the general population (Cohen 2006). See *A Closer Look at Specific Environments* below for more information on how much time people spend indoors.

By far, allergies and asthma are the most prevalent of all chronic diseases, with 60 million people in the US affected as compared with 3 million people with Parkinson's Disease, 5 million with Alzheimer's, 6 million who have had a stroke, 7 million with heart disease, 10 million with cancer and 17 million with diabetes. Since 1980, the number of people (young and old) who have died from asthma has increased by more than 50 percent, with 60 percent of deaths occurring in older people. The number of deaths among children under 19 years old has increased by nearly 80 percent (New Asthma Estimates: Tracking Prevalence, Health Care and Mortality 2001). With respect to the quality of indoor air, the following statistics regarding allergies and asthma have particular relevance:

- Twenty million people in the US have asthma, nine million of which were children. Ten million people have allergic asthma, which is triggered by substances capable of causing an allergic reaction (allergens).
- Asthma affects 8 percent to 10 percent of the US population and takes an enormous physical and economic toll.
- From 1980 to 1994, the proportion of Americans with asthma increased by 75 percent. In children under the age of five, the proportion grew by 160 percent.
- There is no single trigger or event that precipitates the onset of asthma or an asthma attack for all people, although family history of allergy and asthma is a predisposing factor.
- Exposure to airborne particles and allergens, along with environmental tobacco smoke and other combustion-related products, air pollution and pesticides, influence the biological processes that trigger attacks and increase the severity of symptoms.
- Minimizing or eliminating exposure to known triggers can reduce the number of asthma attacks and their severity (AAAAI 2005, USEPA 2005)

For more information about asthma, see the AQS Research Report, *Asthma and Damp Buildings: Making the Connection*, which is available free of charge from the AQS-Aerias Indoor Air Quality Resource Center website at www.aerias.org.

People with immunosuppressive diseases also are at increased risk for adverse health effects from indoor air pollutants. People who are waiting or have recently had organ transplants are another high risk group, as again, their immune systems may be impaired, which severely limits their ability to fight off infections and disease, and in general may make them more sensitive to irritants. See Table 1 and Table 2 for the number of children and adults living in the US with high-risk medical conditions, including chronic illnesses as reported by the CDC's National Health Interview Survey.

Adding It All Up

Taken separately, each sensitive population group includes enough people to garnish significant concern. Taken together, the total number of people potentially at risk from indoor air pollution is striking. The CDC's National Health Interview Survey 2002 and 2003 lists the following as high-risk medical conditions:

- **Children:** Cystic fibrosis, sickle cell anemia, diabetes, congenital heart disease, other heat disease and conditions, asthma, cerebral palsy, muscular dystrophy, down syndrome, birth defects, other developmental disorders, mental retardation, transplants, cancer, HIV/AIDS, end stage renal disease (ESRD) and seizures

- **Adults:** Asthma, chronic obstructive lung disease (chronic bronchitis and emphysema), coronary heart disease, angina, myocardial infarction (heart attack), cancer, stroke, birth defect, mental retardation, cerebral palsy, senility/dementia/Alzheimer, multiple sclerosis, Parkinson's disease, transplants, cancer, HIV/AIDS, ESRD and seizures (Lu et al)

When looking at Table 1 and Table 2, consider that of the nearly 300 million people living the US, about 25 percent (75 million) are under the age of 18 and a little more than 12 percent (36 million) are 65 years of age or older. This means that 37 percent of the US population (111 million) is potentially at a higher risk of health problems from indoor air pollution as a function of age, and approximately 54 million people of all ages have one or more high-risk medical conditions. Table 1 and Table 2 are compiled from a variety of sources as reported in Lu et al.

Steps are being taken to minimize the risk by those who design, build and manage the indoor environments in which these people live, work and play, including a new standard from the GREENGUARD Environmental Institute (GEI) that provides specific guidance on levels of indoor air pollutants. The following takes a closer look at these environments, followed by a preview of the GREENGUARD standard.

