5.11 Radon Exposure

2023 SHMP Update Changes

- The 2023 State Hazard Mitigation Plan (SHMP) risk assessment was expanded to include this hazard. The hazard profile has been created to describe the hazard, location, extent, previous occurrences, and probability of future occurrence (including how future conditions may impact the hazard). Figures from federal and State of West Virginia (the State) agencies are incorporated.

5.11.1 Hazard Profile

The following section provides the hazard profile (hazard description, location, extent, previous occurrences and losses, probability of future occurrences, and projected future conditions) and vulnerability assessment for the radon exposure hazard in West Virginia.

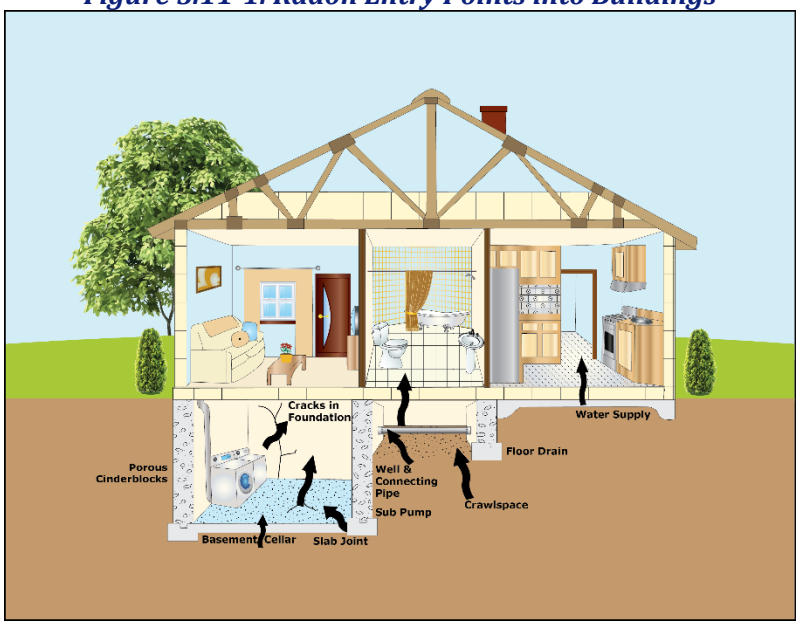
Hazard Description

Radon is a natural gas that cannot be seen, smelled, or tasted. It is a noble gas that originates from natural radioactive decay of uranium and thorium. It is a large component of the natural radiation to which humans are exposed and can pose a serious threat to public health when it accumulates in poorly ventilated residential and occupation settings. According to the U.S. Environmental Protection Agency (U.S. EPA), radon is estimated to cause more than 20,000 lung cancer deaths per year, second only to smoking as the leading cause of lung cancer (U.S. EPA 2022). West Virginia is ranked as the 31st state with the highest radon levels, with an estimated 29% of homes having a high level of radon (American Lung Association n.d.).

The distribution of radon correlates with the distribution of radium, its immediate radioactive parent, and with uranium, its original ancestor. Because of the short half-life of radon, the distance radon atoms travel from their parent before they decay is generally limited to feet or tens of feet. Radon can enter a building in several ways, as described below and shown in Figure 5.11-1 (U.S. EPA 2023):

- Radon in soil air flows into the building in the following ways: cracks in solid floors and walls, construction joints, gaps in suspended floors, gaps around service pipes, and cavities inside walls

Figure 5.11-1. Radon Entry Points into Buildings



Sources: U.S. EPA 2023

- Radon dissolved in water from private wells and exsolved during water usage
- Radon emanating from uranium-rich building materials (such as concrete blocks or gypsum wallboard)

LOCATION

Radon is detected across the entire United States, with some states experiencing higher levels than others. It is found in the atmosphere in trace amounts; however, it can enter buildings through cracks and holes in foundations (U.S. EPA 2022). The U.S. EPA developed a map of radon zones to identify areas in the United States that have the potential for elevated indoor radon levels. The map was developed using data on indoor radon measurements, geology, aerial radioactivity, soil parameters, and foundation types and uses three zones to show potential risk (U.S. EPA 2022). The three zones are described in Table 5.11-1.

