A REPORT TO THE UTAH LEGISLATURE
NATURAL RESOURCES, AGRICULTURE, AND ENVIRONMENT INTERIM LEGISLATIVE COMMITTEE

ON

WAYS TO INCREASE PUBLIC AWARENESS ABOUT THE RISKS OF RADON GAS

AND

WAYS TO MITIGATE UTAH RESIDENTS' EXPOSURE TO RADON

AS REQUESTED BY
2021 GENERAL SESSION HOUSE BILL 45

August 22, 2022

by

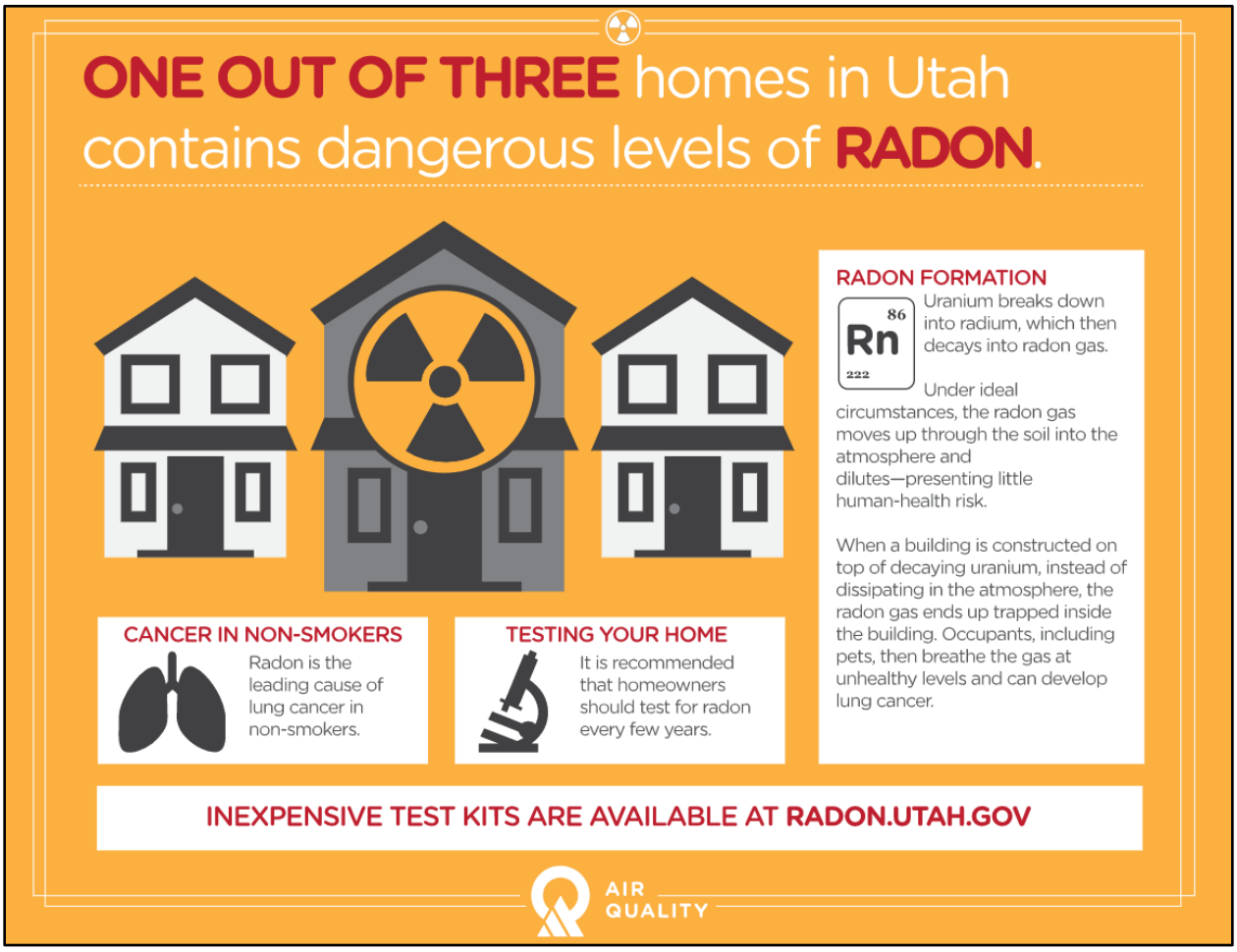
Dr. Steve D. Bowman[1], P.E., P.G, LEED AP, Jessica J. Castleton[1], M.S., P.G., and Eleanor Divver[2]
[1]Utah Geological Survey, Geologic Hazards Program
[2]Utah Department of Environmental Quality, Radon Program

EXECUTIVE SUMMARY

As requested by the 2021 Utah Legislature General Session House Bill 45, the Utah Department of Natural Resources, Utah Geological Survey (UGS), Geologic Hazards Program, in collaboration with the Utah Department of Environmental Quality (DEQ), Radon Program, has prepared this report for the Utah Legislature Natural Resources, Agriculture, and Environment Interim Committee on:

- ways to increase public awareness about the risks of radon gas, and
- ways to mitigate Utah residents' exposure to radon.

Radon is a radioactive gas that emanates from uranium-bearing rock and soil and may concentrate in enclosed spaces like buildings and basements. Radon is a major contributor to the ionizing radiation dose received by the general population and is the second leading cause of lung cancer after smoking. Since 1973, over 5,800 fatalities are estimated to have occurred in Utah from lung cancer caused by radon gas. One out of three homes in Utah test above the recommended Environmental Protection Agency (EPA) action level:



Source: Utah Department of Environmental Quality (https://deq.utah.gov/waste-management-and-radiation-control/testing-your-home-for-radon).

In response, the UGS and the DEQ Radon Program developed six recommendations to increase the public awareness of radon gas hazards and six recommendations to mitigate Utah residents' exposure to radon. The summarized recommendations are:

Increase Public Awareness of Radon Gas Hazards

- Require an approved radon gas hazard brochure (paper or digital) be provided to the buyer before the sale of residential property.
- Require approved radon testing be conducted prior to the sale of residential property.
- Request the Utah State Board of Education add a radon, radiation, and radioactivity section to the Utah Core Standards.
- Require radon testing for Utah schools, daycare and prison facilities, and public buildings.
- Require radon mitigation contractors and laboratories to forward test data to the DEQ/UGS.
- Consider requesting a radon hazard awareness booth and materials for preparedness and community fairs.

