

Biological Effects of Ionizing Radiation (BEIR) VI Report: "The Health Effects of Exposure to Indoor Radon"

Public Summary: The Health Effects of Exposure to Indoor Radon

Radon is a naturally occurring gas that seeps out of rocks and soil. Radon comes from uranium that has been in the ground since the time the earth was formed, and the rate of radon seepage is very variable, partly because the amounts of uranium in the soil vary considerably. Radon flows from the soil into outdoor air and also into the air in homes from the movement of gases in the soil beneath homes. Outside air typically contains very low levels of radon, but it builds up to higher concentrations indoors when it is unable to disperse. Some underground mines, especially uranium mines, contain much higher levels of radon.

Although radon is chemically inert and electrically uncharged, it is radioactive, which means that radon atoms in the air can spontaneously decay, or change to other atoms. When the resulting atoms, called radon progeny, are formed, they are electrically charged and can attach themselves to tiny dust particles in indoor air. These dust particles can easily be inhaled into the lung and can adhere to the lining of the lung. The deposited atoms decay, or change, by emitting a type of radiation called alpha radiation, which has the potential to damage cells in the lung. Alpha radiations can disrupt DNA of these lung cells. This DNA damage has the potential to be one step in a chain of events that can lead to cancer. Alpha radiations travel only extremely short distances in the body. Thus, alpha radiations from decay of radon progeny in the lungs cannot reach cells in any other organs, so it is likely that lung cancer is the only potentially important cancer hazard posed by radon.

For centuries, it has been known that some underground miners suffered from higher rates of lung cancer than the general population. In recent decades, a growing body of evidence has causally linked their lung cancers to exposure to high levels of radon and also to cigarette smoking. The connection between radon and lung cancer in miners has raised concern that radon in homes might be causing lung cancer in the general population, although the radon levels in most homes are much lower than in most mines. The National Research Council study, which has been carried out by the sixth Committee on Biological Effects of Ionizing Radiation (BEIR) VI, has used the most recent information available to estimate the risks posed by exposure to radon in homes.

The most direct way to assess the risks posed by radon in homes is to measure radon exposures among people who have lung cancer and compare them with exposures among people who have not developed lung cancer. Several such studies have been completed, and several are under way. The studies have not produced a definitive answer, primarily because the risk is likely to be very small at the low exposure encountered from most homes and because it is difficult to estimate radon exposures that people have received over their lifetimes. In addition, it is clear that far more lung cancers are caused by smoking than are caused by radon.

Since a valid risk estimate could not be derived only from the results of studies in homes, the BEIR VI committee chose to use the lung-cancer information from studies of miners, who are more heavily exposed to radon, to estimate the risks posed by radon exposures in homes. In particular, the committee has drawn on 11 major studies of underground miners, which together involved about 68,000 men, of whom 2,700 have died from lung cancer. The committee statistically analyzed the data to describe how risk of death from lung cancer depended on exposure. In this way, the committee derived two models for lung cancer risk from radon exposure.

In converting radon risks from mines to homes, the committee was faced with several problems. First, most miners received radon exposures that were, on the average, many times larger than those of people in most homes; people in a few homes actually receive radon exposures similar to those of some miners. It was necessary for the committee to estimate the risks posed by exposures to radon in homes on the basis of observed lung cancer deaths caused by higher exposures in mines. The committee agreed with several earlier groups of experts that the risk of developing lung cancer increases linearly as the exposure increases; for example, doubling the exposure doubles the risk, and halving the exposure halves the risk. Furthermore, the existing biologic evidence suggests that any exposure, even very low, to radon might pose some risk. However, from the evidence now available, a threshold exposure, that is, a level of exposure below which there is no effect of radon, cannot be excluded.

The second problem is that the majority of miners in the studies are smokers and all inhale dust and other pollutants in mines. Because radon and cigarette smoke both cause lung cancer, it is complicated to disentangle the effects of the 2 kinds of exposure. That makes it especially difficult to estimate radon risks for nonsmokers in homes using the evidence from miners. A final problem is that the miners were almost all men, whereas the population exposed to radon in homes also includes men, women, and children.

The committee used the information from miners and supplemented it with information from laboratory studies of how radon causes lung cancer. Then, with facts about the US population, including measurements of radon levels in homes, it estimated the number of lung-cancer deaths due to radon in homes. In 1995, about 157,400 people died of lung cancer (from all causes including smoking and radon exposure) in the United States. Of the 95,400 men who died of lung cancer, about 95% were probably ever-smokers; of the 62,000 women, about 90% were probably ever-smokers. Approximately 11,000 lung cancer deaths are estimated to have occurred in never-smokers in 1995.

The BEIR VI committee's preferred central estimates, depending on which one of the two models are used, are that about 1 in 10 or 1 in 7 of all lung-cancer deaths—amounting to central estimates of about 15,400 or 21,800 per year in the United States—can be attributed to radon among ever-smokers and never-smokers together. Although 15,400 or 21,800 total radon-related lung-cancer deaths per year are the committee's central estimates, uncertainties are involved in these estimates. The committee's preferred estimate of the uncertainties was obtained by using a simplified analysis of a constant relative risk model based on observations closest to residential exposure levels. The number of radon-related lung-cancer deaths resulting from that analysis could be as low as 3,000 or as high as 32,000 each year. Most of the radon-related lung cancers occur among ever-smokers, and because of synergism between smoking and radon, many of the cancers in ever-smokers could be prevented by either tobacco control or reduction of radon exposure. The committee's best estimate is that among the 11,000 lung-cancer deaths each year in never-smokers, 2,100 or 2,900, depending on the model used, are radon-related lung cancers.

Radon, being naturally occurring, cannot be entirely eliminated from our homes. Of the deaths that the committee attributes to radon (both independently and through joint action with smoking), perhaps one-third could be avoided by reducing radon in homes where it is above the "action guideline level" of 148 Bqm-3 (4 pCiL-1) to below the action levels recommended by the Environmental Protection Agency.

The risk of lung cancer caused by smoking is much higher than the risk of lung cancer caused by indoor radon. Most of the radon-related deaths among smokers would not have occurred if the victims had not smoked. Furthermore, there is evidence for a synergistic interaction between smoking and radon. In other words, the number of cancers induced in ever-smokers by radon is greater than one would expect from the additive effects of smoking alone and radon alone. Nevertheless, the estimated 15,400 or 21,800 deaths attributed to radon in combination with cigarette-smoking and radon alone in never-smokers constitute an important public-health problem.