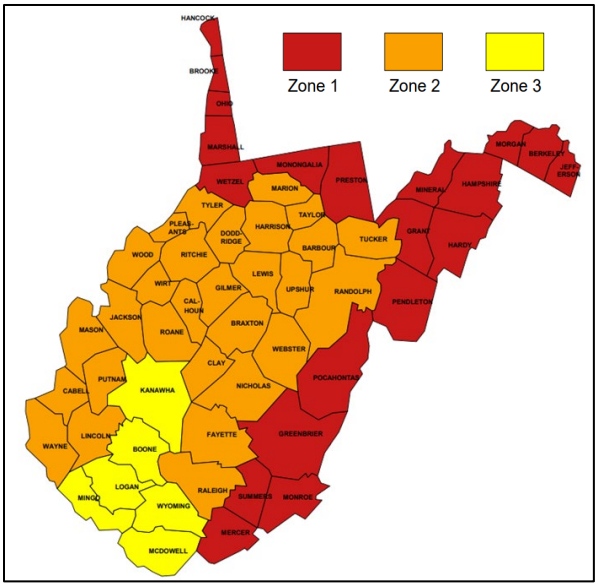
Table 5.11-1. Radon Zones

Zone	Description
Zone 1 (red zone)	Highest potential for elevated indoor radon levels; average indoor radon levels may be greater than 4 pCi/L (picocuries per liter)
Zone 2 (orange zone)	Moderate potential; average indoor radon levels may be between 2 and 4 pCi/L
Zone 3 (yellow zone)	Low potential; average indoor radon levels may be less than 2 pCi/L

Source: U.S. EPA 2014

Figure 5.11-2 illustrates the radon zones for West Virginia. A majority of the State is located in Zone 2, having moderate potential for elevated indoor radon levels. The northern and eastern portions of the State are shown as Zone 1, having the highest potential for elevated indoor radon levels. A small portion of the State is shown as Zone 3, having low potential for elevated indoor radon levels.

Figure 5.11-2. U.S. EPA Radon Zones in West Virginia



Source: U.S. EPA 2014

EXTENT

Radon levels are measured in units called picocurie per liter or pCi/L. A pCi/L is a unit of radioactivity corresponding to one decay every 27 seconds in a volume of one liter, or 0.037 decays per second in every liter of air (U.S. EPA 2012). The average radon concentration in the indoor air in homes in the United States is about 1.3 pCi/L (U.S. EPA 2022). The U.S. EPA recommends that homes be repaired if the radon level is 4 pCi/L or more. However, the U.S. EPA also recommends that Americans consider fixing their home if radon levels are between 2 and 4 pCi/L because there is no known safe level of exposure to radon.

The worst-case scenario for radon exposure would be caused by a large area of tightly sealed homes inducing high levels of exposure to residents over a prolonged period of time without awareness of this by the residents. The most likely scenario is a single household exposed to a very low concentration of radon with no adverse health effects.

Exposure can cause lung cancer. Lung cancer is the only known effect on human health from exposure to radon in air, and thus far, no evidence indicates that children are at greater risk of lung cancer than adults (U.S. EPA 2016). The main hazard is actually from the radon daughter products (polonium-218, lead-214, bismuth-214), which may become attached to lung tissue and induce lung cancer by their radioactive decay (U.S. EPA 2022). Table 5.11-2 lists (1) cancer risks from exposure to radon at various levels for smokers and non-smokers, (2) lung cancer risks from radon exposure compared to cancer risks from other hazards for smokers and non-smokers, and (3) action thresholds.

Table 5.11-2. Radon Risk for Smokers and Non-Smokers

Radon Level (picoCuries per liter [pCi/L])	Cancer Rate per 1,000 People with Lifetime Exposure	Comparative Cancer Risk of Radon Exposure	ACTION THRESHOLD
SMOKERS			
20	About 260 people could develop lung cancer	250 times the risk of drowning	Fix structure
10	About 150 people could develop lung cancer	200 times the risk of dying in a home fire	
8	About 120 people could develop lung cancer	30 times the risk of dying in a fall	
4	About 62 people could develop lung cancer	5 times the risk of dying in a car crash	
2	About 32 people could develop lung cancer	6 times the risk of dying from poison	Consider fixing structure between 2 and 4 pCi/L
1.3	About 20 people could develop lung cancer	(Average indoor radon level)	Reducing radon levels below 2 pCi/L is difficult
0.4	About 3 people could develop lung cancer	(Average outdoor radon level)	
NON-SMOKERS			
20	About 36 people could develop lung cancer	35 times the risk of drowning	Fix structure
10	About 18 people could develop lung cancer	20 times the risk of dying in a home fire	
8	About 15 people could develop lung cancer	4 times the risk of dying in a fall	
4	About 7 people could develop lung cancer	The risk of dying in a car crash	
2	About 4 people could develop lung cancer	The risk of dying from poison	Consider fixing structure between 2 and 4 pCi/L

Radon Level (picoCuries per liter [pCi/L])	Cancer Rate per 1,000 People with Lifetime Exposure	Comparative Cancer Risk of Radon Exposure	ACTION THRESHOLD
1.3	About 2 people could develop lung cancer	(Average indoor radon level)	Reducing radon levels below 2pCi/L is difficult
0.4	-	(Average outdoor radon level)	

Source: U.S. EPA 2022
Note: Risk may be lower for former smokers.
** 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.*

Warning Time

Due to the way radon is formed, there is no set warning time. However, it is recommended that homes are tested for radon, and actions are taken if the radon level is 4 pCi/L or higher. Living spaces below the third floor should be tested. New construction should be tested prior to permitting occupancy.

