ATSDR Clinician Brief: Radon

Properties

Radon is a chemically and biologically inert noble gas produced when naturally occurring uranium and thorium undergo radioactive decay. Radon undergoes further radioactive decay into daughters (progeny) until reaching a stable form of lead.

Two isotopes of radon (radon-220 and radon-222) are the daughters in two decay chains that begin with naturally occurring thorium-232 and uranium-238, respectively, in rock, soil, water, and air. Radon in this brief will refer to radon-222 and its daughters. It has a half-life of 3.8 days and is a colorless, (heavy) odorless gas that is imperceptible to the senses.

Sources of Radon

Radon is normally found at very low levels in the outdoor air. It is also present in rock, soil, water, and building materials. The burning of coal and other fossil fuels also releases radon. When radon escapes from soil or is discharged from emission stacks to the outdoor air, it is diluted to levels that are normally lower than indoor air.

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The main source of indoor radon gas is from rock and soil underneath buildings where it infiltrates through crawl spaces, cracks in solid floors, construction joints, cracks in walls, gaps in suspended floors, gaps around service pipes, and cavities inside walls. Radon may also enter dwellings through the water supply and natural gas that had previously been in contact with underground uranium and thorium-bearing rock and soil. Since uranium and thorium are ubiquitous in the earth's crust, rock and soil will continually release radon in the environment. The radioactive radon attaches to dust particles, smoke, walls, floors, ventilation equipment, and clothing, allowing it to be inhaled into the lungs.

Exposure to high concentrations can occur in any location with geologic radon sources (EPA 2007; Field 1999). https://www.epa.gov/radon/epa-map-radon-zones

These sources can include underground uranium, hard rock and vanadium mines, and water treatment plants. Radioactively contaminated sites can include uranium mill sites and associated mill tailing piles, phosphate fertilizer plants, oil refineries, power plants, and natural gas and oil piping facilities.

Locations that are not contaminated, but at which elevated natural radon levels exist, can include utility and subway tunnels, fish hatcheries, natural caverns, and excavation sites (EPA 2007; Field 1999; Fisher et al. 1996).

Background levels of radon in outdoor air are generally quite low, typically around 0.4 picocuries per liter of air (pCi/L). They can vary based on location and the geology of the soil. However, the average indoor level in the U.S. is 1.25 pCi/L. (EPA 2012 & 2017).

In indoor locations, such as dwellings, schools, or office buildings, levels of radon are generally higher than outdoor levels. This is especially true of newer construction that is more energy-efficient but can increase the levels of radon inside. Basements and lower levels of the buildings are likely to have higher levels of radon, as it is a heavy gas.

The action level recommended by the Environmental Protection Agency (EPA 2019) for indoor exposure to radon is 4 pCi/L.

- Nearly one out of every 15 dwellings in the U.S. is estimated to have elevated radon levels at or above EPA's action level of 4 pCi/L.
- The American Cancer Society (2015) estimated that there are 8 million dwellings in the U.S. with elevated levels of radon.

The EPA and the U. S. Surgeon General recommend testing all dwellings below the third floor for radon. (EPA 2017)

Routes of Exposure

Everyone is potentially exposed to environmental radon. However, only those people in environments with increased levels of radon are at a higher risk of potentially developing negative health effects.

The toxic effects of radon depend on several factors. These factors can include the extent of exposure, particularly the concentration, duration and frequency of exposure. Exposure is determined by assessing potential exposure pathways, including potential sources and routes of exposure, and other exposure risk factors, such as being a smoker. Risk of developing disease also involves individual characteristics such as age, genetic factors and health status.

INHALATION

The most important route of exposure to radon is inhalation. Indoors, radon infiltration from soil into buildings may result in inhalation exposure. This is also the case of radon released from water into the air when clothes and dishes are washed, toilets are flushed and water splashes during showering. Inhalation exposure of radon may also result when household appliances are not properly vented to the outside.

INGESTION

Oral exposure to radon can occur as a result of radon gas dissolving in water. For example, the water that contacts the rocks and soil will contain dissolved radon. As such, in most drinking water, radon is naturally present. Some radon swallowed in drinking water passes through the stomach walls and intestine into the bloodstream. After radon reaches the lungs, it is readily breathed out through pulmonary circulation. Therefore, ingestion is a minimal exposure route (ATSDR 2012, Ishikawa et al. 2003).

DERMAL

Data are very limited regarding the absorption of radon following dermal exposure and this is not considered a significant exposure route (ATSDR 2012).