Mitigate Utah Residents' Exposure to Radon Gas

- Adopt statewide Appendix F of the International Residential Code and the Radon Resistant New Construction standard.
- Require approved radon testing be conducted prior to the sale of residential property.
- Develop a no to low interest loan program for radon mitigation in existing residences.
- Consider requesting that a modern, online radon gas test database be created and to distribute radon test data by U.S. Census block rather than ZIP code for better data useability.
- Request a study to determine natural, background levels of radon gas on a statewide level.
- Request a study to evaluate the current indoor radon gas action limit and its effectiveness.

INTRODUCTION

As requested by the 2021 Utah Legislature General Session House Bill 45, the Utah Department of Natural Resources, Utah Geological Survey (UGS), Geologic Hazards Program, in collaboration with the Utah Department of Environmental Quality (DEQ), Radon Program, has prepared this report for the Utah Legislature Natural Resources, Agriculture, and Environment Interim Committee on:

- ways to increase public awareness about the risks of radon gas, and
- ways to mitigate Utah residents' exposure to radon.

Radon is a radioactive gas that emanates from uranium-bearing rock and soil and may concentrate in enclosed spaces like underground mines, buildings, and basements. Radon is a major contributor to the ionizing radiation dose received by the general population and is the second leading cause of lung cancer after smoking (World Health Organization [WHO], 2009). Lung cancer risk increases proportionally with increasing radon exposure. However, most radon-induced lung cancers are caused by extended exposure to low and moderate radon concentrations, rather than by high radon concentrations, because fewer people are exposed to high indoor radon concentrations (WHO, 2009).

Between 1973 and 2017, an estimated 5,826 fatalities in Utah were attributable to lung cancer caused by radon gas (Utah Environmental Public Health Tracking Network, 2021 [table 1]; WHO, 2009). These deaths have an estimated total first-year treatment cost that range from $2.7 to $3.6 million (Sasha Zaharoff, Utah Department of Health, personal communication, 2015). Using the economic value of a statistical life of $11.8 million (2021 dollars; U.S. Department of Transportation, 2022), the 5,826 fatalities are valued at $68.7 trillion. Thousands of additional fatalities before 1973 undoubtedly occurred, making radon-induced lung cancer Utah's historically deadliest geologic hazard (Bowman, 2020). Uncertainty in radon occurrence and abundance cannot be reduced; therefore, predicting exactly when and where radon will be present in a potentially hazardous concentration is not possible. For that reason, developing property on or near radon-susceptible areas will always involve a level of irreducible, inherent risk. However, effective mitigation measures are available to significantly reduce the hazard.

Table 1. *Estimated fatalities from radon gas in Utah from 1973 to 2017.*

Year		Fatalities[1]
1973–2001	Estimated lung cancer deaths from radon gas.	1,460[2,3]
2002–2011		3,816[3]
2012		98[2,3]
2013		87[2,3]
2014		87[2,3]
2015		90[2,3]
2016		93[2,3]
2017		95[2,3]
Total:		**5,826**

[1] Limited data are available; exact number of fatalities is unknown.
[2] Based on a World Health Organization general estimate that 14% of lung cancer cases are attributable to radon gas, https://epht.health.utah.gov.
[3] Utah Department of Health, Utah Environmental Public Health Tracking Network, 2022, https://epht.health.utah.gov.

Geologic radon hazard evaluation can be done pre- and post-development. Incorporating radon-control measures in new construction is less costly and more effective than installing post-construction, radon-mitigation systems in buildings that develop dangerous levels of indoor radon (U.S. Environmental Protection Agency [EPA], 2001, 2003; WHO, 2009; Kansas State University, undated). A site-specific, predevelopment, radon-hazard investigation uses local geology and radon test data, where available, as a scientific basis to determine if uranium-bearing bedrock and/or soil (unconsolidated) deposits (radon source; also imported fill or mine waste in some instances) are present at a site. If a radon source is present, a potential exists for structures built on the site to develop dangerous levels of indoor radon (radon hazard).

Although the influence of site geology on radon hazard is significant (source and pathways for radon movement), the influence of non-geologic factors, such as occupant lifestyle; building design, construction, and maintenance; season; and weather are also important and can cause indoor radon levels to fluctuate greatly over a period of hours to months in structures built on the same geologic unit (figure 1). Many of these factors, such as occupant lifestyle, can lead to radon test results that are artificially low, understating the hazard.

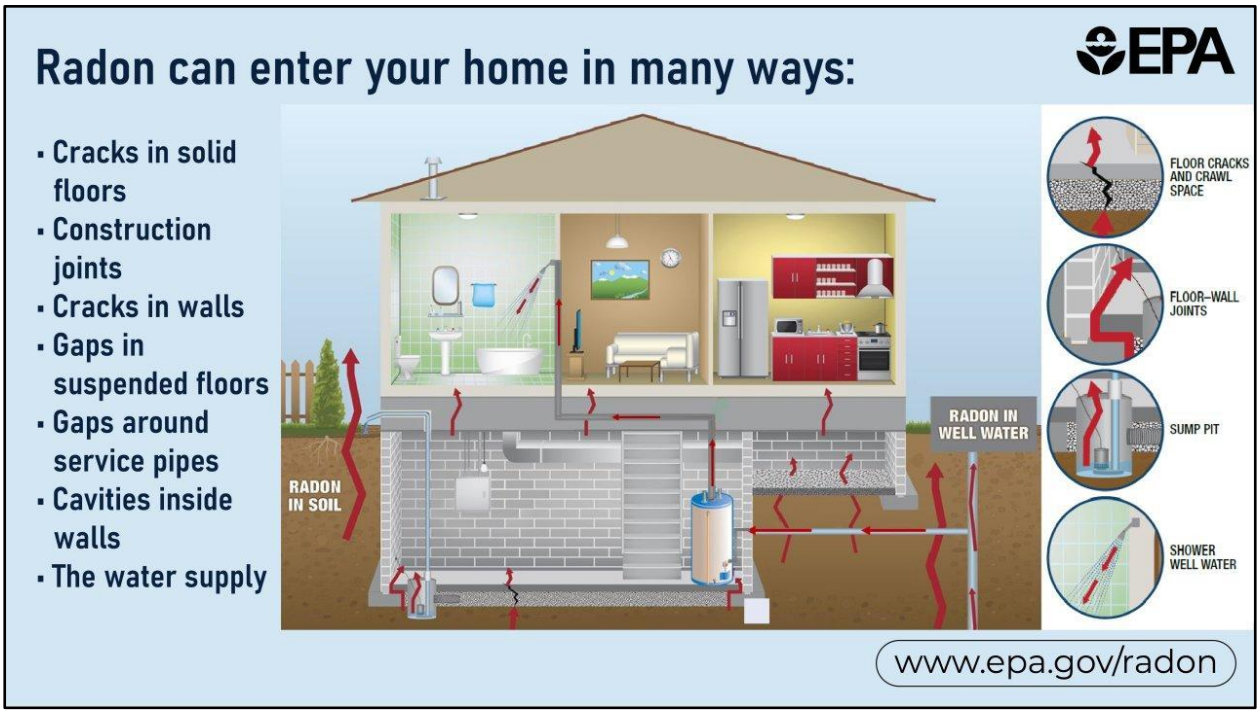


Figure 1. *Radon can enter a home through many paths. Homes built on the same geologic unit may have different levels of indoor radon due to multiple factors. Source: https://www.epa.gov/radon/radon-media-resources-partners-and-stakeholders.*

