Indoor Air Pollution: An Overview

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We've all heard the warnings about the risks of indoor air pollution on health, comfort, learning, and productivity, especially to children and those in sensitive populations groups. In response, many manufacturers have reformulated their products to be less polluting, but are challenged by a lack of universal indoor air quality (IAQ) regulations and standards. Significant differences in criteria among various eco labels and product certification programs around the world further complicate an already complex landscape of IAQ concerns. In addition, building designers, specifiers, and consumers are challenged by the overwhelming amount of information, some of which is contradictory and/or filled with unsubstantiated marketing claims (greenwashing).

Reviewing the basics about the most prevalent and dangerous types of indoor air pollutants associated with indoor materials and products adds some clarity and sharpens the focus on what strategies really work to create and maintain healthy indoor environments.

Volatile Organic Compounds (VOCs)

Volatile organic compounds (VOCs) are the most prevalent indoor air pollutants that originate from products and building materials. Air Quality Sciences (AQS), for example, has measured VOC levels in more than 2,000 different environments and emissions from over 65,000 different materials and furnishings. As a result, more than 12,000 unique VOCs have been identified in product emissions studies, and the majority of these VOCs have been found in buildings. Tables 1 and 2 list the most common VOCs found in green construction and in schools, respectively.

Results from a growing body of research suggest that chemical emissions from common indoor materials and finishes have a variety of adverse effects, including increased risk of asthma, pulmonary infections, and allergies (Mendell 2007). Chemicals in cleaning products, some personal care, and other consumer products also have been implicated. An especially striking finding reveals some chemicals may have health impacts at extremely low levels. Studies have found that exposure to very small traces of VOCs and some industrial chemicals in homes and schools can disrupt the endocrine

CHEMICALS OF CONCERN	MOST FREQUENTLY FOUND
Ethylene glycol	Toluene
Hexane	Xylenes
Methyl propanol	Undecanes
Benzene	Phenol
Ethyl benzene	Nonanes
Carbon disulfide	Dodecanes
Tetrachloroethylene	Decanes
Trichloroethylene	Cyclopentasiloxanes
Methylene chloride	Cyclohexanes
Naphthalene	Ethyl benzene
Phenol	Trimethylbenzenes
Styrene	Acetophenone
Toluene	Ethyl toluene
Xylenes	Ethyl toluene

Table 1: Commonly found VOCs (Green Commercial Construction)

VOC	SOURCE(S)	VOC	SOURCE(S)
Toluene	Cleaners, construction materials	Hexanel	Cleaners, adhesives, deodorizers, cabinetry
Xylenes	Cleaners, construction materials	2-Butoxyethanol	Wood cabinetry, cleaners, paints
Siloxanes	Waxes, polishes, deodorants	Ethanol	Cleaners, disinfectants
Formaldehyde	Furniture, ceiling tile, wood shelving, cabinetry	TXIB	Plastics, paints
Hexanes	Markers, cleaners	Acetaldehyde	Plastics, paints, foam insulations
Acetone	Markers, art supplies	Longifolene	Cleaners, wood products, flooring
1,4 Dichlorobenzene	Cleaners, deodorizers	Naphthalene	Adhesives, art supplies, rubber flooring

Table 2: Common VOCs found in schools

system (hormones), gene activation, and brain development (see Phthalates below).

Formaldehyde

Formaldehyde is widely used to manufacture building materials and numerous household products, and is also 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), which is commonly used in flooring, furniture, shelving, cabinetry, paper products, and decorative fabrics and textiles. It also may be used as a biocide in certain paints, coatings, adhesives, and personal care products.

Based on more than 350 measurements collected in residences and schools, AQS studies have found typical concentrations range from 0.03 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. 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 may also trigger asthma attacks.

Semi-volatile Organic Compounds (SVOCs)

Semi-volatile organic compounds (SVOCs) are the least volatile of all VOCs and thus the least likely to emit into the air (see Table 3). They also constitute a far smaller fraction of the total amount of VOCs found in indoor air. Even so, there is great concern about SVOC emissions from materials and products as these chemicals may attach to indoor surfaces such as airborne particles, dust, and human skin. The particles then become an exposure route for SVOCs when they are inhaled deep within the lungs. Phthalates, which are classified as SVOCs, are an excellent example. Other plasticizers such as bisphenol A and triclosan, flame retardants, perfluorochemicals, pesticides, combustion products, anti-stain agents, and heat transfer fluids are also SVOCs and may attach to particles.

Phthalates

Phthalates are used to make plastics like polyvinyl chloride (PVC) more flexible or resilient and also may be found in solvents. They are used in hundreds of products, including vinyl flooring, adhesives, detergents, lubricating oils, automotive plastics, plastic clothing such as raincoats, and personal care products such as soap, shampoo, hair spray, and nail polish. Before 1999, phthalates were used in pacifiers, soft rattles, and teethers (CDC 2005). In fact, their use is so widespread that researchers have found phthalates in almost all of the US population, with the highest levels in women as well as in children ages 6 to 11 years. Phthalates are known to disrupt the endocrine and reproductive systems and have been linked to liver cancer (CDC 2005). Some phthalates also have been associated with increases in persistent symptoms of allergies and diagnoses of rhinitis, eczema, and asthma (Mendell 2007).

