



Air Pollution Comes Home

Sick Buildings—

By Michelle Laliberte

“Why don’t you go play outside and get some fresh air?”

How many times have you been told this? You might have thought this was just a way to get you out of your parents’ hair for a while. But there might be some sound chemical reasons to spend some time outside of the house. That’s because air pollution can sometimes be a real problem—*inside* the home!

All kinds of activities that take place inside the home can release chemicals or particles into the air. Some are obvious, such as using an aerosol deodorant or painting a room. Some are less obvious, like taking a shower, frying food, or rolling on the new plush carpet with your pet dog. In drafty old buildings, this was not a big problem, because there was enough ventilation to prevent these substances from building up. But to bring fresh air into a building and heat it in the winter or cool it in summer costs money. In response to the energy crisis in the 1970s, builders started sealing up homes and office buildings and air circulation decreased drasti-

cally. With poorer circulation, chemicals released inside the home could build up to potentially dangerous levels. Now, growing public awareness of indoor air pollution has given birth to new terms such as “indoor environmental health” (IEH), and “sick building syndrome” (SBS). But news reports may sometimes go too far, sensationalizing the subject to the point of scaring the daylights out of us. Should we be worried? What should you do?

Sources of indoor air pollution

Stanley Watras lived in Boyertown, PA and worked at the Limerick Nuclear Power Plant. During December of 1984, Stanley set off alarms at the plant as he attempted to *enter* through portal radiation monitors. Every day for two weeks Stanley went through decontamination while the authorities at the nuclear power plant tried to find the source of his radiation contamination. It was confusing because the power plant was not yet producing fission products, but the contamination source was eventually found.

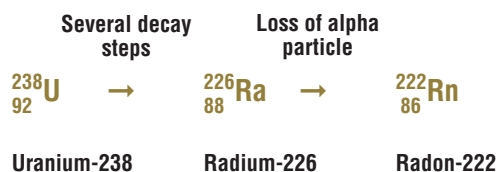
It was coming from Stanley’s house. At Stanley’s urging, his home was tested for

radiation contamination, and it showed radon levels 650 times the average level. Radon is a naturally occurring radioactive gas that is a byproduct of decaying uranium and a known cause of lung cancer. His family, including small children, was immediately evacuated. High radon levels were also found in nearby houses. Stanley’s home is on the Reading Prong, a region that stretches from Reading, Pennsylvania through New Jersey and into New York. This granite formation has very high deposits of low-grade uranium.

Radon

Radon-222 is produced by the natural disintegration of the radioactive element radium-226. Radium itself is produced by the decay of uranium-238, which is found in rock layers and bedrock. It is present in most of the soil and rock around the world, especially areas with lots of granite, shale, and phosphate rock.

With the loss of an alpha particle, radium is converted to radon gas. Radon itself is not harmful. It is chemically inert (it’s a noble gas after all) and has a short half-life of only 3.8 days. However, Rn-222 undergoes radioactive decay to form polonium-218, which in turn undergoes decay in a continuing chain termi-



nating in stable Pb-206. These progeny nuclei are charged and chemically reactive, so they attach to airborne dust particles that can be inhaled into the lung. Several of the progeny are alpha-emitters; when they undergo decay, the energetic alpha particles blast into and damage the surrounding cells.

Because radon is a gas, it can permeate your house through the basement or crawl space or through exposed soil and rock beneath and around your home's foundation. Sometimes, it can seep in through well water, or migrate into your home through natural gas lines.

In order to measure and report an amount of radiation, we need a standard unit; the standard measure for the intensity of radioactivity of some radioactive substances is the curie (Ci). The curie is a measure of the number of atoms in a collection of atoms that are giving off radiation per an interval of time. Radium decay is used as the basis for the curie, and one gram of Ra-226 gives off 2.2 trillion decays per minute. A curie is a lot of radiation, so we routinely speak of radiation intensity in terms of a picocurie. Pico is a prefix meaning one trillionth, or 10^{-12} , so a picocurie (pCi) is equal to 2.2 disintegrations per minute.

Back to radon—the EPA has set safe limits for indoor radon at 4 picocuries per liter of air (4 pCi/L). The average indoor level of Ra is 1.3 pCi/L, and about 0.4 pCi/L is normally found in air outdoors. The level of radon gas in Stanley's (remember Stanley?) home was an astonishing 415 pCi/L, a level that has been estimated to carry a risk equivalent to smoking 135 packs of cigarettes per day. In fact, this level of radon far exceeds that allowed in uranium mines!