Indoor radon measurements have shown that some buildings constructed on uranium-bearing geologic units can have low indoor radon levels, whereas other buildings constructed on uranium-poor geologic units can have high indoor radon levels (Otton, 1992; Solomon and others, 1993; EPA, 2017). Varley and Flowers (1998) found only a very weak correlation between the overall radon concentration in soil gas and indoor radon levels. Therefore, site geology alone is not a direct predictor of future indoor radon levels or individual radon exposure (Utah Department of Health, 2015). However, Varley and Flowers (1998) did observe a stronger correlation with indoor radon levels at sites having high radon soil gas concentrations, indicating that site geology is a useful general predictor of future radon hazard.

Background

Radon is an odorless, tasteless, colorless radioactive gas that is naturally occurring and results from the radioactive decay of uranium, which is found in small concentrations in nearly all soil and rock. However, certain soils and rocks contain significant concentrations of uranium, resulting in high radon gas emissions. Radon has been classified as a known human carcinogen and has been recognized as a significant health problem by groups such as the American Lung Association, the American Medical Association, the American Public Health Association, and the U.S. Centers for Disease Control (EPA, 2003). The EPA (2017) estimated that radon is responsible for about 21,000 lung cancer deaths every year in the United States. About 2,900 of these deaths (14.5%) occur among people who have never smoked. Cao and others (2017) revised the EPA estimate to 15,600–19,300 radon-induced lung cancer deaths annually in the U.S, based on data from underground miners also exposed to diesel engine exhaust.

Since even a single alpha particle can cause major genetic damage to a cell, radon-related DNA damage can occur at any level of radon exposure. Therefore, there is no threshold concentration below which radon does not have the potential to cause lung cancer (WHO, 2009). Current estimates of the proportion of lung cancers attributable to radon range from 3% to 14%, depending on the average radon concentration in the country concerned and the calculation methods; the analyses indicate that the lung cancer risk increases proportionally with increasing radon exposure (WHO, 2009; Kim and others, 2016). Radon is much more likely to cause lung cancer in people who smoke, or who have smoked in the past, than in lifelong non-smokers; however, radon is the primary cause of lung cancer among people who have never smoked.

Although outdoor radon concentrations rarely reach dangerous levels because air movement and open space dissipate the gas, radon is highly mobile and can enter buildings through foundation cracks and other openings, such as around utility pipes. Indoor radon concentrations may easily reach hazardous levels. Radon gas concentrations are commonly measured in the United States in picocuries per liter (pCi/L) or elsewhere in Becquerels per cubic meter (Bq/m^3). The EPA (2017) recommends action to reduce indoor radon levels that are greater than 4 pCi/L and cautions that indoor radon levels less than or equal to 4 pCi/L may still pose a risk of lung cancer. In terms of quantifying the radon level:

> *A house having 4 picocuries of radon per liter of air (4 pCi/L) has about 8 or 9 atoms of radon decaying every minute in every liter* [about 1.1 quart] *of air inside the house. A 1,000 square foot house with 4 pCi/L of radon has nearly 2 million atoms decaying in it every minute (State of Michigan, 2021).*

However, WHO (2009) recommends that action be taken at levels greater than or equal to 100 Bq/m^3 or greater than or equal to 2.7 pCi/L, based on 13 European case-controlled studies of more than 14,000 participants that showed a very significant 8% and 16% increase in lung cancer per 2.7 pCi/L radon concentration increase, based on measured and long-term average radon concentrations, respectively. In addition, WHO (2009) analysis of seven North American and two Chinese case-controlled studies found an 11% and 13% increase in lung cancer per 2.7 pCi/L radon concentration increase, based on measured and long-term average radon concentrations, respectively. Based on these 22 case-controlled studies of 21,169 participants, WHO (2009) found a 10% weighted average increase in lung cancer per 2.7 pCi/L radon concentration increase, based on measured radon concentrations. WHO (2009) also estimated a 20% increase in lung cancer per 2.7 pCi/L radon concentration increase, based on European long-term average radon concentrations, as long-term data were not available for the North American or Chinese studies.

The EPA 4 pCi/L indoor radon gas action guidance is based on outdated information from the 1980s and 1990s as stated in their own documents (EPA, 1992):

> *When EPA and HHS* [U.S. Department of Health & Human Services] *issued the 1986 Citizen's Guide* [to Radon]*, there was less information on indoor radon than is available now* [1992]. *The recommendations in 1986 were based primarily on limited experience with homes whose indoor air had been contaminated with radon from uranium mill tailings. Research in these homes showed that most could be mitigated consistently to an average indoor radon level of 4 picocuries per liter (pCi/L).* Based on this technology limitation and the limited mitigation data available at that time, the EPA established 4 pCi/L as the action level at which people should fix their homes. However, the radon action limit was never revised afterward as more data and mitigation methods became available, leaving millions of Americans at risk from radon gas (figure 2).

Radon Risk If You Have Never Smoked

Radon Level	If 1,000 people who never smoked were exposed to this level over a lifetime*...	The risk of cancer from radon exposure compares to**...	WHAT TO DO:
20 pCi/L	About 36 people could get lung cancer	35 times the risk of drowning	Fix your home
10 pCi/L	About 18 people could get lung cancer	20 times the risk of dying in a home fire	Fix your home
8 pCi/L	About 15 people could get lung cancer	4 times the risk of dying in a fall	Fix your home
4 pCi/L	About 7 people could get lung cancer	The risk of dying in a car crash	Fix your home
2 pCi/L	About 4 person could get lung cancer	The risk of dying from poison	Consider fixing between 2 and 4 pCi/L
1.3 pCi/L	About 2 people could get lung cancer	(Average indoor radon level)	(Reducing radon levels below 2 pCi/L is difficult.)
0.4 pCi/L		(Average outdoor radon level)	

Note: If you are a former smoker, your risk may be higher.
* Lifetime risk of lung cancer deaths from EPA Assessment of Risks from Radon in Homes (EPA 402-R-03-003).
** Comparison data calculated using the Centers for Disease Control and Prevention's 1999-2001 National Center for Injury Prevention and Control Reports.

