CCHRC
Cold Climate Housing Research Center

Indoor Air Quality

Indoor air quality (IAQ) affects not just the health of people inside, but their ability to enjoy their home. Some symptoms of poor indoor air quality are obvious, such as musty smells or mold, while others are more subtle. Long-term exposure to indoor pollutants can make it harder to concentrate and in some cases may even lead to severe medical conditions.

Because the health effects of indoor air quality are difficult to quantify, they are often overlooked. However, Lawrence Berkeley National Lab recently reported that the harm caused by indoor air pollutants falls somewhere between traffic accidents and heart disease in terms of loss of healthy life (see sidebar on page 3). Other recent studies have found that the worst indoor pollutants are not necessarily the ones that receive the most attention. Most people understand the danger of carbon monoxide, secondhand smoke, and radon, but lesser-known toxins like $PM_{2.5}$, acrolein, and formaldehyde are often more prevalent in homes, and therefore more dangerous.

What Are You Breathing?

While the health impacts of outdoor air pollution have been studied extensively, indoor air pollution has remained largely unstudied. In a 2013 study, Sherman characterized the significance of indoor air pollutants in residential buildings: $PM_{2.5}$ is very important; formaldehyde and acrolein are important; and second-hand smoke, radon, and ozone are sometimes very important. Logue et al. (2011) found that $PM_{2.5}$ was the most hazardous pollutant in 80% of cases they analyzed, followed by acrolein in 16% of the cases, and formaldehyde in 4% of the cases (these studies excluded mold).

There has been much focus recently on $PM_{2.5}$ in the outdoor air. In cold climates, it is primarily generated from burning solid materials for heat. These particles, less than 2.5 micrograms, enters the body through the lungs and can move quickly into the bloodstream, causing respiratory and heart problems that can be especially dangerous for children and the elderly. $PM_{2.5}$ is also generated inside homes from cooking, lighting candles, or using woodstoves.

Volatile Organic Compounds (VOCs) are chemicals that can be harmful in a gaseous state. In a house, the greatest health risks come from formaldehyde and acrolein. Acrolein is an indoor pollutant produced from cooking and burning that mainly affects the respiratory tract. Formaldehyde off-gasses, or transfers from items like furniture and paint into the air. It can cause respiratory irritation and, in the event of long-term exposure, cancer. Benzene and toluene are VOCs that come mostly from

Cold weather inversions create high levels of $PM_{2.5}$ during the Fairbanks winter. Photo by Ned Rozell.

Pets and home furnishings both introduce pollutants inside the house.

petroleum products, they are prevalent in Alaskan homes with attached garages (Schlapia and Morris, 1998), even short-term exposure can lead to damage to the central nervous system.

While chemical hazards are difficult to identify in your home, biological hazards, such as water damage or mold, are easier to spot. If conditions are right, including high humidity and air leakage through the building envelope, mold can grow in the structure of the house. In the U.S., approximately 20% of asthma cases and up to 20% of respiratory diseases can be attributed to dampness and mold within homes (Mendell et al., 2011).

Carbon dioxide (CO_2) can also be considered a contaminant in high concentrations. It is typically found in the air at 400-500 parts per million (ppm). However, a recent study of an office environment found significant impacts to decision making as CO_2 levels increased (Satish et al, 2012). For example, when they increased from 600 ppm to 1,000 ppm, decision-making performance in participants declined in most areas evaluated. Exposure to 2,500 ppm carbon dioxide led to even greater decline. While these health impacts may seem mild compared to asthma or cancer, the economic impact of reduced mental performance is itself worthy of further investigation.

$PM_{2.5}$, acrolein, and formaldehyde contributed more than 80% of the damage to human health in the vast majority of cases studed by Logue et al. These common toxins are hard to recognize.

Attached garages can be a dangerous source of indoor pollutants.

Pollutant	Health Effect	Source
$PM_{2.5}$	• Premature death in people with heart or lung disease • Nonfatal heart attacks • Irregular heartbeat • Aggravated asthma • Decreased lung function	Combustion from indoor and outdoor sources: candles, wood stoves, cooking, cigarettes
Acrolein	• Asthma • Lung cancer • Decreased lung function	Heated cooking oil, smoke from candles, wood stoves, cigarettes
Formaldehyde	• Irritation to eyes and respiratory tract • Cancer	Off-gassing of furniture, carpet, paint, foam, synthetic fabric, cosmetics, building materials
Mold	• Asthma • Respiratory infections	Moist and damp conditions, high humidity
Benzene, toluene	• Short-term exposures can lead to central nervous system problems and irritation of skin, eyes, and nose • Prolonged exposure to benzene can lead to leukemia and cancer	Petroleum products, paint, cigarettes
Carbon Dioxide	• Higher concentrations lead to reduced cognitive function	Occupants breathing

The Cost of Poor Air Quality

It is difficult to quantify the cost of poor IAQ on a per building basis. The nature of the effects of exposure to environmental pollutants are usually long term and may not become apparent until years after exposure. Asthma in young children may be the exception to the long-term effects. In a study based in Hooper Bay and Fairbanks, CCHRC looked at 19 homes of children with asthma and 17 control homes. The study found that children with asthma lived in homes with higher incidence of pollutants and poorer ventilation (Davies, et al., 2005). The project included retrofits in all homes and pre- and post-retrofit analysis and surveys. Medical tests found no significant psychological changes but surveys showed that overall health of the children improved in 79% of the homes. The cost of improving IAQ is minimal when compared to the benefits: lower medical bills, fewer lost days from work or school, and increased productivity.