Previous Occurrences and Losses

The West Virginia Department of Health and Human Resources administers the State's radon program, which is responsible for radon testing reports and mitigation notifications. Radon testers and mitigation specialists within the State are required to report radon test results to the program's director on a monthly basis. However, this information is not available through an open source.

Federal Emergency Management Agency (FEMA) Disaster Declarations

There have been no disaster declarations as a result of radon exposure.

U.S. Department of Agriculture (USDA) Disaster Declarations

There have been no USDA disaster declarations as a result of radon exposure.

Previous Events

High radon levels can be present anywhere, but certain areas have a higher chance of falling into radon-heavy zones. Previous high radon occurrences can help predict that locations in proximity could also have concerning radon levels present. These previous radon measurements are organized by county, which classifies counties into radon zones.

A 2008–2017 study conducted by the American Lung Association provides additional insight on the previous occurrences of radon within the State. The highest average radon concentration was found in Morgan County, with an estimated mean radon level of 13.4 pCi/L; Fayette County had the lowest concentration with a mean radon level of 0.8 pCi/L (American Lung Association 2022).

Probability of Future Hazard Events

Overall Probability

Radon exposure is inevitable and may be exacerbated by other factors. Radon concentration in soil gas depends on a number of soil properties, the importance of which are still being evaluated. The radon content of soil gas clearly tends to be higher in soils containing higher levels of radium and uranium, especially if the radium occupies a site on or near the surface of a grain of soil from which the radon can easily escape. The amount of pore space

in the soil and its permeability for airflow, including cracks and channels, are important factors determining radon concentration in soil gas and its rate of flow into a building. Soil depth and moisture content, mineral host and form for radium, and other soil properties may also be important.

Projected Future Conditions

Projected future conditions may create conditions that result in higher levels of radon being released into the atmosphere and water supplies. Variances in rainfall events may result in more high-intensity events, which may increase landslide frequency and result in releases of radon gases that were stored below the ground surface. While precipitation has been variable in West Virginia, winter and spring precipitation amounts are projected to increase (NOAA 2022). These rains have potential to create torrential floods, landslides, and mudslides, particularly in the mountainous regions of the State. As projected future conditions drive rain events to greater extremes, the risk of landslide increases as well.

Warming temperatures globally will melt permafrost, releasing more radon gas into the atmosphere. Within West Virginia, temperatures have risen 1°F since the beginning of the 20th century (NOAA 2022). Increased reliance on air conditioning and fans due to warmer temperatures, leads to decreased air exchange rates in tightly sealed homes, increased radon concentrations on upper floors where residents spend greater amounts of time, and higher radon concentration and exposure (Duke University 2023).

5.11.2 Vulnerability Assessment

To understand risk, a community must evaluate what assets are exposed and vulnerable in the identified hazard area. For radon exposure, the entirety of West Virginia has been identified as a potential hazard area. Therefore, all assets in the State (population, structures, critical facilities, and lifelines), as described in the State Profile, are vulnerable. The impacts on State assets, critical facilities and community lifelines, population, and socially vulnerable population is discussed below.

State Assets

All State assets are exposed to radon. This includes 1,117 State assets and all 185 critical facilities and community lifelines. The vulnerability to these assets from radon exposure is considered low; however, assets located in Zone 3 are more at risk for radon exposure.

Critical Facilities and Community Lifelines

While the entire general building stock and critical facility inventory in the State is exposed to the risk of radon, radon does not result in direct damage to structures and facilities. Critical facilities or lifelines with elevated radon levels will require remediation systems to be installed such as installing a gas permeable layer for new construction, sealing cracks or installing a vapor retarder for existing structures, installing vent pipes, and installing vent fans (U.S. EPA 2022).

Population

For the purposes of this assessment, the entire population of West Virginia (1,807,426) is exposed; however, populations living in Zone 3 have a higher probability of being exposed to elevated radon levels in their homes.

Exposure to radon is the second-leading cause of lung cancer after smoking and the leading cause of lung cancer among non-smokers. As stated earlier, radon is responsible for more than 20,000 lung cancer deaths every year. Lung cancer is the only known effect on human health from exposure to radon in air, and thus far, no evidence indicates that children are at greater risk of lung cancer than adults (U.S. EPA 2013).

Table 5.11-2 details additional cancer risks from radon exposure. The main hazard is from the radon daughter products (polonium-218, lead-214, and bismuth-214), which may become attached to lung tissue and induce lung cancer by their radioactive decay. (U.S. EPA 2022).

