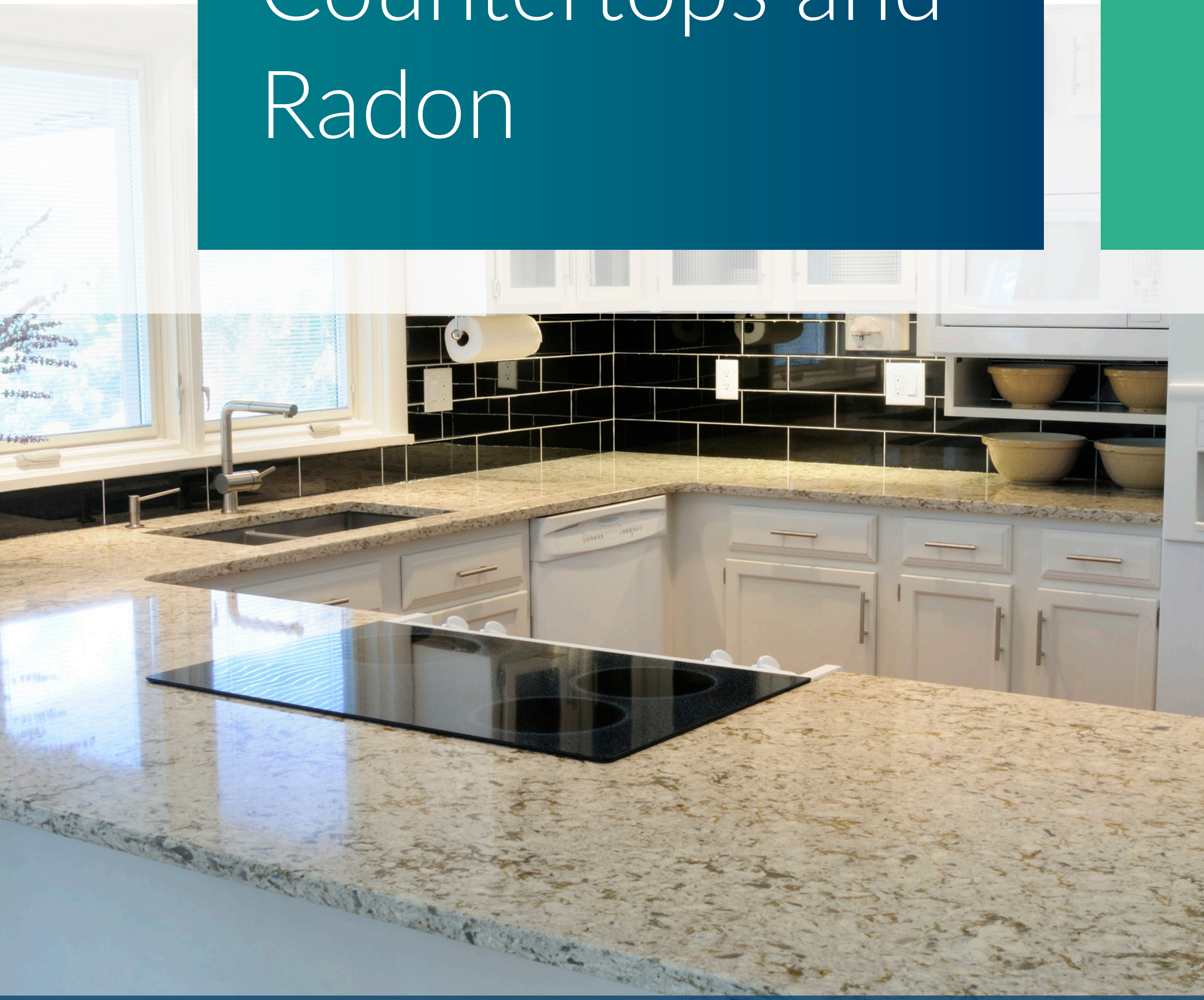
Environmental
Health & Engineering

Natural Stone Countertops and Radon



SUMMARY

Radon gas occurs naturally in the environment and is present in outdoor and indoor air throughout the world. Radium, which is the source of radon gas, is a natural and minor constituent of many common building materials such as concrete, brick, gypsum, and natural stone. Granite and other stones that are a popular choice for countertops and other decorative features in homes have been evaluated extensively. Over 500 measurements of radon emissions from granite have been published in the peer reviewed scientific literature. This information provides a reasonable basis for preliminary estimates of typical and upper bound levels of radon in indoor air of homes associated with emissions from natural stone countertops.