Table 1. High-risk conditions in children ages 0 to 17 years: NHIS 2003 (Lu et al)

Condition	Estimate (number of children in US)
Cystic Fibrosis	19,946
Sickle Cell Anemia	152,186
Diabetes	85,955
Congenital Heart Defects	212,101
Other Heart Ailments	748,070
Asthma	6,213,435
Cerebral Palsy	168,475
Dystrophy	29,226

Down Syndrome	141,616
Birth Defects	203,687
Other Developmental Problems	506,748
Mental Retardation	441.326
Seizures	404,234
Transplants	5,669
Cancer	114,870
HIV/AIDS	5,000
ESRD	9,267
Total	**8,699,111**

Table 2. High-risk conditions in adults: NHIS 2003 (Lu et al)

Condition	Estimate (number of children in US)
Asthma	7,071,068
Emphysema	3,114,666
Bronchitis	8,560,342
Coronary Heart Disease	7,321,612
Angina	4,947,320
Myocardial Infarction	6,737,119
Diabetes	14,011,824
Cancer	2,366,813
Transplants	143,618
HIV/AIDS	700,000
ESRD	610,641
Pregnant Women	4,000,000
Total	**41,941,344**

A Closer Look At Specific Environments

Time Spent Indoors: Adults

Given the amount of time people spend indoors (nearly 90 percent each day), the quality of indoor air has enormous implications for people's health, especially for those who are in a sensitive population group. The state of California was the first to quantify how much time its citizens spend indoors. In 1987 and 1988, CARB conducted a statewide survey of activity patterns of its citizens over 11 years of age (California Activity Pattern Survey). Participants completed recall diaries of activities and locations and responded to questions regarding their use of and proximity to potential pollutant sources. The results showed that Californians spent, on average, 87 percent of their time indoors: 62 percent of the time indoors at home and 25 percent of the time indoors but not at home, including someone else's home, work, school, shopping, church, restaurant and various other places (Jenkins et al 1992).

From 1992 to 1994, the EPA conducted the National Human Activity Pattern Survey (NHAPS), which was conducted as a follow-up to California Activity Pattern Study (CAPS), and was closely patterned after this landmark study. The NHAPS was the first US national study designed to collect exposure-relevant information on human activity patterns. Telephone interviews were conducted with more 9,000 respondents across the 10 EPA regions in 48 states. The national results were generally consistent with CAPS. On average, US citizens spent 86.9 percent of their time indoors:

- 69 percent at home
- 5.4 percent in office or factory
- 1.8 percent in a bar or restaurant
- 11 percent in other indoor locations
- 5.5 percent in vehicles
- 7.6 percent outdoors (Klepeis et al 2001).

Results from both the CAPS and NHAPS surveys showed that children under 12 spent significantly less time in offices, factories, bars and restaurants than children over 12 years of age or adults. Children in California under the age of 12 also spent a larger percentage of time indoors and outdoors and a lower percentage in vehicles than did adults (Klepeis et al 2001).

The results from NHAPS are comparable with US time budgets reported by Robinson and Thomas (1991) from a 1985 study and Canadian time budgets reported by Leech et al (1996). For both these of these two studies, which spanned a period of about 10 years, respondents reported spending 89 percent of the time spent indoors with 5 percent in a vehicle and 6 percent outdoors (Klepeis et al 2001).

Time Spent Indoors: Children

Because children comprise California's largest sensitive population group with respect to toxic effects of air pollution, CARB authorized a study of children's activity patterns in that state. Previous studies of children's activities did not obtain specific location information or include large enough sample for reliable estimates, according to CARB. In this study, 1,200 English speaking children 11 years of age or younger were interviewed from spring 1989 to winter 1990. The participants were asked if they used or were near sources of pollution, such as ETS, solvents, pesticides, paints and gas appliances. The results showed that overall children spent on average 85 percent of their time indoors:

- 70 percent at home
- 15 percent at other indoor locations
- 4 percent in enclosed transit
- 1 percent in outdoor transit
- 10 percent outside (Wiley et al 1994)