Particles

Particles, as noted above, can provide an exposure pathway for SVOCs, but they also can present a serious health risk on their own. They 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. Inhaling particulates can cause eye, nose, and throat irritation and can increase the risk for respiratory infections. Health care professionals are especially concerned about the long-term effects of inhaling ultrafine particles (less than 2.5 µm), because they can travel deep into the lungs where they can remain embedded for years or be absorbed into the bloodstream. Exposure to high levels of fine particles also can play a role in developing respiratory diseases such as asthma, pneumonia, and chronic obstructive lung disease (COPD), which includes chronic bronchitis and emphysema. Larger particles (greater than 10 µm) do not cause as much concern, 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). Particles can originate from a number of sources, including fibrous or shedding materials, operating equipment such as printers and other image devices, and reactions among certain cleaning chemicals and ozone.

Polybrominated Diphenyl Ethers (PBDEs)

Polybrominated diphenyl ethers (PBDEs) are a class of widely used brominated flame retardants (BFRs). They are added

VOC	SOURCE(S)	VOC	SOURCE(S)
Very volatile organic compounds (gaseous)	VVOCs	<0 to 50 – 100	Propane, butane, methyl chloride
Volatile organic compounds	VOCs	50 – 100 to 240 – 260	Formaldehyde, d-Limonene, toluene, acetone, toluene, ethanol (ethyl alcohol) 2-propanol (isopropyl alcohol), hexanal
Semi-volatile organic compounds	SVOCs	240 – 260 to 380 - 400	Pesticides (DDT, chlordane, plasticizers (phthalates), fire retardants (PCBs, PBB)

Table 3: Classification of VOCs (adapted from WHO)*

* World Health Organization. 1989. "Indoor air quality: organic pollutants." Report on a WHO Meeting, Berlin, 23-27 August 1987. EURO Reports and Studies 111. Copenhagen, World Health Organization Regional Office for Europe. As presented in US EPA. 2010. "An Introduction to Indoor Air Quality: Volatile Organic Compounds." US Environmental Protection Agency Website. Last updated December 3, 2010. Available online at *www.epa.gov/iaq/voc2.html#8*

to the plastics used in televisions, computers and other electronic products, building materials, furniture, foams, textiles, and clothing. Electronics and electrical equipment make up more than 50 percent of BFR applications. Brominated flame retardants have been found to disrupt the endocrine systems in experimental animals. These endocrine disruptions also may damage nerve cells during brain development, which in humans continues up to two years after birth. In addition, the PBDE chemical structure closely resembles polychlorinated biphenyl (PCBs), which have well-established toxic effects, including birth defects, cancer, thyroid imbalances, and neurologic damage (Birnbaum and Staskal 2004).

Other Pollutants

There can be other indoor pollutants of significant concern including ozone, combustion gases (carbon monoxide and nitrogen oxides), tobacco smoke, pesticides, radon and microbiologicals such as mold and animal allergens. However, these are not typically associated with materials and furnishings and have not been covered in this technical brief. More information these pollutants may be found at *http://www.aerias.org/DesktopDefault.aspx?tabindex=3&tabid=79*.

For more information see the AQS white paper, Chemicals in COMMON Products: Risky Business for Children's Health, which is available free from the Aerias – AQS Indoor Air Quality Resource Center (aerias.org), under the Premium Content tab.

Regulating IAQ

In the US alone, there are more than 80,000 chemical compounds registered for use, with 62,000 of them grandfathered under the Toxic Substance Control Act (TSCA) without mandatory testing. According to California Policy Research Center, about 2,000 new compounds that may pose hazard to human health are introduced into commercial use each year. Under TSCA, the US Environmental Protection Agency has required testing on fewer than 200 chemicals and restricted only five chemicals (Wilson et al 2006). With respect to children's products, the Consumer Product Safety Improvement Act of 2008 significantly strengthened the Consumer Product Safety Commission's hand in protecting consumers and children from hazardous products, but it only addresses a few of the industrial compounds that can adversely impact children's health.

This is about as far as regulating IAQ goes, especially at the federal level. States, however, are beginning to recognize indoor environmental hazards as having a strong impact on children's health and are starting to enact regulations and legislation to limit children's exposure to indoor air pollutants (Zajac et al 2009).

Source Control Still the Best Bet for Healthy Indoor Environments.

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 pollutants is often not feasible or practical. A more realistic goal is to use building materials, furnishings, finishes, office equipment, cleaning products and processes that emit low levels of VOCs.

Products that are regularly tested to ensure 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 GREENGUARD Environmental Institute's (GEI) website (*www.greenguard.org*).

Visit us at *www.aqs.com* to learn more about how AQS can help you, or call us at (770) 933-0638 and ask for Product Evaluations. Also visit the AQS Aerias IAQ Resource Center to learn more about VOCs, particulates, and other indoor pollutants. Aerias may be accessed from the AQS website or at *www.aerias.org*.

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