Figure 2. *Radon risk if you've never smoked. Source: EPA, https://www.epa.gov/radon/health-risk-radon#never.*

Current radon mitigation methods can consistently reduce average indoor radon levels to less than 2.7 pCi/L. As there is no known threshold concentration below which radon exposure presents no risk (WHO, 2009), radon mitigation should be seriously considered whenever radon is detected or where there is a potential geologic source of radon. As a result of these factors, the UGS strongly recommends that radon mitigation be performed where indoor radon levels are greater than or equal to 2.7 pCi/L.

Geology of Radon

Radon gas is by far the most important natural source of ionizing radiation. Radon (^{222}Rn) is a noble gas formed from radium (^{226}Ra), which is a decay product of uranium (^{238}U) (Sprinkel and Solomon, 1990; Otton, 1992; WHO, 2009). Radon gas, which has a half-life of 3.8 days, emanates from uranium-bearing bedrock and soils. Therefore, it is possible to estimate the potential for elevated indoor radon levels based on the uranium content of the geologic deposits at a site (EPA, 2017). Most soil and rock contain small amounts of uranium (1–3 ppm [parts per million]). Granitic rocks, metamorphic rocks, some light-colored volcanic rocks, black shale, and soils derived from those rock types are often associated with elevated uranium content (as much as 100 ppm; Otton, 1992). The higher the uranium content, the greater the probability that buildings built on a site will develop elevated indoor radon levels.

The permeability of site geologic units and the presence of groundwater affect the mobility of radon from its source (Otton, 1992). If a radon source is present, the ability of radon to move upward into structures is facilitated by high-permeability soils (those composed primarily of sand, gravel, cobbles, and boulders). Conversely, radon movement is impeded where permeability is low (silt and clay). However, if the less-permeable deposits (silt and clay) are themselves derived from uranium-bearing bedrock, those deposits effectively are a radon source. In bedrock, faults, joints, and fractures, along with the rock's primary porosity and permeability, influence the rate of radon gas migration. If the source of radon is below the groundwater table and the overlying sediment is not derived from a uranium-bearing bedrock unit, saturation of soil by groundwater may inhibit radon gas movement by dissolving radon in the water, reducing its ability to migrate upward through the soil.

However, in areas where groundwater is used as a source of culinary water, radon may enter a building through its water system (Otton, 1992). Short transit times from source to user may not permit radon in groundwater to dissipate before entering a building, allowing radon to escape into indoor air as people take showers, wash dishes and clothes, or otherwise use water. Areas most likely to have high levels of radon in groundwater are typically areas that have high uranium concentrations in underlying geologic units (Otton, 1992). In Utah, groundwater has not been observed to inhibit the movement of radon gas because the source of the radon gas is typically not below the groundwater table but tends to be within or above it (Castleton and others, 2018b).

SOURCES OF UTAH RADON INFORMATION

The nearly 30-year-old, outdated, and broad-based EPA interactive radon zone map for Utah (figure 3) identifies seven Utah counties (Carbon, Duchesne, Grand, Piute, Sanpete, Sevier, and Uintah) as Radon Zone 1—counties with predicted average indoor radon screening levels greater than 4 pCi/L. All remaining Utah counties are identified as Radon Zone 2—counties with predicted average indoor radon screening levels from 2 to 4 pCi/L. No Utah counties are in Radon Zone 3—counties with predicted average indoor screening levels less than 2 pCi/L.

The explanation accompanying the 1993 EPA radon zone map states:

> *The purpose of this map is to assist national, state and local organizations to target their resources and to implement radon-resistant building codes. This map is not intended to be used to determine if a home in a given zone should be tested for radon. Homes with elevated levels of radon have been found in all three zones. All homes should be tested regardless of geographic location. The EPA recommends that this map be supplemented with any*

available local data in order to further understand and predict the radon potential for a specific area.

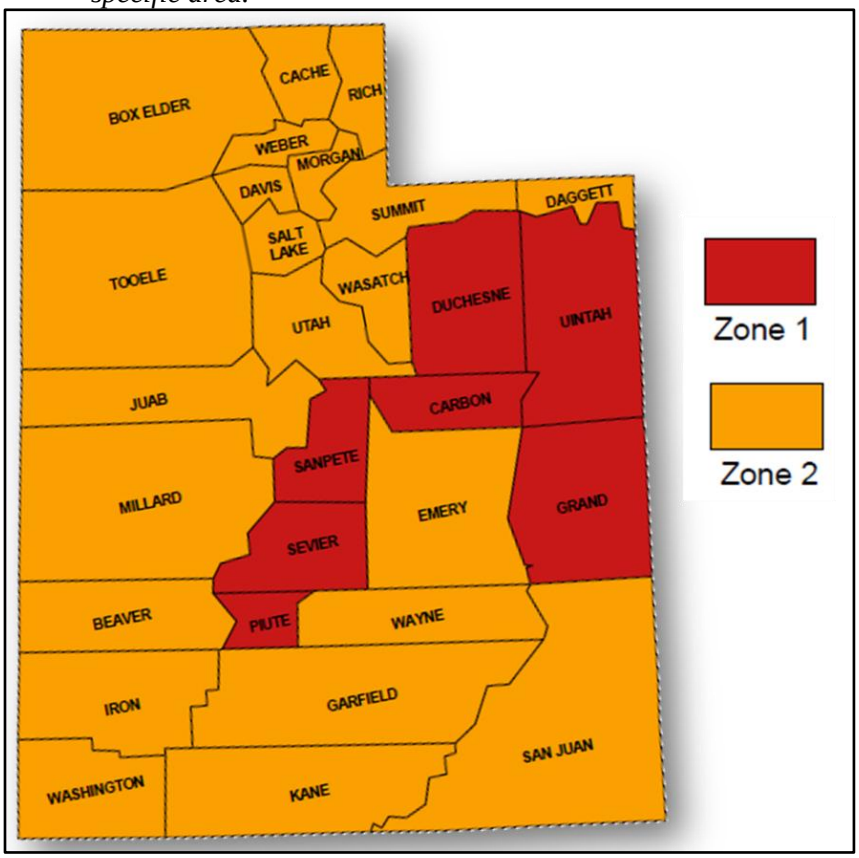


Figure 3. *EPA Utah radon zone map. Zone 1 indicates counties with predicted average indoor radon screening levels greater than 4 pCi/L and Zone 2 indicates counties with predicted average indoor radon screening levels from 2 to 4 pCi/L. Source: https://www.epa.gov/radon/epa-map-radon-zones-and-supplemental-information#region8.*

The 1993 EPA Map of Radon Zones (figure 4), covering the United States, shows Utah's radon hazard in relation to the rest of the country. This nearly 30-year-old map was based on limited indoor radon gas testing for radon hazard planning rather than determining if buildings in specific areas should be tested for radon gas. Radon gas hazard mapping using the available Utah DEQ radon testing data shows that the risk is significantly higher than the outdated EPA mapping (figure 5). This indicates that more testing, education, outreach, and mitigation are needed in Utah.