These results agree with estimates from other studies in the US and other industrialized nations. Compared with adults and adolescents, children spent on average 68 minutes more per day outdoors and 42 minutes less per day in transit. The data from this study also revealed some important differences by age:

- Children ages 0 to 2 years spent 104 minutes more per day indoors than children ages 9 to 11
- Boys ages 0 to 2 years spent an average of 115 minutes per day near ETS than older boys (66 minutes per day)
- More girls (41 percent) than boys (35 percent) reported exposure to ETS each day
- More boys (35 percent) than girls (29 percent) reported being near gas oven fumes
- More girls (60 percent) than boys (40 percent) ages 9 to 11 years reported potential exposure to personal care aerosols (Wiley et al 1994)

Poor IAQ in Schools

Because children spend a great deal of time at school, maintaining good indoor air quality in these environments is critical for minimizing their exposure to potentially dangerous indoor air pollutants. Air Quality Sciences, Inc. (AQS) has measured VOC levels in more than 200 US schools and found 345 different VOCs in the indoor air. Table 3 lists the 15 most common VOCs found in these schools. Other frequently found VOCs of concern in schools include perchloroethylene and methylene chloride, potential carcinogens related to spot cleaners, degreasers and art supplies.

Table 3. Common VOCs found in schools

VOC	Source(s)	VOC	Source(s)
Toluene	Cleaners, construction materials	Hexanal	Cleaners, adhesives, deodorizers
Xylenes	Cleaners, construction materials	2-Butoxyethanol	Wood cabinetry, cleaners, paints
Siloxanes	Waxes, polishes, deodorants	TXIB	Cleaners, paints
Formaldehyde	Furniture, ceiling tile, wood shelving, cabinetry	Ethanol	Disinfectants
Hexane	Markers, cleaners	Acetaldehyde	Plastics, paints
Acetone	Markers, art supplies	Longifolene	Cleaners, wood products, flooring
1,4 Dichlorobenzene	Cleaners, deodorizers	Naphthalene	Adhesives, art supplies

The AQS test results also showed that the average total VOC (TVOC) level was 276 $\mu g/m^3$, with a minimum of 1.7 $\mu g/m^3$ and a maximum of 4600 $\mu g/m^3$. Most standards and guidelines consider 200 $\mu g/m^3$ to 500 $\mu g/m^3$ TVOC as acceptable. Levels higher than this may result in irritation to some occupants. While TVOC is a good indicator of elevated VOCs and complicated VOC mixtures may lead to irritation, minimizing the presence of specific chemicals with known health hazards is required.

Formaldehyde in Schools. Formaldehyde exposure is a major concern, particularly in schools that use portable classrooms. Formaldehyde is used widely by industry to manufacture building materials and numerous household products, and also is a by-product of combustion and certain other natural processes. Primary sources include pressed wood products such as particleboard, plywood and medium density fiberboard (MDF); finished furniture, shelving and cabinetry made with composite boards and certain coatings; decorative fabrics and textiles; and paper products. It also may be used as a biocide in certain paints and coatings, adhesives and personal care items.

Based on more than 300 measurements collected in residences, office buildings and schools, AQS studies have found typical concentrations range from 0.01 ppm to 0.03 ppm in office buildings and 0.05 ppm to 0.08 ppm in homes. An average level of 0.04 ppm has been found in schools, with new or recently renovated or refurbished school environments reaching 0.14 ppm.

Available clinical and epidemiological data indicate that individual responses to formaldehyde may vary substantially. Irritation may occur at levels of 0.08 ppm or less, and odor detection has been measured as low as

0.03 ppm. When formaldehyde is present in the air at levels exceeding 0.1 ppm, some people may experience watery eyes; burning sensations of the eyes, nose and throat; coughing; wheezing; nausea; and skin irritation. Some people are very sensitive to formaldehyde, while others have no reaction to the same level of exposure. Other health effects include coughing, fatigue and severe allergic reactions. High concentrations also may trigger asthma attacks.

