

What's in Air We Breathe

By Max Sherman, Ph.D., Fellow ASHRAE

Given how long indoor air has been studied, we might think we actually know what's in it. Surprisingly, we have a poor idea, at least until recently. Logue, et al., have done a hazards assessment¹ of the nine most hazardous chemicals in indoor air.²

Burned Stuff

The Banpo villagers of central China had chimneys in their homes 7,000 years ago.³ They figured out it was not a good idea to breathe the products of combustion. Today, we still burn stuff in our homes: food, gas, candles, wood, etc. Logue, et al., identified several products of combustion that are at hazardous levels, including acrolein, benzene, butadiene, nitrogen dioxide and fine particles. Acrolein⁴ was at the top of the list of priority hazards. Although it's not the stuff found in the highest concentrations, its very low acceptable level means it is quite often at unacceptable levels.

Smelly Stuff

Many of the hazardous chemicals found by Logue, et al., have detectable odors at relatively low concentrations. One class of such compounds is called "aldehydes," which typically are smelly and irritating.⁵ Logue, et al., found formaldehyde and ac-

etaldehyde to be a hazard in most homes; formaldehyde is right after acrolein on the list. Unlike acrolein, formaldehyde is a useful industrial chemical, and it is found in many household materials such as wood products, adhesives, etc.

Another name for "smelly" is "aromatic," but in chemistry that word refers to a special class of smelly compounds. Three aromatic compounds identified as priority hazards are benzene, naphthalene and paradichlorobenzene (PDB). Most of the benzene found probably comes from outside the conditioned space proper, but that is not true of the other two.

Dead Stuff

We like to kill stuff in our buildings even more than we like to burn stuff. We use lots of pesticides, germicides, fungicides, bactericides, herbicides, biocides, and disinfectants in our buildings. Not surprisingly, chemicals designed to kill living things are often not very good for us either.

The only two chemicals that Logue, et al., found consistently hazardous in this category are our aromatic friends naphthalene and PDB. Naphthalene is the traditional "moth ball" many of us remember, but it has been phased out in favor of PDB. PDB is also in products such as toilet or urinal "freshener" blocks. Many find the PDB odor fresh and pleasing.

That is not to say that other intentional poisons are not important in indoor air, but no other single chemical seems to show up broadly enough to make the hazards list.⁶

Nasty Stuff

Chlorine is in a lot of poisonous compounds. This is not surprising as it is pretty nasty stuff.⁷ While PDB was the only chlorine-containing compound to be found a priority hazard, there were lots of chlorine containing chemicals lower down on the list including hexachlorobutadiene, benzyl chloride, vinyl chloride, methylene chloride, tetrachloroethene, dichloropropane, tetrachloroethane, dichloroethane, trichloroethene, and, of course, chlorine.

One such chemical deserves special attention as it should have been on the priority hazards list, but wasn't: carbon tetrachloride ("carbon tet"). Fifty years ago carbon tet was a miracle chemical. It was used for dry cleaning and a host of consumer products.⁸ Unfortunately, it

1. Logue, J.M., T.E. McKone, M.H. Sherman, B.C. Singer. "Hazard assessment of chemical air contaminants measured in residences." Published online in advance of print in *Indoor Air* at <http://onlinelibrary.wiley.com/doi/10.1111/j.1600-0668.2010.00683.x/abstract>.

2. The assessment was limited to residential environments, but I won't let that deter me from generalizing to the whole of the indoor environment.

3. This village was discovered outside of the Imperial city of Xian. If you can get the tour bus to stop there, it is on the way to see the famous terra-cotta warriors.

4. Acrolein was used as a chemical weapon in World War I. Unlike most of the other chemical weapons, acrolein is not outlawed by the Chemical Weapons Convention (CWC). This is partly because it can be made incidentally as a product of combustion.

5. "Smelly" is not necessarily bad. Cinnamaldehyde is the odorous part of cinnamon and smells fantastic, but if you get the pure stuff on exposed skin it is like poison ivy on steroids. Don't ask.

6. Since "no pest strips" have fallen out of favor, PDB and naphthalene are probably the only poisons that emit continuously in our homes.

7. Like acrolein, chlorine was used in WWI as a chemical weapon, which is probably why you didn't know it was green-yellow. In fact, chlorine is the father of all the chemical weapons as it was the first one used.

8. If you have a lava lamp from the '60s, be careful. It is probably filled with carbon tetrachloride. One of the great advances of modern chemistry has been the ability to make a non-toxic lava lamp.

Advertisement formerly in this space.

was found to be really bad stuff⁹ and was banned in consumer products in 1970. The major industrial use that continued was in the making of refrigerants such as R-11 and R-12. That use dwindled, of course, with the Montreal Protocol in 1989.