Radon mapping is completed at a regional scale, and it is possible that radon hazard can be significantly higher or lower when examined at a local scale, as is evident by indoor radon testing in existing structures. Local radon data for Utah are available from two principal sources: the DEQ Radon Program (https://deq.utah.gov/waste-management-and-radiation-control/radon/radon-program) and the UGS (https://geology.utah.gov).

County-level radon hazard mapping by the DEQ Radon Program and based on available indoor radon gas testing data indicate that 17, or 59%, of Utah's 29 counties have high indoor radon gas levels above 4 pCi/L and 5, or 17%, of Utah's counties have moderate indoor radon gas levels between 2 and 4 pCi/L. **Seven of Utah's counties (Daggett, Emery, Garfield, Kane, Piute, Rich, and Wayne) do not have enough indoor radon gas testing data to be mapped.**

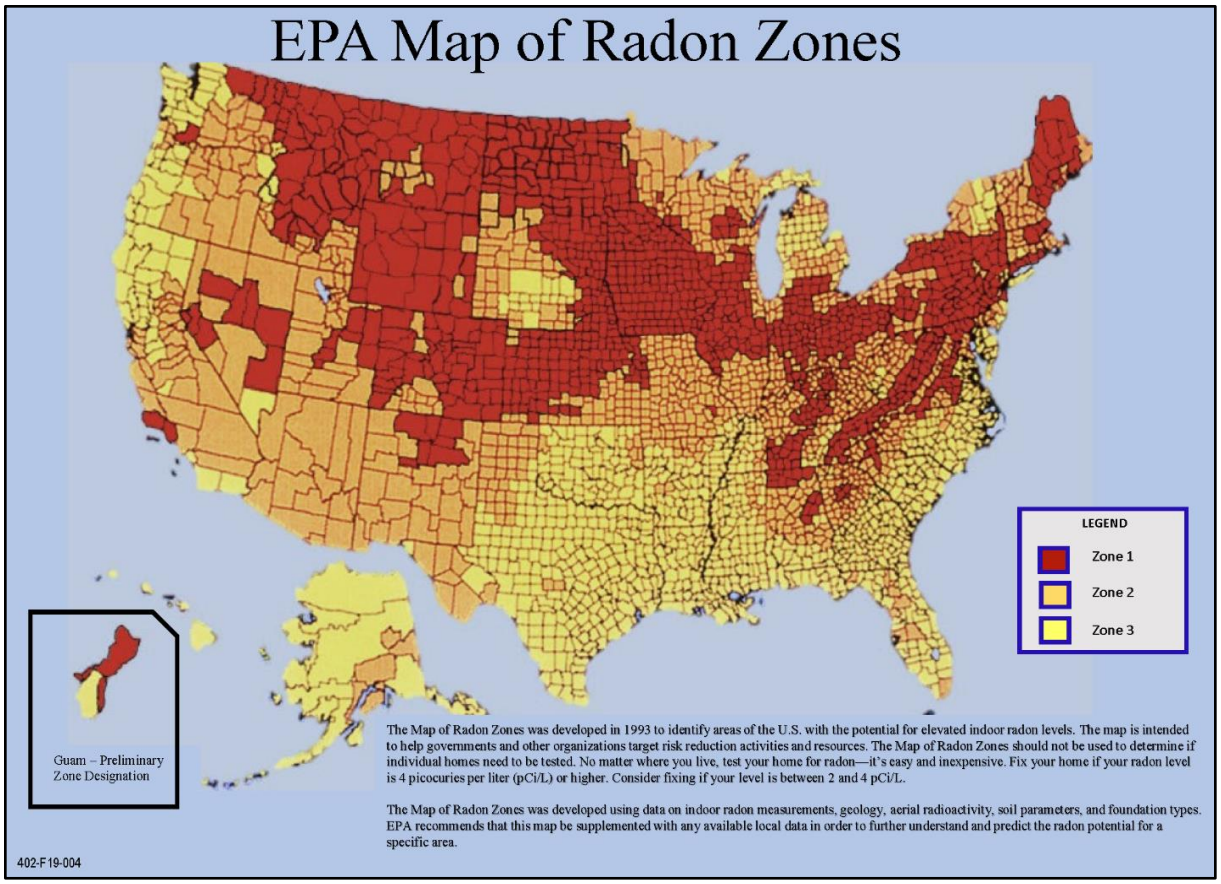


Figure 4. *1993 EPA Map of Radon Zones [for the United States]. Source: https://www.epa.gov/sites/default/files/2015-07/documents/zonemapcolor.pdf.*

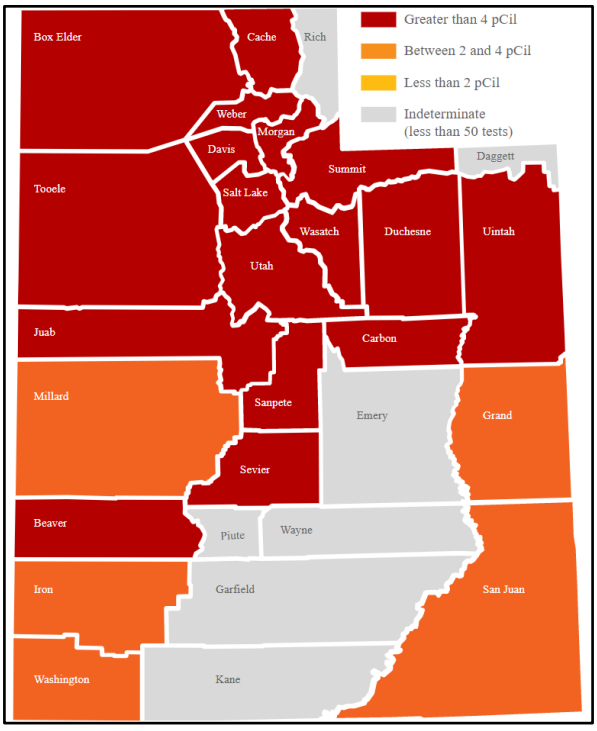


Figure 5. *Utah Department of Environmental Quality radon zone mapping based on current testing. Source: https://deq.utah.gov/waste-management-and-radiation-control/radon-silent-killer-lurks-in-one-out-of-three-utah-homes.*

Utah Department of Environmental Quality Radon Program

The DEQ has conducted a Radon Program for 30 years, increasing awareness of radon in Utah and working to decrease radon-induced lung cancer cases and deaths. The DEQ works with many partners, including homebuilders, medical professionals, real estate professionals, non-profit organizations, schools, tribal governments, and the like. Through the DEQ website, radon testing is easy and inexpensive (about $10.95). Reducing radon in Utah homes with certified radon mitigators has significantly improved the health and saved the lives of Utahns.