Populations at Risk

- People who live in dwellings with elevated radon levels (NCI 2011)
- Children are vulnerable to elevated radon exposure
    - Children exposed to radon may have higher estimated radiation doses than adults related to the differences in a child's lung size, higher minute volume and faster respiration rate.
    - Radon exposures during childhood may not show up as health effects until adulthood.
- People who smoke are vulnerable as are children and adults who do not smoke but live in smoking households (HPA 2009).
    - The risk of lung cancer from radon exposure is estimated to be 10 to 20 times greater for persons who smoke cigarettes in comparison with those who have never smoked.
    - Tobacco has elevated levels of radon daughters attached to its leaves, mostly polonium-210 and lead-210.
    - There is a synergistic effect between the alpha radiation of the radon daughters with the smoke particles emitted by tobacco when it burns. Some radon daughters will attach to dust or smoke particles in the air. This is the "attached fraction" of radon daughters, which when inhaled, stays in the lungs longer and delivers a higher radiation dose to the lung.
- People who have chronic respiratory disease, such as asthma, emphysema or fibrosis, often have reduced expiration efficiency and increased residual volume (i.e., greater than normal amounts of air left in the lungs after normal expiration).
- People who work in environments with elevated radon levels (EPA 2007)
    - Miners (additive effects of cigarette smoke in lung cancer among miners exposed to radon)
    - Workers in water treatment plants (When water is sprayed into the air to oxygenate it, radon is released and is available to be inhaled)
    - Persons who study or explore caves (speleologists)
    - Fish hatchery and farm workers
    - Radon mitigation professionals
    - Scientists studying radon or other radionuclides

Health Effects

The primary adverse health effect of exposure to increased levels of radon is lung cancer. The high-energy alpha emissions from radon deposited in the airways are the primary cause of toxicity concern (ATSDR 2012).

- Cigarette smoking is the number one cause of lung cancer with radon gas exposure being the second leading cause. Elevated levels of radon gas exposure are responsible for about 21,000 lung cancer deaths in the U.S. every year (NCI 2011, EPA 2007).
- The World Health Organization (WHO 2009) estimates that radon causes between 6% and 15% of all lung cancers worldwide. However, lung cancer caused by radon exposure takes many years to develop.
- For people who smoke, exposure to elevated radon levels increases their already heightened lung cancer risk.
- Epidemiologic studies of miner cohorts have reported increased frequencies of chronic, nonmalignant lung diseases, such as emphysema, chronic interstitial pneumonia, and pulmonary fibrosis. The risk of these diseases developing increases as cumulative exposure to radiation from radon daughters and cigarette smoke increases. This increased risk also applies with exposure to silica dust and diesel exhaust particles that were especially present in mines before actions were taken to limit their concentrations (ATSDR 2010).

The sequence of events leading from irradiation of living cells to cancer is generally believed to involve ionization of atoms in DNA. Ionizing radiation can cause genetic instability through DNA breaks, gene mutations, and inaccurate cell repair.

The main health problems from radon exposure arise when radon daughters primarily attached to dust or smoke particles (termed the attached fraction) is inhaled. Once inhaled, these particles deposit in the airway (particularly the tracheobronchial tree) and irradiate nearby cells repetitively with alpha particles as each radon daughter atom transforms through the decay chain. These alpha particles can deliver a large, localized radiation dose.

Smoking and other aerosol-generating activities (e.g., vacuum cleaning, cooking, and use of wood-burning fireplaces and circulating fans) will increase the exposure. The exposure is much higher in dwellings with people who smoke relative to those with people who do not smoke. These exposures are also higher in dusty mines relative to well ventilated ones. The air in homes with wood burning fireplaces and stoves is comparable in quality to that of mines.

Clinical Evaluation

Patients with potential exposure to increased radon levels should undergo a thorough medical evaluation that includes a detailed occupational and environmental exposure history, a physical exam that targets respiratory complaints, and appropriate imaging and lab testing as part of the differential diagnosis. Direct biological indicators of exposure are not generally available and are of questionable clinical utility since they cannot be used to accurately determine amount of radon exposure, nor can they be used to predict whether harmful health effects will develop in the future.

PATIENT HISTORY

It is essential to take a patient history that emphasizes the occupational and environmental opportunities for exposure that occurred in the past. The initial interview should document the patient's:

- Medical history
  - Past medical history (history of lung disease or other respiratory/health conditions)
  - Current respiratory and other health symptoms
  - Medical radiation history
  - Smoking history
- Occupational exposure history
  - Any work in occupations with a high risk for elevated radon exposure or exposure to other sources of ionizing radiation
  - Source and total exposure, if known; also any protective equipment used
  - When and for how long exposure or employment at that job occurred
  - Any other chemical exposures that may have occurred
  - Any known direct contact with elevated levels of radon, the concentrations (if known), and the duration (which allows estimation of the total radiation dose)
- Environmental radon exposure history
  - Results of any radon testing done in patient's dwellings over the past 20 or more years
  - Type of dwelling foundation (e.g., built on a slab, with a crawl space, finished or unfinished basement)
  - How much time spent in the basement or lower level of the dwelling (depending on the type of dwelling)
  - Types of ventilation (such as opening windows and frequency) systems in the dwelling
  - Energy-efficiency of the dwelling (helps to determine how tightly the building may be sealed, which keeps radon inside the dwelling)
  - Number and type of gas appliances used in the dwelling (Are these vented to the outside? Do they have double wall vent pipes? These questions will identify improperly vented gas-fed stoves and fireplaces, gas dryers, and water heaters.)