The average and maximum radon concentrations estimated from these data to result from emissions by natural stone are low in comparison to relevant benchmarks of radon exposure. The radon concentration estimated as a result of average radon emissions from natural stone reported in the scientific literature is approximately:

- 300 times lower than (or 0.3% of) levels of radon in outdoor air,
- 1,000 times below (or 0.001% of) the average concentration of radon found in the air of U.S. homes, and
- 3,000 times less than (or 0.00004% of) the action level for indoor air recommended by the U.S. Environmental Protection Agency (EPA).

Further refined assessments of indoor exposure to radon as a result of emissions from natural stone will be possible as additional information becomes available about other types of stones in the marketplace, including their various applications in homes and radon emission rates. Nonetheless, information available at present indicates that radon levels associated with natural stone countertops in homes are low in comparison to background levels of exposure and natural stone is a minor contributor compared to other sources of radon gas.

INTRODUCTION

Natural stone is a popular choice for countertops in homes throughout the United States. These surfaces are typically referred to as “granite” but in fact can consist of a variety of stone types that includes actual granite and marble. Regardless of the specific type, all natural stones used as countertops are composed of several major minerals and numerous minor constituents. Radium is one of the minor components of some countertops made from natural stone.

Radon, produced from radium, is a radioactive gas that occurs naturally in the environment and is present in outdoor and indoor air throughout the world. Radon has been found to pose a health risk for exposed individuals as the concentration increases. Useful benchmarks for evaluating exposure include action levels recommended by the EPA, baseline concentrations of radon in indoor and outdoor air, and goals for radon indoors established by the Congress of the United States.

In considering the public’s health, we ask an important question - how much do natural stone countertops contribute to the amount of radon inside U.S. homes in comparison to those benchmarks? The answer is very little, according to the best scientific evidence that is available at this time.

The objective of this white paper is to explain why this is the case and to demonstrate this conclusion with three robust yet simple examples that cover a range of realistic household conditions.

We begin with a summary of radon emissions from natural stone countertops reported in the scientific literature; next, describe how ventilation influences levels of radon in indoor air of homes; then present estimates of radon levels in homes that could arise from natural stone countertops; and conclude by comparing those levels to the benchmark values mentioned above.

RADON EMISSIONS FROM STONE COUNTERTOPS

The amount of radon released from a natural stone countertop in a home depends on the surface area of countertop in the home and the amount of radon released per unit area of stone. Sufficient information is available to derive reasonable estimates for both of those parameters.
An average kitchen with stone countertops has a working surface area of approximately 50 square feet (ft2) according to a large sample of sales data provided to Environmental Health & Engineering, Inc. by the Marble Institute of America, while a typical bathroom installation is approximately 18 ft^2 of stone. Accounting for both the kitchen and bath, the underside face of the counter, and the thickness of the stone (about 1.2 inches), a typical installation of natural stone countertop includes a total surface area of approximately 140 ft^2. To produce the most health protective estimates, we assume that the entire surface area is open to the room and contributing radon to the indoor air.

Over 500 measurements of radon released from granite and marble have been reported in peer reviewed articles published in the leading scientific journals that focus on radiation and health.[1-17] Stones included in those studies were mined from quarries throughout the world and reflect the diversity of stones in the U.S. market. Radon emissions, sometimes called the exhalation rate, are expressed as the amount of radioactivity released per square foot of stone per hour (pCi ft^{-2} h^{-1}). As shown in Figure 1, most of the stones tested so far have an exhalation rate between 0.1 and 5 pCi ft^{-2} h^{-1}, while the average and maximum values are 1.9 and 34 pCi ft^{-2} h^{-1}, respectively.