The DEQ website reports short-term, indoor radon test results by county and ZIP code and lists over 65,000 completed tests. The test results are binned into ranges and the results are totaled for each bin; the total number of tests and maximum and average test values are reported by ZIP code and by county. Individual test results at specific locations are not reported and not all ZIP codes have test result information. Average completed radon test levels (measured in pCi/L) and percent of completed radon tests greater than 4.0 pCi/L are available from the Utah Department of Health, Utah Environmental Public Health Tracking website (https://epht.health.utah.gov/epht-view/query/selection/radon/RadonSelection.html). In addition, the DEQ website includes numerous links to general information on the geology, chemistry, health effects, and mitigation of radon hazards.

Utah Geological Survey, Geologic Hazards Program

The UGS Geologic Hazards Program began investigating radon hazard in the late 1980s, and prepared a generalized, statewide map of potential radon-hazard areas, based chiefly on the location of uranium-bearing bedrock (Sprinkel, 1987). The DEQ Radon Program surveyed indoor radon levels in several potential radon-hazard areas identified on the map (Sprinkel and Solomon, 1990; Solomon and others, 1993a, 1993b). Clusters of indoor radon levels greater than 4 pCi/L were identified, and the UGS and DEQ Radon Program subsequently conducted detailed geologic field investigations and indoor radon surveys in those areas.

Results of the UGS investigations include maps of relative radon hazard. Black (1993) prepared a revised statewide radon-hazard map that includes both bedrock and soil (unconsolidated) geologic units associated with elevated radon levels. Most recently, the UGS has produced 7.5-minute quadrangle radon-hazard maps, either as part of comprehensive geologic-hazard map sets (Castleton and others, 2011, 2014, 2018a) or at the request of county health departments (Castleton and others, 2018b).

Currently available UGS radon-hazard investigations and maps include many of the most populous areas of Utah. These maps are available online in the UGS *Utah Geologic Hazards Portal* (https://geology.utah.gov/apps/hazards/), under the Problem Soil and Rock Hazards section, Geologic Radon Susceptibility layer.

Site-specific, predevelopment, radon-hazard investigations in a location that has an available UGS radon-hazard investigation and map can use those data to help determine appropriate mitigation measures. However, the investigations and maps do not include all potential radon-hazard areas in Utah. Site-specific, predevelopment, radon-hazard investigations are necessary where radon-hazard mapping is not available to determine if geologic, soils, and hydrologic conditions are conducive to producing a radon hazard.

RADON CONTROL

Pertaining to radon gas control to reduce the hazard from radon gas, the World Health Organization (2009) states:

> *Installing radon prevention measures in new structures for human occupancy is generally the most cost effective and efficient way to limit radon exposure in individual households. Over time, this approach will lead to a greater reduction in the total number of lung cancers attributed to radon exposure than the alternative method of only reducing radon in existing buildings that exceed the radon action level.*

Therefore, **the UGS recommends that a radon mitigation system be incorporated in all new construction as outlined in Appendix F of the International Code Council's *2018 International Residential Code* (ICC, 2018b) intended for human occupancy**, and for IBC Risk Category II, III, and IV facilities (ICC, 2018a) in areas mapped by the UGS at a scale of 1:24,000, as having moderate or high radon hazard, or in areas lacking radon-hazard maps, where a site-specific, predevelopment, geologic investigation determined that a radon source is present at a site. In areas mapped by the UGS, at a 1:24,000 scale, as having a low radon hazard, the UGS recommends that consideration be given to incorporating a radon-control system in all new construction as above. Depending on the location, these mitigation systems can be as simple as a passive vapor barrier below the building floor or basement concrete slab.

Appendix F (ICC, 2018b) addresses radon-resistant new construction techniques. Though not currently adopted in Utah Code, adopting Appendix F would significantly help reduce the hazard and risk from radon gas, Utah's most deadly geologic hazard, by sealing foundations and venting the building foundation subgrade soils, allowing the upward-flowing radon gas to be dissipated into the air above the building. Typical costs for adopting radon-resistant construction measures are around $500 for a new residential home. Active radon mitigation systems installed in existing structures typically range from $1,200 to $1,700.

The AARST *Rough-In of Radon Control Components in New Construction of One- and Two-Family Dwellings and Townhomes* (https://standards.aarst.org/RRNC-2020/4/index.html) standard, along with EPA Publication EPA/402-K-01-002 (2001), *Building Radon Out – A Step by Step Guide on How to Build Radon Resistant Homes*, provides specific guidance on how to incorporate radon-prevention systems in new construction. The EPA Publication 402-95-012 (1995), *Passive Radon Control System for New Construction*, provides architectural drawings (CAD format) intended for architects, home builders, designers, radon mitigators, and others interested in the installation of passive radon control systems in one- and two-family dwellings.

RADON HAZARD RECOMMENDATIONS

Increase Public Awareness About the Risks of Radon Gas

- **Increase Homebuyers Awareness of Radon Gas Hazards**
    - Require real estate professionals, or the owner when for sale by owner, to provide prospective homebuyers with a state-approved, paper or digital brochure explaining the risk from radon gas and ways to mitigate the risk.

- Require an approved indoor radon gas test be conducted before the sale of residential property. If the results of the radon test are greater than or equal to 4 pCi/L, recommend that a radon mitigation system be installed by a Utah Licensed Radon Mitigation Contractor (S354 classification) to reduce the indoor radon gas level to less than 4 pCi/L before the closing of the residential property sale.

- **Increase Utah Student Awareness of Radon** – Request the Utah State Board of Education (USBE) add a section in the next version of the Utah Core Standards specifically dealing with natural/geologic hazards, including *Radon, Radiation, and Radioactivity and its Role in our World*. The Utah Geological Survey and the Utah Department of Environmental Quality can assist the USBE with natural and geologic hazard (including radon gas) information and other materials, including a teacher's kit with curriculum, Geiger counters, safe radiation sources, interactive assignments, curriculum, and digital presentations.

