A Close-Up Look at the Quality of Indoor Air

By Brian Rohrig

EVERY MINUTE, YOU TAKE ABOUT 16 BREATHS. THAT MEANS YOU TAKE MORE THAN 8 MILLION BREATHS EVERY YEAR. With each inhalation, everything suspended in the air enters your lungs. In urban areas, vehicle exhaust, smoke from power plants and factories, and other chemicals can make this air a toxic brew. But once you make it into the climate-controlled air-conditioned comfort of the great indoors, is the air safe from all these dirty chemicals? Not really.

In most cases, it is not the outside air getting in, but rather pollutants that originate from within the structure itself (Fig. 1). Because many homes and buildings are poorly ventilated, the concentration of toxic gases and airborne irritants can build up to dangerous levels. So what are these indoor air pollutants, and what are their harmful effects to human health?

Radon gas

Radon is the perfect example of a silent killer. If you look to the far right and bottom corner of the periodic table, you will find radon, the heaviest noble gas (atomic mass number of 222). It is one of the densest gases known. Radon is colorless and odorless. But according to the U.S. Environmental Protection Agency, radon causes 20,000 lung cancer deaths each year in the United States. It is the second leading cause of lung cancer in the United States. You can find some radon in every home, but if the level is abnormally high, it should be cause for concern.

Radon occurs in many isotopic forms. Radon-222 is the most common form in the environment, and it is a member of the radioactive decay chain of uranium-238. Uranium is commonly found in rocks and soil, especially those with high concentrations of granite. Like all radioactive elements, uranium's nucleus is unstable and decays to other nuclei, emitting high-energy particles or rays. The highly energetic particles and rays can do substantial chemical damage to living organisms—if their concentration inside these organisms is high enough.

Because radon is dense, it tends to travel horizontally through the soil, accumulating in the basement. It can enter the basement through cracks or other gaps in the foundation. It can also enter through the water supply.

THINKSTOCK

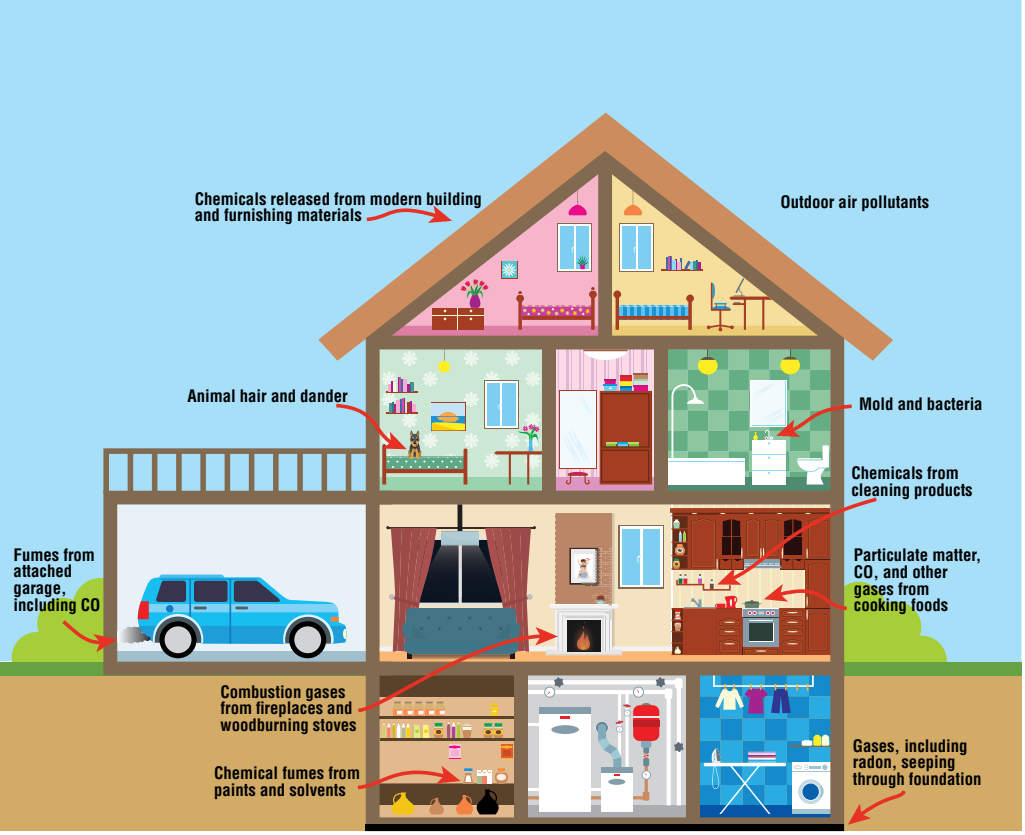

Figure 1. Common sources of indoor air pollution inside and around the home

Since radon-222 is radioactive, it decays into other elements, known as "daughter products." These daughter products pose the greatest harm, especially polonium-218 and polonium-214 (Fig. 2). Both of these are solids and can adhere to dust particles, which, when inhaled, can get lodged in the lungs. Once in the lungs, these isotopes continue to decay, emitting alpha particles.

