> Radon in Buildings

What is radon?

Radon is an invisible, odourless, radioactive gas. It is formed by the disintegration of radium, which is a decay product of uranium. Radon emits alpha particles and produces several solid radioactive products called radon daughters.

Some amounts of radon gas and radon daughters are present everywhere in the soil, water, and air. Particularly high radon levels occur in regions where the soil or rock is rich in uranium. Radon is emitted by radium in the ground, groundwater and building materials. It can enter the indoor air where it and its decay products accumulate in poorly ventilated areas. Harmful levels of radon and radon daughters can accumulate in confined air spaces, such as basements and crawl spaces.

Radon daughters are inhaled with air and deposit in the lungs. The lung absorbs alpha particles emitted by the radon daughters. The resulting radiation dose increases the risk of lung cancer.

What are the health effects of radon?

Inhaling radon daughters increases the risk of lung cancer. The link between the concentration of radon daughters in the air and the risk of lung cancer is based mainly on data from a study of lung cancer mortality among uranium miners and other workers exposed to very high levels of radon daughters.

Radon daughters are solid particles. Most of the radon daughters become attached to tiny dust particles (aerosols) in the indoor air. A variable proportion remains unattached. When these particles are inhaled, a fraction of both attached and unattached radon daughters is deposited in the lungs. Inside the lung, radon daughters emit alpha particles that are absorbed in the nearby lung tissues. Since alpha particles cannot penetrate more than a fraction of a millimeter into the tissue, the damage is confined to the lung tissue in the immediate area.

Radon daughters also emit some low intensity beta particles and gamma rays that travel farther through the lung tissue. Because beta and gamma rays are absorbed over a large lung volume (i.e., not concentrated in a small area), their harmful effects are thought to be minimal.

People exposed to high radon levels have an increased risk of developing lung cancer. The extent of risk depends on the radon concentration in the air and the duration of exposure. The Committee on the Biological Effects of Ionizing Radiation (BEIR, IV, 1988) has estimated lifetime risk of 350 extra lung cancer cases if one million people are exposed to 1 Working Level Month (WLM) of radon daughters. In 1999, BEIR VI stated the number of lung cancer cases due to radon exposure in homes in the United States has been estimated to range from about 3,000 to 32,000.

Smoking increases the risk of lung cancer. Smokers exposed to radon daughters are at greater risk of developing lung cancer.

What do uranium and radon have in common?

The following figure illustrates the radioactive decay chain that produces radon and radon daughters.

Figure--Production of radon and radon daughters from uranium

URANIUM ----> THORIUM ----> RADIUM ----> RADON ----> RADON DAUGHTERS

Each radioactive isotope decays at a unique rate described as the half-life of that isotope. This is the time required for half the atoms of a radioactive substance to disintegrate. Radon's half-life is 3.8 days. This means that, in the absence of its parent radium, the intensity of alpha particles from a given sample of radon will decrease by one-half in 3.8 days; to half the remainder (i.e., one-quarter of the original) in another 3.8 days; to an eighth in another 3.8 days; and so on. However, this does not happen indoors because as old radon decays new radon continuously comes out from the decaying radium present in the ground and walls.

Radon daughters have very short half-lives ranging from a fraction of a second to 27 minutes. As a result, radon daughters are present in significant quantities only as long as radon is present. If all the radon gas is removed, the radioactivity of radon daughters will fade away quickly.

What are the units of measuring radon levels?

The concentration of radon in the air is measured in units of picocuries per litre (pCi/L) or becquerels per cubic meter (Bq/m^3). One Bq corresponds to one disintegration per second. One pCi/L is equivalent to 37 Bq/m^3.