So even though Logue, et al., found significant amounts of carbon tetrachloride in the indoor air, it was not put on the priority hazards list because there were no sources. The existing levels are presumably coming from the long residence time it has in the global atmosphere, as there are no longer domestic¹⁰ sources of any significance.

Another interesting chlorine compound is chloroform. It is a precursor to carbon tetrachloride and is similar to it, but less hazardous. It can be a hazard in some homes, usually when the concentration in the water is elevated.

Other Stuff

Other chemicals such as cadmium or chromium are important to health but not related to indoor air. The following chemicals are important to indoor air at least some of the time.

Carbon Monoxide and Environmental Tobacco Smoke are special cases of burned stuff. When these contaminants are

generated, they may dominate the other listed hazards. Their health impacts are well studied. Since they come from specific activities/situations, they are usually either present or not.

Radon is a radioactive, noble gas that is a problem in certain parts of the country where it can be a significant hazard. It typically is transported via soil gas into the building. In those areas, radon-resistant building practices can be used as can radon mitigation protocols. Radon is not usually a concern unless the soil has radium-bearing materials.

Fine Particles are not technically chemicals, but are nevertheless a priority hazard. Their impacts on the body have to do less with their composition than their size. Large particles do not penetrate very far in the lung and can be removed relatively easily, and therefore do not cause much problem.¹¹ Finer particles come from many different sources both inside and outside of buildings. As mentioned earlier, combustion is a prime source of particles, but there are other chemical and physical processes that can produce and transport them.¹²

Water Vapor is not actually a contaminant at all, but it can be problematic. If the concentration of water in air (i.e., the

9. For example, when heated in air carbon tetrachloride can make phosgene, which was the chemical weapon used in WWI when it was discovered that chlorine by itself was not as effective at killing people as hoped.

10. In fact, the sources of carbon tetrachloride you just breathed are likely foreign. The time for it to mix in the atmosphere (~1 year) is much less than its residence time (~50 years) and that makes a global issue. We are getting it from developing countries that have not banned its use.

11. That is unless you are allergic to what they consist of, which can be the case for pollen or pet dander.

12. If curious, read *The Secret Life of Dust* by Hanna Holmes (2003). You will be impressed.

Advertisement formerly in this space.

Advertisement formerly in this space.

humidity) gets too high, it enables the growth of mold. Molds can produce spores and mycotoxins that are, at best, unpleasant; it is generally a good idea to avoid the conditions that will enable mold growth. People can experience discomfort if the water vapor level becomes too high or too low. Water vapor is qualitatively different from the other chemicals discussed.

Unknown Stuff is all around us. According to those who study IAQ extensively, there is more danger from the stuff we *don't* know about than the stuff we *do* know about. There is all sorts of talk of plasticizers, endocrine disruptors, ultrafine particles and phthalates. Whether this unknown stuff is a significant problem is unknown.¹³

What to do About Stuff

We'd like to take sensible precautions regarding the hazards we do know about. ASHRAE has Standards 62.1 and 62.2 to provide minimum ventilation requirements. Ventilation dilutes (indoor) contaminants, but the best approach is to minimize the contaminant sources inside first. Given the existing priority hazards,¹⁴ there are a few recommendations to consider:

Don't burn stuff indoors. Move combustion sources outside, which is what sealed combustion appliances, or sealed fireplaces, essentially do. When that is not possible, use exhaust systems to

remove the products of combustion before they can spread indoors. For example, use the kitchen exhaust hood when cooking.

Use materials that don't emit much stuff. Many products and materials use formaldehyde and other volatile organic compounds in the manufacturing process. Whenever possible, choose materials that emit less. Fortunately, the industry is beginning to provide information that makes that possible

Contain your poisonous stuff. When you do find it necessary to kill things, do it in a controlled way. Keep poisons contained to the time and place they are needed so as to minimize their concentrations in the indoor air.

Filter stuff out of the air. Cleaning chemicals out of the air can be a costly process overall, but filtering particles is pretty easy if you have an air-handling system to begin with. Use good quality filters and maintain them to reduce exposure to fine particles.

I am not sure knowing what is in indoor air is actually comforting,¹⁵ but it is probably appropriate for ASHRAE members to have some idea of the stuff we breathe.

Max Sherman is a senior scientist at Lawrence Berkeley National Laboratory, Berkeley, Calif., and group leader of its Energy Performance of Buildings group. He was the first chair of ASHRAE Standards Project Committee 62.2. ●

13. This is great for researchers as it justifies further work for them. It is not, however, terribly useful for those who just want to know if there is a significant problem to be dealt with.

14. Just to stave off letters, let me state the obvious: just because something is on the priority hazards list does not mean that it is a problem for you. Similarly, just because the priority hazards are not a problem for you, does not mean that you have good IAQ.

15. I personally have decided to avoid being exposed to anything that was used as a chemical weapon during WWI...and not to play with pure cinnamaldehyde.

Advertisement formerly in this space.