- **Test School and Daycare Facilities for Radon –** Require that every five years, Utah school and daycare facilities be tested as part of school inspections by local and/or state health departments. If radon levels are greater than 4 pCi/L, require investigating increasing the HVAC blower run time and/or installing a radon gas mitigation system.

- **Test Prison Facilities and Public Buildings for Radon –** Require that every five years, Utah prison facilities and public buildings be tested for radon. If radon levels are greater than 4 pCi/L, require investigating increasing the HVAC blower run time and/or installing a radon gas mitigation system.

- **Increase Public Access to Indoor Radon Gas Test Data** – Require all radon mitigation contractors and laboratories performing radon gas testing to forward a copy of the results and test location to the Utah Department of Environmental Quality/Utah Geological Survey for inclusion in a statewide online, public database of radon gas testing data.

- **Increase Public Awareness of Radon Gas Hazards** – Create a radon gas hazard awareness booth, along with materials to be used at various emergency preparedness, community fairs, and other public gatherings, along with the distribution of free radon gas test kits to Utah residents at these events. Additional funding will need to be through the Governor's Office of Planning and Budget and or the legislature.

Mitigate Utah Residents' Exposure to Radon

- **Reduce Utahns' Exposure to Indoor Radon Gas in New Construction**

  - Adopt statewide, Appendix F (Radon Control Methods) of the latest adopted International Residential Code (IRC) in the State Construction and Fire Codes Act. Appendix F requires passive or active radon mitigation systems, depending on the location and radon test data, be installed at time of construction.

  - Adopt statewide, the latest edition of the AARST *Rough-In of Radon Control Components in New Construction of One- and Two-Family Dwellings and Townhomes* (https://standards.aarst.org/RRNC-2020/4/index.html) in the State Construction and Fire Codes Act. The purpose of this standard is to provide minimum requirements for the rough-in of radon control mitigation components in new dwelling units under construction, making future radon mitigation less costly.

- **Reduce Utahns' Exposure to Indoor Radon Gas** – Require an approved indoor radon gas test be conducted before the sale of residential property. If the results of the radon test are greater than or equal to 4 pCi/L, recommend that a radon mitigation system be installed by a Utah Licensed Radon Mitigation Contractor (S354 classification) to reduce the indoor radon gas level to less than 4 pCi/L before the closing of the residential property sale. If results are between 2.7 and 4.0 pCi/L, seriously consider installing a mitigation system.

- **Reduce Utahns' Exposure to Indoor Radon Gas in Existing Residences**– Develop a no or low interest loan program for radon mitigation of existing residential property. Such a program could utilize the Utah State Tax Commission for payouts and payments via annual individual income tax filings for simplicity, Utah homeowner verification, and reduced overhead costs.

- **Increase Public Access to Indoor Radon Gas Test Data** – Create a new, online, public radon test database; collect and archive radon test data; and maintain the database. This database would distribute radon gas testing data by fixed U.S. Census block areas instead of U.S. Postal Service ZIP Codes, which can change boundaries, have new codes added, or have codes deleted, resulting in problems using the distributed data. Currently, the Utah Department of Environmental Quality (DEQ) radon test data are stored in an Excel spreadsheet. Additional funding will need to be sought through the Governor's Office of Planning and Budget and or the legislature.

- **Reduce Utahns' Exposure to Radon Gas** – Request the Utah Geological Survey to determine natural, background levels of radon across Utah, considering radon-gas-producing susceptible geologic units and their spatial distribution, and based on the best available science to improve the quality and accuracy of radon gas hazard mapping used for radon gas mitigation in new construction. Additional funding will need to be sought through the Governor's Office of Planning and Budget and or the legislature.

- **Reduce Utahns' Exposure to Indoor Radon Gas** – Request a study to evaluate the EPA's greater than or equal to 4.0 pCi/L radon gas action limit and provide recommendations on whether Utah should adopt a stricter radon gas action limit and the subsequent impact. Additional funding will need to be sought through the Governor's Office of Planning and Budget and or the legislature.

REFERENCES

Bishop, C.E., 1998, Radon-hazard potential of Beaver basin area, Beaver County, Utah: Utah Geological Survey Special Study 94, 39 p., 20 figures, approximate scales 1:178,600 and 1:2,777,800, https://ugspub.nr.utah.gov/publications/special_studies/SS-94.pdf.

Black, B.D., 1993, Radon-potential-hazard map of Utah: Utah Geological Survey Map 149, 1:1,000,000 scale, https://ugspub.nr.utah.gov/publications/hazards_maps/M-149.pdf.

Black, B.D., 1996a, Radon-hazard potential of western Salt Lake Valley, Salt Lake County, Utah: Utah Geological Survey Special Study 91, 27 p., 1 plate, scale 1:50,000, https://ugspub.nr.utah.gov/publications/special_studies/SS-91.pdf.

Black, B.D., 1996b, Radon-hazard potential in Tooele Valley, Tooele County, Utah: Utah Geological Survey Public Information Series 44, 2 p., 1 figure, approximate scale 1:126,700, https://ugspub.nr.utah.gov/publications/public_information/pi-44.pdf.

Black, B.D., 1996c, Radon-hazard potential in the lower Weber River area, Weber and Davis Counties, Utah: Utah Geological Survey Public Information Series 45, 2 p., 1 figure, approximate scale 1:71,400, https://ugspub.nr.utah.gov/publications/public_information/pi-45.pdf.

Bowman, S.D., 2020, Introduction, *in* Bowman, S.D., and Lund, W.R., editors, Guidelines for investigating geologic hazards and preparing engineering-geology reports, with a suggested approach to geologic-hazard ordinances in Utah, second edition: Utah Geological Survey Circular 128, p. 1–14, https://ugspub.nr.utah.gov/publications/circular/c-128.pdf.

Cao, X., MacNaughton, P., Laurent, J.C., and Allen, J.G., 2017, Radon-induced lung cancer deaths may be overestimated due to failure to account for cofounding by exposure to diesel engine exhaust in BEIR VI miner studies: PLOS ONE, https://doi.org/10.1371/journal.pone.0184298, September 8, 2017.

Castleton, J.J., Elliott, A.H., and McDonald, G.N., 2011, Geologic hazards of the Magna quadrangle, Salt Lake County, Utah: Utah Geological Survey Special Study 137, 73 p., 10 plates, scale 1:24,000, CD, https://ugspub.nr.utah.gov/publications/special_studies/SS-137/SS-137.pdf.

Castleton, J.J., Elliott, A.H., and McDonald, G.N., 2014, Geologic hazards of the Copperton quadrangle, Salt Lake County, Utah: Utah Geological Survey Special Study 152, 24 p., 10 plates, scale 1:24,000, CD, https://ugspub.nr.utah.gov/publications/special_studies/ss-152/ss-152.pdf.