Although the short-term health effects of formaldehyde exposure are well known, less is known about its potential long-term effects. Because of the concern that formaldehyde may cause cancer, the US EPA has classified formaldehyde as a probable human carcinogen under conditions of unusually high or prolonged exposure. The International Agency for Research on Cancer (IARC), however, upgraded its initial classification of formaldehyde as a probable human carcinogen to a known human carcinogen in 2004. The California Air Resources Board supported the IARC findings by classifying formaldehyde as a "toxic air contaminant" after state experts concluded that based on current research, there is "no safe exposure threshold [for formaldehyde] … to preclude cancer."

The World Health Organization (WHO) recommends keeping exposures below 120 $\mu g/m^3$ (0.10 ppm). The State of California recommends that levels be kept below 0.027 ppm. The Occupational Safety and Health Administration's (OSHA) Hazard Communication Standard includes an important labeling provision addressing formaldehyde emissions from products. Specifically, hazard warning labels are required on any manufactured product that may emit 0.10 ppm or greater, regardless of its formaldehyde content. In order to receive certification as a low-emitting product from the GREENGUARD Environmental Institute, products must emit 0.05 ppm or lower. Products meeting the GREENGUARD Children & Schools standard for sensitive populations must meet 0.0135 ppm, based on intended use.

Healthcare Facilities: Do No Harm

New science and technological innovations constantly require US healthcare providers to transform the way they deliver services and to provide high-quality treatment in an every-changing environment. Over the past 10 years, results of studies that have linked chemical contaminants in the environment and the incidence of disease has created an additional impetus for transforming healthcare practice (Cohen 2006) and how healthcare facilities are built, operated and maintained. Healthcare facilities comprise less than three percent of all buildings in the US, but they have some of the most specialized indoor environmental requirements (see Table 4).

Table 4. US healthcare facilities functions*

Building Functions	**Number of Buildings**
Inpatient	11,000
Outpatient	116,000
Total US healthcare facilities	127,000
Total US buildings	4,657,000

* 1999 Commercial Buildings Energy Consumption Survey, Energy Information Administration, Washington, DC Available online at www.eia.doe.gov

The following are among the unique attributes of these unique environments, including hospitals, nursing homes, rehabilitation facilities, physicians' offices and clinics:

- Patients at Risk: healthcare facilities house many persons with heightened susceptibility to infections, respiratory distress and other problems associated with air contaminants

- Occupant Density: Because the density of people in healthcare settings is relatively high, at risk patients are likely to be in close proximity to infectious individuals.

- Aging Building Systems: Many hospitals are aging and their ventilation systems are outdated and are in serious need of maintenance and repair (Riley).

In addition to energy and water conservation, lighting and preserving the outdoor environment, creating a healing environment that takes the above attributes into consideration requires paying particular attention to the indoor air patients breathe. Filter systems on outdoor air intakes may protect against outdoor air pollutants entering the hospital, but many air contaminants are emitted from building materials, furnishings, finishes and cleaning products and processes. As with other types of indoor environments, building materials, flooring, furnishings and finishes can release many different VOCs, SVOCs and MVOCs into hospital air and/or can harbor mold, bacteria and viruses. The potential implications can be subtle but significant, including effects ranging from longer patient recovery times to more sick days for staff (Rossi and Lent 2006). See *Indoor Air: A Host to a Wide Variety of Contaminants* above for details about the different types of indoor air contaminants and their potential health effects.

To address these issues, a number of voluntary guidelines have been established. On the best received is the Green Guide for Health Care (www.gghc.org), which is a collaborative effort by a group of leading US architects and designers. Their goal was to develop a green building tool that would be appropriate for the healthcare sector. The Green Guide for Health Care (GGHC) is modeled on the US Green Building Council's Leadership in Energy and Environmental Design (LEED) standard, but goes beyond LEED and includes a more robust framework based on environmental health considerations aligned with healthcare system priorities. Each recommendation in the guide is accompanied by a summary of its impact on patient health, worker health or the health of the environment (Cohen 2006).