Radon gas problems can be corrected (mitigated) by increasing ventilation throughout the house, especially in the basement. Sealing cracks and openings in the foundation can also help to keep some of the radon out. You can't smell it, so to be safe, all homes should be tested for radon gas levels; commercial test kits are available at many hardware stores. So, what happened to Stanley Watras? He and his family eventually moved back into the home after fixing the radon



Test kits for radon and CO are commercially available.

problem, and now Stanley is successfully working in the radon mitigation field!

Formaldehyde

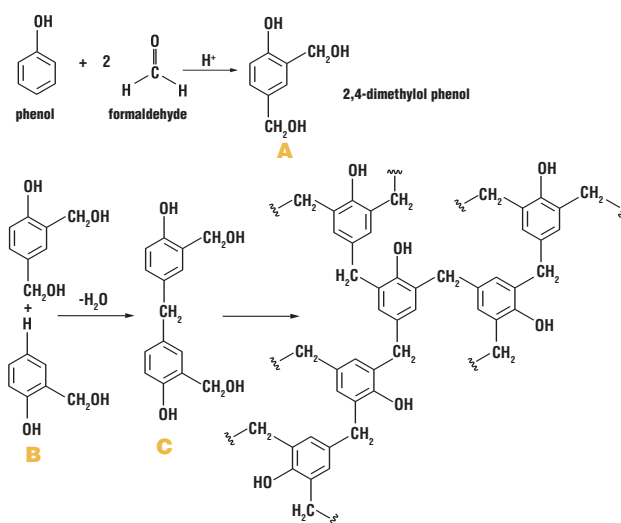
Formaldehyde (CH_2O) is a volatile and flammable organic chemical that can be released into the air as a pungent, suffocating gas. It is naturally produced in our bodies in very minute quantities as part of normal metabolism. We are exposed to formaldehyde in the air, food, and in cosmetic products. Known by its other names methanal, methylene oxide, and formalin (a 37% mixture in water), formaldehyde is one of the top 25 most abundantly produced chemicals in the world. It is used as a disinfectant, preservative, fire retardant in foam insulation, clothing, paper products, carpeting, and—yuck—embalming fluid. Formaldehyde is added to cotton products to give them wrinkle-resistance, and is added to many more products, including (believe it or not) Italian cheeses, fish, dried foods, and toothpaste.

When combined with urea or phenol, formaldehyde makes an excellent adhesive resin, so it is widely used in the building and furnishings industry. The construction of pressed-wood products such as particleboard often involves the use of formaldehyde-based resins. You can

find particleboard all through a home as subflooring and shelving. The formaldehyde reacts chemically with urea or phenol to form a resin that binds the materials of particleboard together. Formaldehyde reacts with phenol to form 2,4-dimethylol phenol (**A**). This compound reacts with 2-methylol phenol (**B**) in a condensation reaction to form compound **C**. A condensation reaction is one where two reactants are joined together as a small molecule is split out; in this case, the small molecule is H_2O . Compound **C** polymerizes to form the resin known as Bakelite, which sets, or hardens, binding particles together.

When the polymer resin forms and the material sets, there is not supposed to be any formaldehyde left; it should have all reacted. The problem comes from small amounts of unreacted formaldehyde that gets entrapped in the resin and is released over time. The release, or outgassing, of the excess formaldehyde is gradual, occurring rapidly at first and then slowing over time. Thus, exposure is greater in a new home furnished with new products.

Formaldehyde is a potent eye, upper respiratory and skin irritant. Exposure causes central nervous system problems, including headaches, fatigue, and respiratory depression. It has the potential for inducing asthmatic attacks and recent epidemiological studies of work-exposed individuals suggest that formaldehyde causes nasal cancer. To minimize your exposure, buy solid wood furniture when possible, and keep your home properly ventilated.



The formation of a polymer resin used for particleboard. Formaldehyde is a key reagent.

Molds and biological pollutants

Molds, mildew, fungi, bacteria and house dust are some of the main biological pollutants in the home. Spores generated from mold and mildew are released into the air and form new colonies wherever they land. Areas of the home with high humidity, such as bathrooms, kitchens, laundry rooms, and basements are sources for these living pollutants. Mold can be found growing on paper, textiles, grease, dirt, and even soap scum.

Rather than a single substance, house dust is a varied mixture of potentially allergenic materials. It may contain fibers from different types of fabrics; cotton lint, feathers, and other padding materials; dander from cats, dogs, and other animals; bacteria; food particles; bits of plants and insects; and other allergens peculiar to an individual home.