- Source of water at the dwelling (well, county or city). Water from large water systems is likely to stand in a reservoir for several days and be spray oxygenated, allowing it to release radon before it reaches the dwellings.
- Presence of smokers in the dwelling
- Past residences
- Sources, intensities, when, and for how long possible exposure to elevated levels of radon occurred

PHYSICAL EXAMINATION

The physical exam should include the following, paying close attention to lungs, as these are most likely to be affected by radon exposure.

- Auscultation of heart and lungs
- Extremity examination

TESTS AND IMAGING

The decision to perform tests should be based on the patient's history and clinical evaluation, weighing possible risks and benefits of testing.

Currently, **no effective community-wide screening methods** are available for medical prevention or early diagnosis and treatment of lung disease due to elevated levels of radon, once exposure has occurred.

Using radon air testing results as a proxy for exposure, the following tests may be considered to assess for lung disease:

- **Simple Pulmonary Function Test** (PFT or Spirometry)
- **Chest Radiograph.** Radiological changes from exposure to elevated radon levels are not typically evident until after many years, sometimes decades after the long-term exposure
- **Low dose Computerized Tomography (LDCT) Scan**

Treatment and Patient Management

There is no specific treatment for radon exposure. Treatment of lung disease is indicated based on the specific problem encountered.

Most radon daughters decay via alpha or beta emission with half-lives so short that methods for reducing toxicity would be ineffective. Although selected radon daughters (e.g., polonium-210) have longer half-lives, medical interventions such as pulmonary lavage carry significant risk and are not recommended.

For individuals who do not have lung cancer or do not qualify for screening, interviews for radiography or LDCT screening eligibility represent teachable moments to discuss efforts to reduce lung cancer risk, such as testing their dwellings for elevated levels of radon and radon reduction.

Patient Follow-Up

Patients who have been exposed to elevated levels of radon may need outpatient follow-up.

- Periodic clinical evaluations may detect abnormalities at an early stage, if they occur. Further testing may be performed based on symptoms, physical exam findings, and standard clinical practice.
- Screening for cancer should be done in accordance with the recommendations of the U.S. Preventive Services Task Force (USPSTF), based on the patient's age, gender, and other risk factors.

Consider consultation with a specialist in occupational and environmental medicine who can assist with development of a periodic monitoring plan, as appropriate.

Patient Counseling and Risk Reduction

INFORM THOSE AT RISK

Patients identified as having exposures to elevated levels of radon or significant exposure history should be informed of the potential risk of disease, and especially the interaction between smoking and radon exposure increasing the risk of lung cancer.

- Testing is the only effective way to find out a radon problem.
- When purchasing or renting a dwelling, request a radon test.
- Ventilating the dwelling is a temporary way to reduce radon concentrations.*
- The benefits of reducing elevated radon levels through remediation outweigh the costs.
- Stopping smoking in the dwelling may greatly reduce the possibility of lung disease among those living in it.

* Temporary weather dependent measure.

TESTING DWELLING FOR RADON

Ask your patients if they have tested their dwelling for radon. If they have not, inform them about the potential health risk posed by radon and urge them to test their dwelling for radon.

Radon testing is the most important measure to identify if a dwelling has elevated levels of radon.

- Short-term and long-term tests (lasting a few days to several months) are available to identify whether there are increased levels of radon gas in the dwelling.
- Short-term testing is the quickest way to determine the presence of a potential problem, but it is the least accurate for determining long-term exposure. These "do-it-yourself" short-term testing kits are typically available at local hardware stores.

- Testing should be conducted in the lowest-inhabited area of the dwelling. Closed house conditions should be met. These conditions include keeping doors and windows shut (allowing very brief periods to open doors when entering or leaving the dwelling), placing the test units away from windows, doors, and vents and following all written testing instructions that help ensure accuracy.

RADON REDUCTION (REMEDIATION)

Methods for reducing the potential exposure to elevated levels of radon (and therefore its toxic effects) consist of periodically testing for radon in indoor air and reducing radon concentrations to below the EPA recommended action level of 4 pCi/L (preferably 2.5 pCi/L), using active soil depressurization (ASD) in existing dwellings and radon-reducing features in new dwelling construction.

Active Soil (Subslab) **depressurization**

- ASD with suction lowers the soil pressure below that inside of the dwelling and prevents inward soil gas migration.
- Pipes, attached to a suction fan, are inserted into the ground below the basement floor, creating a low-pressure region under the house (Brenner 1989).
- This depressurization is one of the most effective methods of lowering radon levels in many dwellings and can reduce indoor radon levels by as much as 99%.

SMOKING CESSATION

Smoking cessation can greatly reduce the risk of respiratory diseases, including lung cancer.

- Stopping smoking reduces the radiation dose from radon, since the presence of smoke particles increases the radiation dose from radon daughters.
- This risk reduction strategy is of particular importance for children as the risk of lung cancer for children co-exposed to tobacco smoke and high levels of radon is much greater than children exposed to high levels of radon alone (ATSDR 2012).

Other Sources of Information on Radon

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CLINICAL RESOURCES

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- The Association of Occupational and Environmental Clinics (AOEC) (Accessed Dec. 28, 2021).
  http://www.aoec.org/

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