An alpha particle is a helium nucleus—two protons and two neutrons—which is released from the nucleus of a decaying radioactive atom (Fig. 2). Alpha particles are harmless if they are emitted outside the body, because they cannot penetrate the skin. But if they originate in atoms inside the lungs, they can be deadly, because they cause damage inside the lungs. Alpha particles can damage the DNA of cells, causing mutations that can lead to cancer.

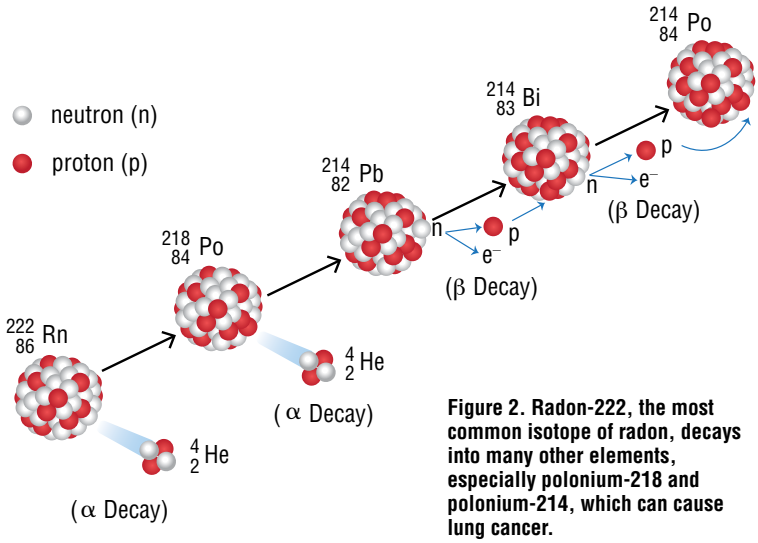

Figure 2. Radon-222, the most common isotope of radon, decays into many other elements, especially polonium-218 and polonium-214, which can cause lung cancer.

The only way to know for sure if you have a high level of radon in your home is to use a radon test kit, which can be purchased from a hardware store or online. If abnormally high levels of radon are detected, you would have to contract the services of a radon removal company, which will eliminate the gas and provide recommendations for future prevention. If you have a bedroom in the basement or spend a lot of time in your basement, it would be a good idea to purchase one of these kits and test for radon.

Volatile organic compounds

Everyone loves that new car smell. Or the smell of a new home. But these odors, as pleasant as they may be, can be hazardous to your health. Some of the most pleasant smells can be quite harmful. Any odor is due to gas molecules in the air entering your nose and stimulating olfactory receptors.

Many of the odors found in homes, especially new ones, are due to volatile organic compounds (VOCs), chemicals used to manufacture interior furnishings, cleaning products, and personal care products. A volatile compound evaporates or sublimates rapidly. Sublimation occurs when particles of a solid substance pass directly into the vapor phase, bypassing the liquid phase altogether.

Volatility is due to weak intermolecular forces of attraction among the molecules that make up the substance. To change phase, intermolecular forces of attraction among molecules must be overcome. This process requires energy. For a highly volatile compound, the ambient temperature is enough to overcome these forces and release gaseous compounds into the air.

Indoor concentrations of VOCs can be 10 times higher than those found outdoors. Because the source of these compounds is within the home itself, VOCs can rise to harmful levels. The concentration of VOCs in new homes is much higher than in older homes, because levels dissipate over time.

One VOC commonly found in homes is formaldehyde (CH_2O), which is mainly released from carpet, laminate flooring, and plywood. It was once commonly used as a preservative for biological specimens, but since it is now known to be a human carcinogen, its use for this purpose has been largely discontinued. Formaldehyde is toxic, especially if ingested.