The emission rate for radon from stone countertops in a home is calculated as the product of the surface area and exhalation rate. A typical kitchen and bath installation of natural stone countertop that had the average radon exhalation would result in radon emissions of approximately 270 pCi per hour (140 ft^2 of stone surface area multiplied by a radon exhalation of 1.9 pCi ft^{-2} h^{-1}). A typical installation of natural stone with the *maximum* exhalation rate reported for natural stones would have a radon emission rate of approximately 4,760 pCi per hour. The emissions from the stone countertops are then

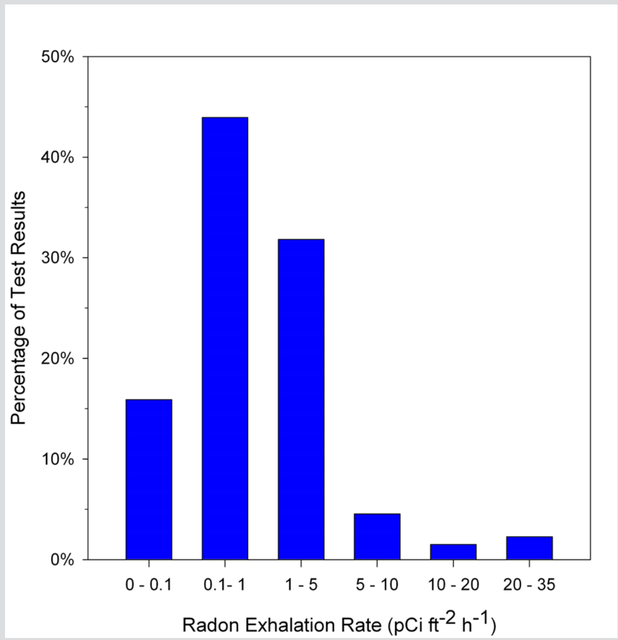


Figure 1 Distribution of radon exhalation rates reported in the peer-reviewed scientific literature.

mixed within the volume of the home and by the exchange of indoor and outdoor air, commonly referred to as ventilation.

THE ROLE OF VENTILATION

Residential buildings of all types are designed to "breathe", that is, to allow outdoor air to enter inside the home and indoor air to exit to the outside. Common pathways through which air moves into and out of homes are illustrated in Figure 2. This breathing or ventilation of a home has an important influence on indoor air concentrations of materials generated by indoor sources, including radon released from natural stone. In brief, concentrations in indoor air decrease as ventilation increases. Ventilation is therefore beneficial for reducing concentrations of materials emitted to indoor air from sources inside of homes.