The concentration of radon daughters is measured in units of working level (WL) which is a measure of the potential alpha particles energy per litre of air. One WL of radon daughters corresponds to approximately 200 pCi/L of radon in a typical indoor environment. However, the relative concentration of radon and radon daughters may vary from one building to another. In the extreme case 1 WL corresponds to 100 pCi/L of radon. This situation is called full equilibrium and is extremely unlikely to occur. Occupational exposure to radon daughters is expressed in working level months (WLM) and a working level month is equivalent to the exposure at an average concentration of 1 WL for 170 working hours. Measurement data are reported in either of the above units. For making comparisons between the data from different sources, the following conversion chart may be useful:

1 pCi/L = 37 Bq/m^3

1 m^3 = 1000 L

0.01 WL = 74 Bq/m^3 = 2 pCi/L

0.02 WL = 148 Bq/m^3 = 4 pCi/L

0.1 WL = 800 Bq/m^3 = 20 pCi/L

The document "Quantities and Units of Ionizing Radiation" provides more details on the units of ionizing radiation.

How does radon enter buildings?

Radium in the soil directly under a building is normally the major source of indoor radon. Less important sources of radium are in ground water and building materials.

The presence of uranium in soil and rock is an important indicator of places where radium and radon can be present. Because radon is a gas, a fraction of the radon produced in the soil can find its way into a building. The rest is trapped in the soil. In the air, radon decays to radon daughters that are solids, and are present in the building air as fine particles.

The concentration of radon and radon daughters in the indoor air depends on:

- the amount of radium in the soil and
- the ease with which the radon it produces can move through soil and building walls where it can then mix with the room air.

Because radon is a gas, changes in the atmospheric pressure also affect its emission from the ground and its accumulation in the building air.

The concrete floor and walls in the basement slow down the movement of radon from the soil into the building. However, cracks in the floor, wall slab joints, and the drainage system allow radon to enter a building.

Indoor radon concentrations are almost always higher than outdoor concentrations. Once inside a building, the radon cannot easily escape. The sealing of buildings to conserve energy reduces the intake of outside air and worsens the situation. Radon levels are generally highest in cellars and basements because these areas are nearest to the source and are usually poorly ventilated.

What are exposure limits for indoor radon?

In Canada, the Canadian Nuclear Safety Commission (CNSC), formerly known as the Atomic Energy Control Board (AECB), sets radiation exposure limits. It gives two types of exposure limits--one for occupationally exposed persons and another for the general public. The annual occupational exposure limit is 4 WLM. The annual exposure limit for the general public is 70 Bq/m^3. In homes and other non-occupational settings, the maximum permissible annual average concentration of radon daughters caused by the operation of a nuclear facility is 0.02 WL (radon level 148 Bq/m^3).

Although there is no regulation in Canada for an acceptable level of radon in homes or public buildings (schools, hospitals, care facilities and detention centres), Health Canada and partners (2007) developed a guideline that indicates when remedial action should be taken.

"Remedial measures should be undertaken in a dwelling whenever the average annual radon concentration exceeds 200 Bq/m^3 in the normal occupancy area.

The higher the radon concentration, the sooner remedial measures should be undertaken.

When remedial action is taken, the radon level should be reduced to a value as low as practicable.

The construction of new dwellings should employ techniques that will minimize radon entry and will facilitate post-construction radon removal, should this subsequently prove necessary."

Health Canada also suggests, that since there is some risk at any level, homeowners may want to reduce their exposure to radon, regardless of levels tested. Some of the steps you can take to reduce radon levels in your home include:

- Renovating existing basement floors, particularly earth floors.
- Sealing cracks and openings in walls and floors, and around pipes and drains.
- Ventilating the sub-floor of basement floors.

(From: Health Canada, 2007. It's Your Health: Radon)

The threshold limit value (TLV®), or occupational exposure limit, established by the American Conference of Governmental Industrial Hygienists (ACGIH®) is 4 working level months (WLM/year).

What do we know about indoor radon levels?

In Canada the provincial governments have jurisdiction over the health effects of background radiation. Canadians concerned about possible radon daughter exposure should contact their local provincial government office for further details.

Little information exists on radon levels in Canadian buildings. One collection of Canadian indoor radon measurements, published in 1980, was the result of a cross-country study of radon in private homes. The study showed that in a small fraction of houses, the concentration of radon daughters exceeded 0.02 WL. The following table, which summarizes the results, shows that levels varied from one geographic area to another and even from house to house. In general, the study showed higher levels of radon where ventilation rates were low. A study carried out in the United Kingdom showed varying degrees of elevated radon levels in offices and similar workplaces in areas where radon levels were high in homes.