Castleton, J.J., Erickson, B.A., and Kleber, E.J., 2018a, Geologic hazards of the Moab quadrangle, Grand County, Utah: Utah Geological Survey Special Study 162, 33 p., 13 pl., scale 1:24,000, https://ugspub.nr.utah.gov/publications/special_studies/ss-162/ss-162txt.pdf.

Castleton, J.J., Erickson, B.A., and Kleber, E.J., 2018b, Geologic radon hazard susceptibility map of eastern Davis County, Utah: Utah Geological Survey Open-File Report 655, 1 plate, scale 1:62,500, https://ugspub.nr.utah.gov/publications/open_file_reports/ofr-655.pdf.

Kansas State University, undated, New homes and radon mitigation (RNCC): National Radon Program Services, online https://sosradon.org/rrnc-Mitigation, accessed April 26, 2022.

Kim, Si-Heon, Hwang, Won Ju, Cho, Jeong-Sook, and Kang, Dae Ryong, 2016, Attributable risk of lung cancer deaths due to indoor radon exposure: Annals of Occupational and Environmental Medicine, v. 28, no. 8, https://aoemj.biomedcentral.com/track/pdf/10.1186/s40557-016-0093-4.pdf.

Otton, J.K., 1992, Geology of radon: U.S. Geological Survey, general interest publication, 29 p., https://pubs.usgs.gov/gip/7000018/report.pdf.

Solomon, B.J., 1993a, Radon-hazard potential in the Sandy-Draper area, Salt Lake County, Utah: Utah Geological Survey Public Information Series 18, 2 p., 1 figure, approximate scale 1:38,500, https://ugspub.nr.utah.gov/publications/public_information/PI-18.pdf.

Solomon, B.J., 1993b, Radon-hazard potential in the Provo-Orem area, Utah County, Utah: Utah Geological Survey Public Information Series 21, 2 p., 1 figure, approximate scale 1:33,300, https://ugspub.nr.utah.gov/publications/public_information/PI-21.pdf.

Solomon, B.J., 1995, Radon-hazard potential of the southern St. George basin, Washington County and Ogden Valley, Weber County, Utah: Utah Geological Survey Special Study 87, 42 p., 27 figures, approximate scales 1:100,000 and 1:112,400, https://ugspub.nr.utah.gov/publications/special_studies/SS-87.pdf.

Solomon, B.J., 1996a, Radon-hazard potential of the central Sevier Valley, Sevier County, Utah: Utah Geological Survey Special Study 89, 48 p., 31 figures, approximate scale 1:250,000, https://ugspub.nr.utah.gov/publications/special_studies/ss-89.pdf.

Solomon, B.J., 1996b, Radon-hazard potential in the St. George area, Washington County, Utah: Utah Geological Survey Public Information Series 35, 2 p., 1 figure, approximate scale 1:72,000, https://ugspub.nr.utah.gov/publications/public_information/pi-35.pdf.

Solomon, B.J., 1996c, Radon-hazard potential in Ogden Valley, Weber County, Utah: Utah Geological Survey Public Information Series 36, 2 p., 1 figure, approximate scale 1:83,300, https://ugspub.nr.utah.gov/publications/public_information/pi-36.pdf.

Solomon, B.J., 1996d, Radon-hazard potential in central Sevier Valley, Sevier County, Utah: Utah Geological Survey Public Information Series 47, 2 p., 1 figure, approximate scale 1:253,400, https://ugspub.nr.utah.gov/publications/public_information/pi-47.pdf.

Solomon, B.J., and Black, B.D., 1996, Radon-hazard potential in southeastern Cache Valley, Cache County, Utah: Utah Geological Survey Public Information Series 46, 2 p., 1 figure, approximate scale 1:57,500, https://ugspub.nr.utah.gov/publications/public_information/pi-46.pdf.

Sprinkel, D.A., 1987 (revised 1988), Potential radon hazard map: Utah Geological and Mineral Survey, Open-File Report 108, 4 p., scale 1:100,000, https://ugspub.nr.utah.gov/publications/open_file_reports/OFR-108.pdf.

Sprinkel, D.A., and Solomon, B.J., 1990, Radon hazards in Utah: Utah Geological and Mineral Survey, Circular 81, 24 p., https://ugspub.nr.utah.gov/publications/circular/C-81.pdf.

State of Michigan, Michigan Department of Environment, Great Lakes, and Energy, 2021, Frequently asked questions about radon: Online, https://www.michigan.gov/egle/0,9429,7-135-3312_4120_4196-10451--,00.html#What%20is%20a%20picocurie, accessed July 21, 2021.

U.S. Department of Transportation, 2021, Departmental guidance on valuation of a statistical life in economic analysis: U.S. Department of Transportation, Online, https://www.transportation.gov/office-policy/transportation-policy/revised-departmental-guidance-on-valuation-of-a-statistical-life-in-economic-analysis, accessed May 13, 2022.

U.S. Environmental Protection Agency, 1992, Technical support document for the 1992 Citizen's Guide to Radon: U.S. Environmental Protection Agency, Office of Radiation Programs, Radon Division Publication EPA 400-R-92-011, variously paginated, https://nepis.epa.gov/Exe/ZyPDF.cgi/000001L3.PDF?Dockey=000001L3.PDF.

U.S. Environmental Protection Agency, 2003, U.S. Environmental Protection Agency assessment of risks from radon in homes: EPA 402-R-03-003, 98 p., https://www.epa.gov/sites/production/files/2015-05/documents/402-r-03-003.pdf.

U.S. Environmental Protection Agency, 2017, Building a new home? Have you considered radon? Radon entry: Online https://www.epa.gov/radon/building-new-home-have-you-considered-radon, accessed May 4, 2022.

Utah Department of Health, 2015, Radon in Utah: Online, http://www.health.utah.gov/enviroepi/healthyhomes/epht/Radon_in_Utah.pdf, accessed May 4, 2022.

Utah Department of Health, 2021, Utah Environmental Public Health Tracking Network: Online, https://epht.health.utah.gov/epht-view/, accessed July 22, 2021.

Varley, N.R, and Flowers, A.G., 1998, Indoor radon prediction from soil gas measurements: Health Physics, v. 74, no. 6, p. 714–718, https://www.researchgate.net/publication/13684488_Indoor_Radon_Prediction_from_Soil_Gas_Measurements.

World Health Organization, 2009, WHO handbook on indoor radon — A public health perspective: Geneva, Switzerland, WHO Press, 94 p., https://www.who.int/publications/i/item/9789241547673.