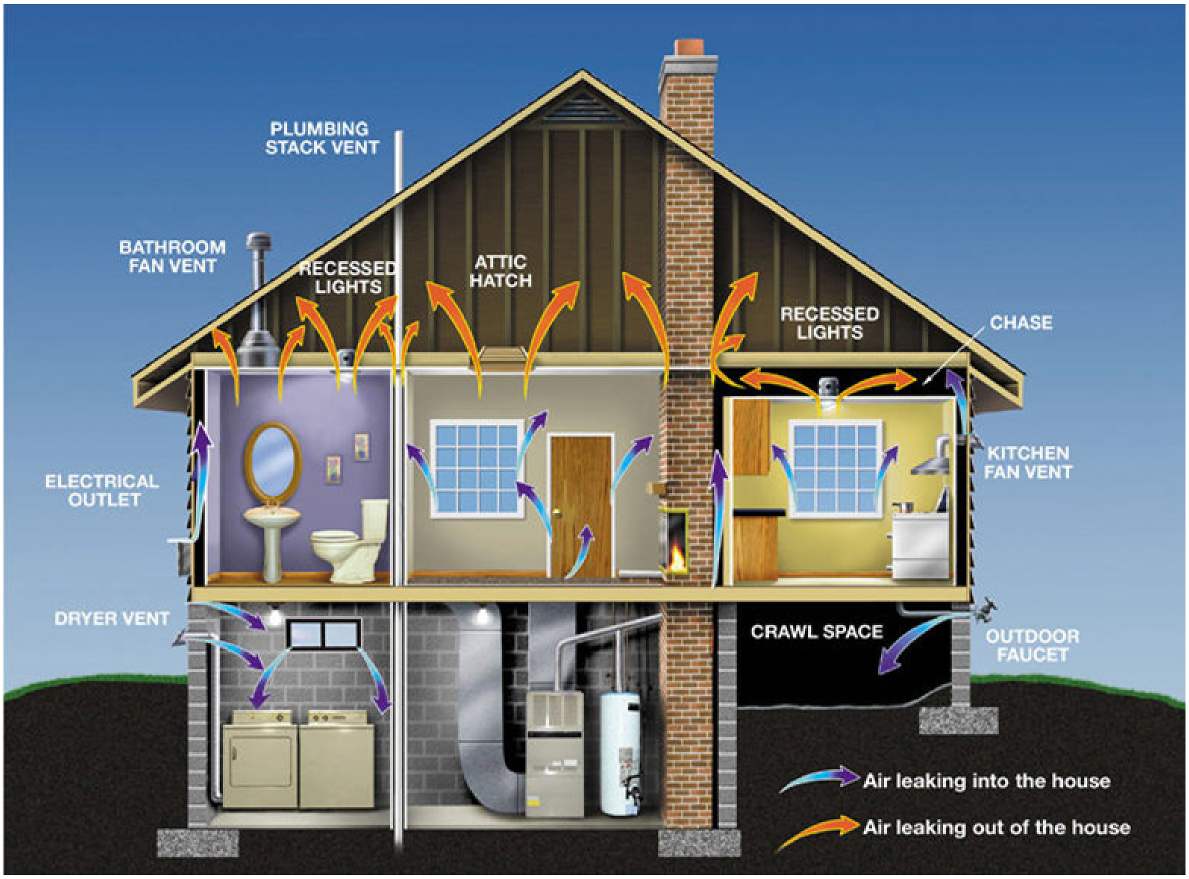


Figure 2 Illustration of ventilation in homes.
Image courtesy of U.S. Environmental Protection Agency.
http://www.energystar.gov/index.cfm?c=home_sealing.hm_improvement_sealing Accessed August 2008.

Two useful and closely related measures of residential airflow are the air exchange rate (AER) and ventilation rate. AER is the fraction of air inside a home that is replaced by outdoor air each hour. Ventilation rate is simply the volume of air flow represented by the AER and is calculated as the interior volume of a home multiplied by the AER. No home is completely airtight nor would we want it to be. Without air exchange and ventilation supplying fresh air and oxygen, we wouldn't survive in a sealed home. Therefore, to appropriately assess the potential impact of radon emissions on occupants in a home the ventilation rate must be included in any evaluation.

Ventilation characteristics for U.S. homes are well understood as a result of numerous studies that have measured AER in a cross-section of residential buildings across the nation.[18] The annual average AER for a typical U.S. home is generally accepted to be approximately 0.5 per hour.[19] This means that a typical single family home with 1,800 ft^2 of living space and 8 foot ceilings has a ventilation rate of approximately 7,200 ft^3 of air per hour (1,800 ft^2 x 8 feet x 0.5 per hour). An additional ventilation rate of 0.2 AER is also considered to evaluate the impact of tighter homes on levels of radon in indoor air.

The next section explains how knowledge of radon emissions from natural stone in a home and the ventilation rate of a home can be used to estimate radon concentrations in indoor air with a simple model.

RADON IN INDOOR AIR FROM NATURAL STONE

Long-term, whole-house average concentrations of indoor radon associated with emissions from natural stone can be estimated from the radon emission rates and ventilation rates discussed above. The concentration in units of picoCuries per liter of air (pCi L^{-1})[20] is calculated by dividing the radon emission rate by the ventilation rate, then dividing by a constant to convert from cubic feet to liters of air.

$$Radon\left[pCi\,L^{-1}\right] = \frac{Radon\ Emission\ Rate\left[pCi\,h^{-1}\right]}{Ventilation\ Rate\left[ft^{3}\,h^{-1}\right] x\ 28\left[L\ ft^{-3}\right]}$$

The results of applying the equation above to three scenarios of radon emission rates and ventilation rates are summarized in Table 1. Annual average concentrations of radon are estimated to range from 0.001 pCi L^{-1} for an average home with the average radon emission rate to 0.06 pCi L^{-1} for a tightly constructed home with the maximum radon emission rate reported in the scientific literature.