Addressing Poor Indoor Air Quality

So how do you address these hidden dangers in your house? The best way to alleviate poor IAQ is to dilute indoor air with cleaner outside air. Experts suggest changing the air inside your home on a regular basis, between one-third to one-half complete air changes per hour. That means moving all the air out of your house and replacing it with outside air every 2 to 3 hours. Often houses do this in the form of a bathroom fan, range hood, or heat recovery ventilator (HRV).

Since cooking is a major source of $PM_{2.5}$ and acrolein, it makes sense to install a working range hood in the kitchen to remove these pollutants before they spread to the rest of the house. Point-of-use ventilation systems for the kitchen and bathroom are useful in keeping some pollutants in lower concentrations if they are used regularly. However, other pollutants do not come from a single source and a whole-house ventilation system is also important.

While the health risks of smoking and radon pose a greater danger in the indoor air, lesser-known pollutants like acroelin, $PM_{2.5}$, and formaldehyde are actually far more common in homes. For more information on radon and other indoor pollutants go to, https://www.epa.gov/indoor-air-quality-iaq

Cooking can produce pollutants such as acroelin and $PM_{2.5}$. Range hoods reduce the impact to indoor air quality.

The Health Cost

The standard way to measure the loss of healthy life is called Disability-Adjusted Life Year, or DALY. One DALY is equivalent to one lost year of healthy life over one person's lifetime. The effects are spread across the population; for example, traffic accidents account for about 4 mili-DALY/person/year (a mili DALY is about 9 hours) and heart disease is about 11 mili-DALY/p/yr. The calculated chronic health damage for all indoor air pollutant hazards is 4–11 mili-DALY/p/yr, placing it somewhere between traffic accidents and heart disease (Logue et al. 2011). $PM_{2.5}$, acrolein and formaldehyde are the predominant contributors to this estimated human health impact. For comparison, acute carbon monoxide poisonings result in 0.049 mili-DALY/p/yr. These figures exclude consideration of secondhand smoke and radon that may also be present in some homes and further increase the health risk for occupants.

How to Maintain Healthy Air

Ventilation serves a crucial role in the indoor air quality of homes in cold climates. It provides fresh air for occupants, removes pollutants, and controls indoor humidity. Outdoor air infiltration, mechanical, and natural ventilation are all options.

Natural ventilation (for example, opening a window or door) provides aesthetics and egress, but is not practical in a cold climate year-round. In prior generations, homes were able to "breathe" quite easily since they were relatively leaky. However, this type of natural ventilation not only wastes energy but can also cause moisture problems within the building envelope. Homes today are built substantially different, with the goal of minimizing air infiltration.

Because natural ventilation and infiltration are considered insufficient for today's relatively energy efficient homes, mechanical ventilation is the preferred method to maintaining good indoor air quality. This includes supply-only, exhaust-only, and balanced ducted ventilation systems.

A supply-only system is usually part of the heating system. Typically a furnace heats air and returns it to the home via fans and ducts. Outside air is added through the intake system to provide fresh air. However, systems of this type pressurize the house, pushing warm, moist air through cracks in the walls, floor, and ceiling, which creates moisture in the walls and leads to mold and rot. Supply-only ventilation systems are not recommended for cold climates.

Exhaust-only ventilation usually uses the bathroom fan and range hood to get rid of stale air. For makeup air, it relies on natural air leakage through the building. In homes that do not have much natural air leakage, specific vents need to be installed in the walls (such as Fresh 80s). Some exhaust-only systems are designed to provide the correct amount of air changes per hour, but there are also shortcomings to this approach. For example, if there is not enough make-up air, the bath fan can create negative pressure in the house, which allows combustion devices to backdraft, or pulls dangerous gases into the house. Additionally, exhaust-only systems do not pull air evenly from all parts of the house. Even the best designed system is not foolproof, and if home occupants do not understand how it works they can easily disable the fans to save energy.

The ideal system for a cold climate is balanced, ducted ventilation. This system features a Heat Recovery Ventilator (HRV) or Energy Recovery Ventilator (ERV) that brings in cold outside air and pre-heats it with warm exhaust air. A balanced ventilation system introduces and exhausts roughly the same amount of air in the home. A ducted system makes sure air from all parts of the house is exchanged on a regular basis, and air can be filtered to remove pollutants.

A Fresh 80 is a type of passive ventilation system that includes a series of holes throughout the house to allow air exchange.

Heat Recovery Ventilators provide balanced ventilation in a home by exhausting stale air and bringing in the same amount of fresh air.

References

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