Homes with Radon Daughter Concentration 0.02 WL and Above	
Location	**Percentage of homes**
Calgary, Alberta	0.8
Charlottetown, Prince Edward Island	1.2
Fredericton, New Brunswick	6.6
Halifax, Nova Scotia	9.3
Montreal, Quebec	2.2
Quebec City, Quebec	3.1
Saint John, New Brunswick	4.2
Sherbrooke, Quebec	8.2
St. John's, Newfoundland	2.1
St. Lawrence, Newfoundland	6.0
Sudbury, Ontario	11.3
Thunder Bay, Ontario	3.3
Toronto, Ontario	1.7
Vancouver, British Columbia	0

Source: McGregor, R.G. Background concentrations of radon daughters in Canadian homes. Health Physics. Vol. 39 (August 1980) p.285-289

How are radon levels detected?

Indoor radon level is measured by air sampling and by alpha dosimetry using radon track etch dosimeters. A number of companies manufacture and sell measuring instruments.

Since radon levels vary greatly from day to day, Health Canada recommends long-term sampling (3 to 12 months) to get a more accurate reading.

Air Sampling Techniques

- Air samples are collected at specified locations. They are brought back to the laboratory to measure the radiation produced in one litre of air. This method reflects an instantaneous point concentration. It does not give a true average concentration for places where radon levels vary from one day to another or during a day.
- A canister containing activated charcoal is exposed to air at the sampling location for a few days. Activated charcoal absorbs radon gas from the air. The sample is brought back to the laboratory to measure the amount of radioactivity absorbed. This inexpensive method gives an average radon level for the period during which the sampler was exposed to the air.
- An electronic instrument, called a working level monitor, is taken to the measurement site. Working level meters give readings immediately. They are best suited for evaluating the effectiveness of control methods for reducing indoor radon levels.

Alpha Dosimetry

- A radon track etch dosimeter is the cheapest long-term monitoring device for alpha radiation from radon gas and radon daughters. The dosimeter contains a piece of plastic inside a small box. When alpha particles strike the plastic, they leave behind damage tracks. The intensity is measured by counting these tracks. Track etch dosimeters are simple to use. They give an average exposure for the duration of the exposure, which can range from several days to months.

What can I do to reduce indoor radon levels?

The usual means of reducing indoor radon levels include:

- reducing the emission from the ground into the building and
- increasing the ventilation in basements and other enclosed areas where radon accumulates.

Increasing ventilation reduces indoor radon levels. Opening a window can help dramatically. The radon level is lower when the inside air is allowed to escape and fresh air can enter the building.

Caulking and sealing cracks and holes in basement floors and walls helps stop the release of radon from the ground into the building. Painting basement floors and wall surfaces also helps. Epoxy paints are the most effective in reducing radon emission. Typically, two or more coats of paint, or paint used with a sealant compound, are needed to seal the pores adequately. Polyethylene sheets serve as a good barrier to radon emission.

Since proper surface treatment reduces the emission of radon, the radon concentration increases inside bricks, slabs, floors and unpainted areas. Driving nails and hooks into the treated wall increases radon emission.

In cases where high radon levels are present because uranium mill tailing was used as landfill, it may be necessary to replace the fill. Alternatively, reducing radon concentration to an acceptable level by coating the surface of the building foundation may be possible. Covering walls with gypsum, plaster or wallpaper does not reduce radon emission.

Air filtration can decrease the radon daughter concentration as much as 90 percent. The majority of radon daughters are attached to airborne particles in the building. Particle removal by air filtration helps decrease radon daughter concentration in the air.

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Want more information?

You may be interested in these related products and services from CCOHS:

Databases
OSH References

For further assistance with a particular workplace topic or issue, contact our Inquiries & Client Services team. This service is free, reliable, and confidential.

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