purchaser to visually compare one decorative panel or kitchen cabinet to another regarding emissions. But, in general, unless a finish is visibly thick and an effective vapor barrier, it probably has little effect on formaldehyde emissions. Their tests also indicate that a typical carpet and padding will roughly cut particleboard underlayment emissions in half and a sheet of drywall will do the same (but the duration of the problem is increased). Resilient tile flooring and a special heavy floor-sealing paint worked well.

If you use particleboard for countertop underlayment, laminate backer board to the bottom or at least coat it with a heavy sealer. On site-built hardwood-veneer cabinets, I'd try a few coats of a good solvent-based finish. Where finishes are impractical, such as on cabinet backs and bottoms and carpet underlayment, look into alternative products. Some possibilities are hardboard, softwood (fir) plywood, exterior composition boards, phenolic particleboards (such as Louisiana Pacific's Redex) or exterior sheathing products such as waferboard. If these are too expensive, use low-emitting particleboard. When in doubt, check with the manufacturer.

Monitoring of 40 houses by Oak Ridge shows that after five years few houses, including those with UF foam insulation, exceed the ASHRAE comfort level of 0.1 ppm of formaldehyde. If you want to try your own monitoring, passive monitors are available from 3M, Occupational Health and Safety Products, 3M Center, St. Paul, Minn. 55101. The monitors cost under $50 and need 24 hours exposure.

Potential Sources of Formaldehyde

Product	Area/use pattern	Concentration (parts per million)
Carpeting	108 ft²	<0.01
Resilient Flooring	108 ft²	<0.01
Particle board underlayment (with tile cover)	108 ft²	<0.01
Softwood plywood subfloor		<0.01
Fiberglass insulation (under drywall)	172 ft²	<0.01
Furniture (particleboard)	11 ft²	0.01
Cigarettes	10/day	0.02
Gas oven	.7 hrs/day	0.03
Decorative paneling (wood veneer)	108 ft²	0.05
Kerosene heater	8 hrs/day	0.05
Furniture (medium-density fiberboard)	11 ft²	0.06
Particleboard underlayment (w/ carpet and cushion)	172 ft²	0.08
Decorative paneling (print overlay)	108 ft²	0.11
UF foam insulation	150 ft²	0.14
Particleboard (uncovered)	108 ft²	0.16

Based on published emissions rates and their own tests, researchers at Oak Ridge National Labs modeled the formaldehyde contributions of common materials to the air of an 11- x 16-foot room with half an air change per hour. Their conclusion: The strongest contributors are UF foam insulation and pressed-wood products. When there are several sources, the emission rates can not be added; rather, the strongest source dominates.

Radon

Radon is a colorless, odorless gas that occurs as part of the natural decay of uranium. Radon, in turn, breaks down into short-lived radon "daughters," which may attach to dust particles, lodge in the lung, and release alpha particles that can cause lung cancer. Estimates of the cancer risk to homeowners are based on statistics on cancer rates in uranium miners. Due to the uncertainties of this type of research, the risk estimates for homeowners may be off by as much as a factor of two.

Radon gas is present to some extent in all soils and groundwater, though the amount varies a great deal from one region to the next and even within one town. The average level of radon in U.S. homes is estimated at 1 to 2 pCi/1 (that's a unit of radiation called a pico-Curie per liter). The average level outdoors is about 0.25 pCi/1. According to existing models, the risk of developing lung cancer from a lifetime exposure to radon in the average home (at 1 pCi/1) is about one quarter of one percent. At a lifetime exposure of 4 pCi/1, the risk rises to 1 percent and so on.

To put this in some perspective, each 4 pCi/1 of lifetime exposure in your home is roughly equivalent to smoking one to three cigarettes per day. This is about 25 times less than the risk of dying in an auto accident. Currently, about 85 percent of all lung cancers are caused by smoking.

Now, the good news. Although experience with remedial measures is limited, it appears that elevated radon levels, once diagnosed, are easy to cure with combinations of ventilation and source control. Most radon enters the home from the soil beneath. So anything that blocks pathways from the soil into the building will reduce concentrations. If cracks exist in the foundation, caulk them. If the basement or crawlspace floor is dirt, cover it with a vapor barrier and sand or concrete. Seal the crawlspace from the house and vent the crawlspace. Swedish researchers have developed a very effective retrofit using a simple array of PVC pipes poked through the basement slab and vented outdoors.

In at least two cases where remedial action was taken, the radon was entering from a sump. The cure, in each case, was to cap the sump and exhaust the radon to the outdoors with a small fan and duct. Sumps that tie into subsurface drains are more likely to contribute to problems. In general, ground coupling of airflows is not a good idea in radon-rich areas.

In some areas, groundwater is the main source of radon problems in homes with wells. The radon is released to the household air when the water is aerated, as in a shower. Charcoal filters developed by researchers at the University of Maine have proven effective at treating radon-rich water.

The chief obstacle in tackling the radon problem is identifying the problem. "If radon gas were green and foul-smelling," says University of Maine physicist Charles Hess, "it would pose no great threat." The only monitors other than expensive and delicate lab equipment are available for about $50 apiece from Terradex Corp., 460 N. Wiget Lane, Walnut Creek, Calif. 94598. Unfortunately, the detectors require two to three months exposure to get a reading.

If you are planning to build a tight home and can afford the luxury, you might test the ground before building. Or, if you are drilling a well before building, have the water checked for radon when it is tested. If the radon level is high, it may indicate that the soil level is high as well. How high is too high? This is difficult to answer. Average soil readings in the U.S. are about 100 pCi/1, but may measure as high as a few thousand. About 25 percent of houses have tested at above 4 pCi/1 and in some regions houses have tested at above 20 pCi/1. The only U.S. standard is a recommendation made by the EPA for structures built around sites contaminated with uranium tailings. The limit was set at 3 pCi/1. Clearly, more research is needed in this area.

Ventilation

In a simplified model, the concentration of a pollutant is inversely proportional to the rate of ventilation. Thus, doubling the rate of ventilation cuts the concentration of an indoor pollutant in half. In fact, it probably does somewhat less than that since other mechanisms are removing pollutants in addition to ventilation.

In the case of radon, cases have been reported where increasing the rate of ventilation has increased the concentration of radon. The reason: ventilation depressurized the house so more radon gas was drawn from the sump where it was originating. Conversely, tightening a house may reduce the concentration of radon, for example, if the living space is sealed from a crawlspace or basement. In general, ventilation helps significantly, but reducing the source is always the first priority.

To make this point, researchers note that levels of indoor pollutants vary from house to house by a factor of 100, while infiltration rates vary by no more than a factor of 10. The message is clear that, in general, source control is far more important than ventilation.

Next month, we'll look at combustion products, allergens, and other household pollutants and learn how to keep them out of your energy-efficient house.