The ingestion of methanol is toxic, too, because the body metabolizes it into formaldehyde. Foods and beverages that contain aspartame are a primary source of methanol in the human body. Also, most methanol poisonings occur as a result of drinking methanol as a substitute for alcohol, a dangerous practice.

Short-term exposure to VOCs can cause headaches, nausea, and throat irritation. Chronic effects include damage to the liver, kidneys, and the central nervous system. Long-term exposure to VOCs has been linked to cancer in laboratory animals.

ADAPTED FROM ILLUSTRATION AVAILABLE AT: http://www.epa.gov/epobox/exposure-assessment-tools-media-air#indoorair (UNDER "SOURCES" AND THEN "INDOOR AIR"); RS GRAPHX, INC.; DOLLAR PHOTO CLUB

Carbon monoxide

It is easy to take for granted the heating systems in our homes. Natural gas, for example, is a relatively safe clean-burning fuel. If all is working properly, you have little to fear. Natural gas is mostly composed of methane and burns according to the following chemical reaction:

$$CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O$$

The above reaction assumes complete combustion, where all of the methane combines with oxygen to yield carbon dioxide and water vapor. However, if combustion is not complete, then carbon monoxide (CO), a potentially lethal compound, is produced as follows:

$$2\,CH_4 + 3\,O_2 \rightarrow 2\,CO + 4\,H_2O$$

No furnace, no matter how efficient, will burn 100% of its methane; some carbon monoxide will always be produced. This is typically not a problem if the furnace is properly ventilated and the products are safely released to the outside. However, if there is a problem with the ventilation, then toxic carbon monoxide can enter the home.

If the flame produced by a furnace is yellow instead of blue, incomplete combustion is occurring, along with the release of copious amounts of carbon monoxide. Just as the Bunsen burner flame in a chemistry lab must be blue to ensure complete combustion and the hottest flame, so must the flame in a home's furnace. The worst possible combination is a faulty furnace and poor ventilation.

Symptoms of carbon-monoxide poisoning include headache, dizziness, nausea, and fatigue.

Often, carbon-monoxide poisoning occurs when gasoline-powered generators are used in the home. These generators should always be placed outside. If an oil-burning heater is installed in the home, it must be properly ventilated. Also, the burning of charcoal produces a lot of carbon monoxide and should never be done in an enclosed space.

Because carbon monoxide is an odorless gas, its presence can easily go unnoticed. Symptoms of carbon-monoxide poisoning include headache, dizziness, nausea, and fatigue. Carbon monoxide binds more readily than oxygen to hemoglobin in red blood cells, effectively displacing oxygen and causing death by suffocation.

Every home should have a carbon-monoxide detector, which is the best way to know if unsafe levels of this gas are present. Older furnaces should be inspected on a regular basis to make sure they are working properly.

The best strategy to rid your home of noxious chemicals is to open the windows and allow the fresh air in to displace the stale air. If you are experiencing chronic respiratory or allergy symptoms, the source could be within your home. It is easy to take the air you breathe for granted, but staying informed about these issues will make you aware of your environment and help you take whatever steps are necessary to ensure the air around you is safe. CM

Other Indoor Air Pollutants

OZONE

Most of the ozone inside our homes comes from outside. Ozone reacts with molecules released by air fresheners and other scented products. The products of these chemical reactions have similar structures to chemicals known to be toxic or to cause irritations.

WOOD SMOKE

Wood smoke contains very small particles that cannot be filtered out by the nose or the upper respiratory system. They can remain deep in the lungs for months before being cleared. Studies have shown that these fine particles increase the risk of heart attacks and strokes.

SCENTED CANDLES

If candles are not burning smoothly, they can give off small particles of soot that can make their way into the lungs. Some scented candles have wicks with a metal core, and a number of these have been found to release significant amounts of lead into the air when they are burned.

SELECTED REFERENCES

Household (Indoor) Air Pollution. World Health Organization: http://www.who.int/indoorair/en/ [accessed Jan 2016].

An Introduction to Indoor Air Quality. Environmental Protection Agency, Oct 13, 2015: http://www2.epa.gov/indoor-air-quality-iaq/introduction-indoor-air-quality [accessed Jan 2016].

Formaldehyde in Your Home. Minnesota Department of Health, Environmental Health Division: http://www.health.state.mn.us/divs/eh/indoorair/voc/formaldehyde.htm [accessed Jan 2016].

Brian Rohrig is a science writer who lives in Columbus, Ohio. His most recent *ChemMatters* article, "Biomimicry: Taking Inspiration from Nature," appeared in the February/March 2016 issue.