Impacts on Socially Vulnerable Populations

Radon exposure may have disproportionate impacts on socially vulnerable populations. Those residents facing economic hardships may not be able to afford to professional radon testing or subsequent mitigative measures. The concentration of individuals living within group quarters increases the number of individuals that may be exposed to radon gas within that building. Individuals experiencing homelessness may unknowingly take shelter in buildings with poor ventilation risking radon exposure.

Additionally, individuals who smoke and experience unsafe radon exposure are more at risk of lung cancer than those who do not smoke and experience unsafe radon exposure. The population over the age of 65 (19.9%) and under the age of 5 (5.2%) are more vulnerable to radon exposure due to their weakened immune systems.

Future Changes That May Impact State Vulnerability

Understanding future changes that impact vulnerability in the State can assist in planning for future development and ensuring that appropriate mitigation, planning, and preparedness measures are in place. The State considered the following factors to examine potential conditions that may affect hazard vulnerability:

- Potential or projected development
- Projected changes in population
- Other identified conditions as relevant and appropriate, including the impacts of future conditions

Potential or Projected Development

Although West Virginia has not experienced significant growth, any areas of growth could be impacted by the radon exposure because the entire planning area is exposed and vulnerable. However, due to increased standards and codes, new development may be less vulnerable to the hazard, while aging infrastructure will become increasingly vulnerable. Implementing risk reduction measures can be incorporated during new construction, which will be more effective than retrofitting an existing structure.

Projected Changes in Population

As population in the State continues to decrease, there is the potential that fewer people will reside or work within the State's radon exposure area. Increased abandoned properties will become increasingly at risk for radon exposure and may affect the homeless population, as previously stated. Additionally, as the population in the State ages (19.9% of the population is currently 65 years of age or older, and that number is expected to increase) more residents may face challenges health challenges related to radon exposure.

Other Factors of Change

Although future conditions may lead to scenarios that result in more radon being released, the projected decrease in population and subsequently development within the State means there will not be a higher number of people exposed to the hazard.

5.11.3 Consequence Analysis

Impacts to the Public

For the purposes of this plan, the entire population of the county is assumed to the risk of radon exposure. As discussed previously, lung cancer is a known health risk due to radon exposure. Lung cancer from radon may lead to loss of life and increased health care costs. Individual households may incur costs due to taking mitigation measures to eliminate potential entry points for radon in their homes.

Impacts to Responders

Radon does not pose an immediate risk to emergency responders. However, emergency responders may still be exposed to radon in places where they spend long periods of time, such as their homes or places of work.

Impacts to Continuity of Operations

Discovering dangerous radon exposure can shut down buildings from being used, which affects day-to-day lives of people who depend on that building for shelter, work, etc. This could also slow down or halt supply chains that are reliant on the businesses located within these structures. Radon-exposed schools may prevent children from attending school in person, which may limit a child's social skill knowledge. Any business that is shut down would require people who are reliant on it for goods and services to travel to neighboring towns to be able to continue their day-to-day operations.

Impacts to Property, Facilities, and Infrastructure

According to the U.S. EPA, the average radon concentration in the indoor air of homes in the United States is about 1.3 pCi/L. The U.S. EPA recommends that homes implement mitigation measures if the radon level is 4 pCi/L or more. However, the U.S. EPA also recommends that residents consider repairing or renovating their homes if radon levels are between 2 and 4 pCi/L because there is no known safe level of exposure to radon (U.S. EPA 2022).

Impacts to the Environment

Radon typically does not cause harm to the environment or natural ecosystems, as it is naturally occurring outdoors in open ventilated areas.

Impacts to the Economic Condition of the State

Retrofitting radon systems to older buildings can be costly but is more cost-effective than rebuilding an entire building exposed to radon. Cost for mitigation measures can vary greatly dependent upon the scale (individual home, larger government buildings, etc.) and the type of mitigation measure. The State could experience significant economic impacts if there were a scenario that required multiple government-owned structures to be

mitigated or reconstructed. If high levels are found, there could be a disruption to government services resulting in economic losses.

Impacts to Public Confidence in State Governance

The public confidence in State governance would mainly depend on how effective the State has been in the past at preparing for and responding to radon exposure. Public confidence also depends on the preparation the State is taking for increased radon exposure. In general, if the State is transparent in sharing relevant information with the public regarding radon exposure, then the public is more apt to trust the State and feel as if it has the capability to protect and assist the residents of West Virginia.

The West Virginia Department of Health and Human Resources administers the State's radon program, which is responsible for radon testing reports and mitigation notifications. The program provides information about how residents can protect their homes from radon exposure and provide free radon testing kits upon request.