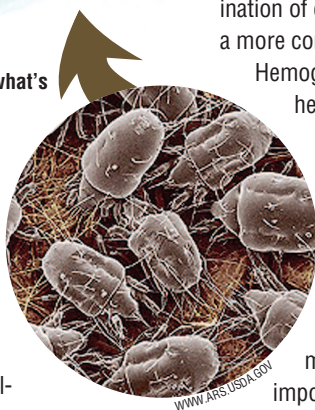
House dust also contains microscopic dust mites. Dust mites feed off of human dead skin cells. They live in bedding, upholstered



Dude—do you have any idea what's crawling all over your pillow?

furniture, and carpets; thriving in summer and then dying off in winter. The Mayo Clinic estimates the average bed contains between 100,000 and 10 million dust mites. You may be sharing your bed with millions of them! The particles seen floating about in a shaft of sunlight include dead dust mites and their waste products. Dust mites have been identified as the single most important trigger for asthma attacks. Asthma, a chronic ailment that afflicts millions around the world, causes inflammation of the airways and affects the way air enters and leaves the lungs, thereby disrupting breathing.

You can pinpoint these triggers of indoor allergens in your home by visual detection.



Keeping mold growth under control is accomplished by making sure basements, bathrooms, and other rooms are clean and dry. Chlorine bleach will remove any visual mold and can be used to clean out humidifiers and air-conditioning condensing units. Use vacuums with high-efficiency filters and consider replacing old carpet with hard surface flooring if anyone in your home is sensitive to these allergens. Wash sheets, pillowcases, and blankets weekly. This removes dust mites' primary source of food—your dead skin cells.

Carbon monoxide

According to the *Journal of the American Medical Association*, 1,500 Americans die each year from accidental exposure to CO, and over 2,000 from intentional exposure (suicide). Carbon monoxide is an extremely hazardous gas that has no warning taste or odor. It is produced by incomplete combustion of organic fuels such as wood, gasoline, natural gas, coal, charcoal, and fuel oil. Like oxygen, carbon monoxide binds to the iron atoms of the hemoglobin (Hb) protein molecules found in our red blood cells, forming a complex called carboxyhemoglobin. Carbon monoxide binds to hemoglobin about 200 times more strongly than does oxygen. It was long believed that because carboxyhemoglobin is unable to transport oxygen, fatal carbon monoxide poisoning is due to asphyxiation. This sounds bad enough, but a detailed examination of carbon monoxide poisoning reveals a more complicated, more insidious situation.

Hemoglobin is a tetramer, that is, each hemoglobin protein has the ability to bind to four oxygen molecules. Its oxygen binding exhibits a phenomenon called cooperativity: once the first oxygen molecule binds, the protein changes its shape in such a way that the remaining three sites bind oxygen more tightly. This is physiologically important, making Hb better at binding O_2 in the oxygen-rich lungs and better at releasing O_2 in the oxygen-poor muscles. However, the CO-bonded iron looks (as far as the protein is concerned) a lot like the O_2 -bonded iron. So the Hb shifts into high-affinity mode when even one CO is bound per protein molecule. This means that it picks up the O_2 well in the lungs but cannot release it in the tissues! A person suffering from exposure to carbon monoxide actually has high oxygen blood content. It's just that the oxygen cannot



A barbeque grill is an example of a CO-producing device. Never use a grill indoors.

be released where it is needed: the brain, heart, and skeletal muscle. For more information on this topic, see Tim Graham's article "The Silent Killer" in the February 2005 issue of *ChemMatters*.

Carbon monoxide buildup occurs when flues or chimneys become blocked and exhaust cannot be vented outside. Faulty furnaces, fuel-burning space heaters, ovens, ranges, and even grills operated in the home without adequate ventilation will also cause carbon monoxide buildup. To prevent this exposure, carbon monoxide alarms and detectors are available in stores and should be installed to alert you of dangerous levels. Also make sure you have your combustion heating systems and chimneys checked by trained professionals every year.

Safe haven

Even though we have only listed several of the many toxic indoor air contaminants, the subject can be frightening. Our homes should be a safe haven, not a hazardous waste dump. Every time you get dizzy, have a sore throat, or have itching, burning eyes will you wonder if it has to do with the air quality of the room? Education is the key to keeping your indoor air clean and healthy. Remember, it's not just the outside air we have to be concerned with anymore. A little forethought and action can go a long way in preventing major health problems arising from contamination occurring in your own home. ▲

Michelle Laliberte is a science writer living in Medina, OH. This is her first article for *ChemMatters*.