Table 1 Annual average whole house concentration of radon in indoor air for three scenarios of emissions from natural stone countertops inside of a typical home

Scenario	Radon Emission Rate (pCi h^{-1})	Ventilation Rate (ft^3 h^{-1})	Radon Concentration (pCi L^{-1})
Average radon exhalation rate, average ventilation rate	270	7,200	0.001
Maximum radon exhalation rate, average ventilation rate	4,760	7,200	0.02
Maximum radon exhalation rate, minimum ventilation rate	4,760	2,880	0.06

Home with 1,800 ft^2 with 8 foot tall ceilings
pCi h^{-1} picoCurie of radon per hour
ft^3 h^{-1} cubic feet of air per hour
pCi L^{-1} picoCurie of radon per liter of air

Information about normal levels of exposure to radon is presented in the next section in order to provide a context for interpreting the concentrations estimated in Table 1.

EXPOSURE TO RADON

As noted earlier, radon is a natural part of our environment that is produced from rocks, soil, and other materials. Background concentrations of radon in outdoor air are generally about 0.4 picoCuries per liter (pCi L^{-1}). The Congress of the United States has established a long-term goal that indoor radon levels be no more than outdoor levels.[22]

In comparison to background, the average concentration of radon in the air of an American home is generally considered to be 1.3 pCi L^{-1}, about three times greater than typical levels in outdoor air.[23] Radon levels in indoor air of homes generally reflect local geology and characteristics specific to the condition of each home. Important sources of radon in indoor air include radon in outdoor air that moves indoors and radon in soil gas that enters through the foundation of homes.

Finally, the EPA recommends an action level of 4 pCi $L^{-1}$for radon concentration in indoor air of homes.[24] The EPA recommends that engineering controls be implemented in homes with concentrations above this action level in order to reduce exposure to radon.

Figure 3 contains a summary of radon concentrations from granite countertops estimated for a typical home in comparison to: outdoor levels, the average level in U.S. homes, and the EPA action level. In a typical home, radon in indoor air associated with emissions from natural stone countertops having the average exhalation rate reported in the literature is estimated to be approximately 300 times below outdoor levels, 1,000 times less than the average concentration of radon inside U.S. homes, and 3,000 times lower than the action level for radon recommended by the EPA. When a lower air exchange rate is paired with the maximum emission rate, the indoor radon concentration is still 7 times lower than outdoors, 12 times lower than the average concentration in U.S. homes and 70 times lower than the EPA action level.

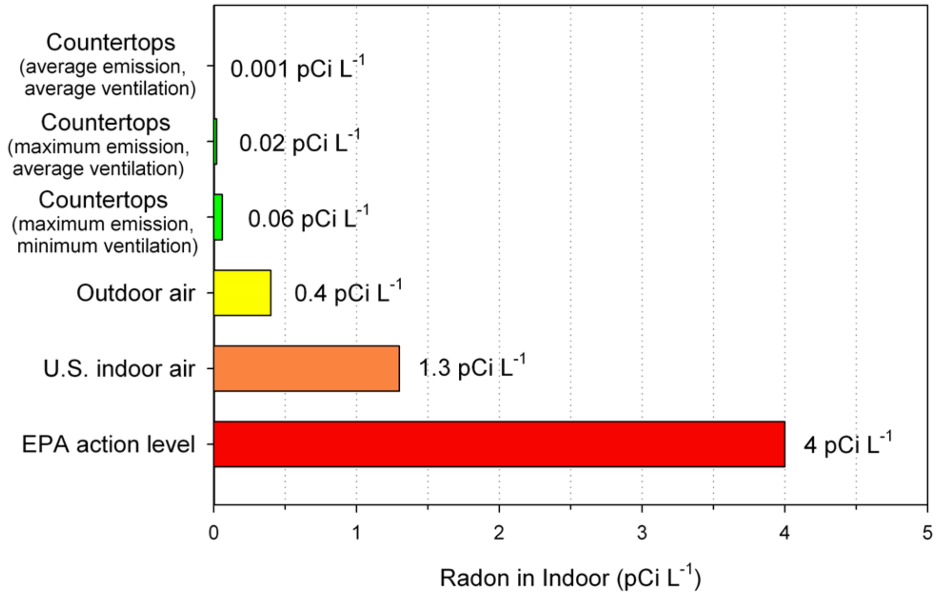


Figure 3 Comparison of radon in residential indoor air associated with natural stone countertops (using average and maximum emission rates) in comparison to background levels of radon in outdoor and indoor air, and the action level for radon in indoor air recommended by the U.S. Environmental Protection Agency.

END NOTES

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