Specifically, the GGHC is a voluntary, self-certifying system modeled after the US Green Building Council's LEED® rating system, with 96 design and construction points and 72 operations points. Unique features include:

- Tailored to the particular structural and regulatory challenges of healthcare buildings
- Introduces health issues as an explicit component of each point
- Incorporates design elements that enhance patient healing and staff well-being

Best practices in the GGHC include:

- Incorporating healing design elements such as day lighting and views of nature
- Using innovative technologies to reduce energy and water use
- Reducing hazardous chemicals, such as mercury, lead, dioxin, cadmium, phthalates and halogenated flame retardants
- Implementing green operations, ranging from organic food to housekeeping and landscaping protocols (GGHC Fact Sheet)

In addition to GGHC, some of the other resources available for establishing healthy building materials and practices include the following list, which was compiled by the Health Care Without Harm website (www.noharm.org):

Green Building Priorities for Healthcare
Priority setting for green construction in healthcare developed by the Building Green Health Care work group of

the Healthy Building Network and Health Care Without Harm. Available online at www.healthybuilding.net/healthcare/Green_Building_Priorities.pdf.

ASHE Green Healthcare Construction Guidance Statement
Vision statement and comprehensive check list of green design and construction goals and strategies developed by the American Society for Healthcare Engineering. Available online at www.healthybuilding.net/healthcare/ASHE_Green_Healthcare_2002.pdf.

Green and Healthy Buildings for the Healthcare Industry
Article by Gail Vittori of the Center for Maximum Potential Building Systems on planning for a green healthcare facility. Available online at www.healthybuilding.net/healthcare/Vittori_Green_and_Healthy_Buildings.pdf.

Kaiser Permanente Position Statement on Green Buildings
Mission statement from Kaiser on green construction in its healthcare facilities. Available online at www.healthybuilding.net/healthcare/KP_Statement.pdf.

Minnesota Sustainable Design Guide
The Guide is a design tool that can be used to overlay environmental issues on the design, construction, and operation of both new and renovated facilities. It can be used to set sustainable design priorities and goals; develop appropriate sustainable design strategies; and to determine performance measures to guide the sustainable design and decision-making processes. Available online at www.sustainabledesignguide.umn.edu/.

CHPS 1350 Specifications
Review of the progressive specifications developed by and now in use by the State of California with an emphasis on their treatment of indoor air quality issues and discussion of issues for healthcare. Available online at www.healthybuilding.net/healthcare/CHPS_1350_summary.pdf.

Key Questions for Environmentally Preferable Flooring Selection
Questions to ask a manufacturer to understand the life cycle impact of a flooring product (adaptable to other products). Available online at www.healthybuilding.net/healthcare/Key_Questions_Flooring_Selection.pdf.

Residences

The prolonged course of illness and disability results in extended pain and decreased quality of life for millions of people living in the US. Chronic, disabling conditions also cause major limitations in activity for more than one (1) of every 10 Americans, or 25 million people (CDC 2008). What this means is likely these people spend nearly all of their time at home. It also means, that healthcare providers who treat people that are sensitive to indoor air contaminants, particularly people with allergies and asthma, must counsel them to remove allergy and asthma triggers as much as possible from their home environments.

This is a major challenge as gaseous and particle pollutant levels in residences are often 2 to 100 times higher than those found outdoors. A home's furnishings, building materials, appliances, cleaning chemicals and hobby materials are just some of the sources of these pollutants. Excessive moisture in homes from water leaks and uncontrolled humidity also can lead to elevated allergens and molds. A consequence of air tight and well-insulated building construction is less fresh air enters structure, which allows pollutant levels to increase by trapping air inside. Eventually, they can become irritating and unhealthy to home occupants. Some also contribute to unacceptable and noxious odors. See *Indoor Air: A Host to a Wide* Variety of Contaminants above for details about the different types of indoor air contaminants and their potential health effects.

Three Steps to Cleaning the Air

No matter the type or size of the building – single family home, apartment, office, school, store, hotel, restaurant, hospital, church or arena – creating and maintaining good indoor air quality requires three key strategies: source control, ventilation and air cleaning, which starts during the design and construction phases and continues throughout a building's life. It is never too late to start managing IAQ in older buildings. Although the overall strategies for air cleaning are the same for most building types, not all of the methods and devices used accomplish this goal are the same. Indoor environmental experts recommend three primary strategies for good IAQ, especially when integrated into a building's overall operation and maintenance. The following highlights each of these strategies: source control, ventilation and air cleaning.

Source Control. The US Environmental Protection Agency, the American Lung Association and other experts agree that source control is the only completely effective way to remove pollutants from indoor environments. They also agree that total eradication of indoor air contaminants often is not feasible or practical. A more realistic goal is to use building materials, furnishings, finishes, office equipment and cleaning products and processes that emit low levels of VOCs. Surface cleaning also removes larger particles and kills bacteria and viruses on floors, furniture, walls, doorknobs, bedding and linens and bathroom fixtures. In addition, keeping the heating, ventilating and air-conditioning (HVAC) system in good working order and air ducts and drip pans clean is important for minimizing dust and particle accumulation and indoor mold growth within the system.

Products that are regularly tested to ensure that their chemical and particle emissions meet acceptable IAQ pollutant guidelines and standards may be found in the GREENGUARD Product Guide, which can be accessed at no charge on the GEI website – **www.greenguard.org**. For more information on cleaning products and processes and indoor air quality, refer to the AQS white paper, *Cleaning Products & Processes: Partnering for Healthier Indoor Environments*, which is available free from the AQS Aerias IAQ Resource Center's website at **www.aerias.org**.

Source control also involves inspecting a building regularly inside and out for any signs of water damage, which is a good indicator that moisture levels are high enough to support indoor mold growth. If water damage or signs of mold are found, they should be remediated immediately. The best way to prevent indoor mold growth is to eliminate all sources of excess moisture, from leaks in the building envelope, improper building pressurization, an inefficient or malfunctioning HVAC system, appliances to building occupant activities.

Ventilation. Ventilation and air cleaning are invaluable for picking up where controlling sources of indoor air pollutants leaves off. The two work hand-in-hand, as many types of air cleaners are an integral part of the HVAC system.

A well-designed and properly operating HVAC system brings in and conditions outdoor air and circulates the air through the building. The primary benefit beyond warming, cooling and managing the humidity the air is to dilute indoor air pollutants to minimize their impact on the indoor environment and building occupants. The HVAC system also transports indoor air contaminants outside. In addition, the HVAC system is invaluable for maintaining appropriate building pressurization, which is critical for preventing moisture intrusion. The downside is the HVAC system may bring in outdoor air pollutants as well as pick up indoor pollutants, such as mold spores, allergens, dust and VOCs from one area of the building and transport them to another.

Air Cleaning. Simply stated, with respect to air cleaning the goal is to remove indoor pollutants by trapping them inside a mechanical device. Effective air cleaning:

- Protects HVAC systems and components
- Protects furnishings and décor of occupied spaces

- Reduces housekeeping and building maintenance
- Reduces furnace and heating equipment fire hazards
- Protects building occupants (USEPA 2006, ALA Special Report on Air Cleaners)

Experts emphasize, however, that air-cleaning devices alone cannot ensure good IAQ, particularly where ventilation itself is inadequate. As noted, air cleaning is most effective when used in conjunction with source control and ventilation (USEPA 2006). For more information on cleaning the indoor air, see the AQS white paper, *Clearing the Air on Indoor Air Cleaners / Purifiers*, which is available free of charge from the Aerias website (**www.aerias.org**).

A Final Note

Homeowners, building owners and facility managers have the responsibility to reduce the risk of adverse health problems for people in high sensitive populations. Visit us at **www.aqs.com** to learn more about how AQS can help you assess your building and develop a plan to create and maintain healthy indoor environments, or call us at (770) 933-0638. Also visit the GREEENGUARD Environmental Institute at **www.greenguard.org** and the AQS Aerias IAQ Resource Center to learn more about indoor contaminants affect on people. Aerias may be accessed from the AQS website or at **www.aerias.org**.

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