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#4278

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Radon Control in New Houses

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Background ventilation of dwellings: a review

BRE

#4278

Radon Control in New Houses

The material for this publication was developed in consultation with the Canadian Home Builders' Association for a series of builders' workshops held across the country.

Cette publication est aussi disponible en français sous le titre
Réduction de la concentration de radon dans les maisons neuves (LNH 6068)

What is Radon?

Radon is a radioactive gas created by the natural radioactive decay of uranium in the Earth's crust. As a step in the decay chain, radon produces radioactive atoms, called "daughters," which emit alpha radiation *(see fig. 1)*. These daughter atoms attach to dust and moisture in the air and

ATOM	RADIOACTIVITY
Uranium-238 (in rock, soil)	
↓	
radioactive intermediates (Thorium, Protactinium, Radium, etc.)	
↓	
Radon-222 (released as gas)	alpha
MOST IMPORTANT RADON DAUGHTERS	
Polonium-218	alpha, beta
↓	
Lead-214	beta, gamma
↓	
Bismuth-214	alpha, beta, gamma
↓	
Polonium-214	alpha
↓	
Lead-210	beta, gamma (slow decay)
↓	
Bismuth-210	alpha, beta
↓	
Polonium-210	alpha, gamma
↓	
Lead-206	none (stable: end of series)

SOURCE: alphaNuclear, Mississauga, Ontario

Fig. 1. The radioactive decay process of Uranium that creates radon.

are breathed in by people. The alpha radiation emitted by these daughters attacks tissue in the lungs. People exposed to high doses of these particles for a long time have been shown to run an increased risk of developing lung cancer.

Much of what we know about radon and its link to lung cancer has been learned through studies and surveys of uranium miners. A clear link between exposure to radon and lung cancer has been established for this group. Testing of homes in uranium mining communities began about 15 years ago and the results spurred researchers to expand their studies to other residential centres. In some houses, the concentration of radon measured higher than levels usually found in uranium mines. The discovery of houses with elevated levels of radon concentration in Canada, the United States, Sweden and some other European countries has brought the health concerns associated with radon to the public's attention.

Health and Welfare Canada has conducted a number of surveys in major urban centres across Canada to measure radon levels in a large sample of households. In a significant number of houses, and in some cities more than others, radon concentration was found to be far above the normal level. Although there is considerable debate on what "normal" levels are, it is generally thought that normal indoor levels of radon concentrations are about five times normal outdoor levels. In some cities surveyed, 20 times the normal indoor level was found in a significant number of homes. At this level, Health and Welfare Canada recommends that remedial action be taken within twelve months. (How radon levels are measured and Health and Welfare Guidelines are discussed further on in this publication.)

Traditionally, attention has focused on people exposed to very high dosages of radon in particular industrial settings. Studies are now showing that people exposed over a long time to the levels of concentrations found in some houses may also have higher health risks.

Consumers have also been more directly involved in assessing radon problems in their homes. Recently, low-cost easy-to-use radon detection devices and services have been developed, which enable homeowners to carry out their own measurements — previously this would have taken a team of scientists. It all adds up to greater public discussion of the problem and more demands on the builder to respond appropriately.

Why Should Builders be Concerned About Radon?

All soil is made up of many tiny particles of rock. The small spaces between individual soil particles are filled with air which can move through the soil. Gases released by biological processes (such as methane), moisture (always present in the soil), and radon (released by the soil) mix with this air or soil gas and are carried along by it *(fig. 2)*.

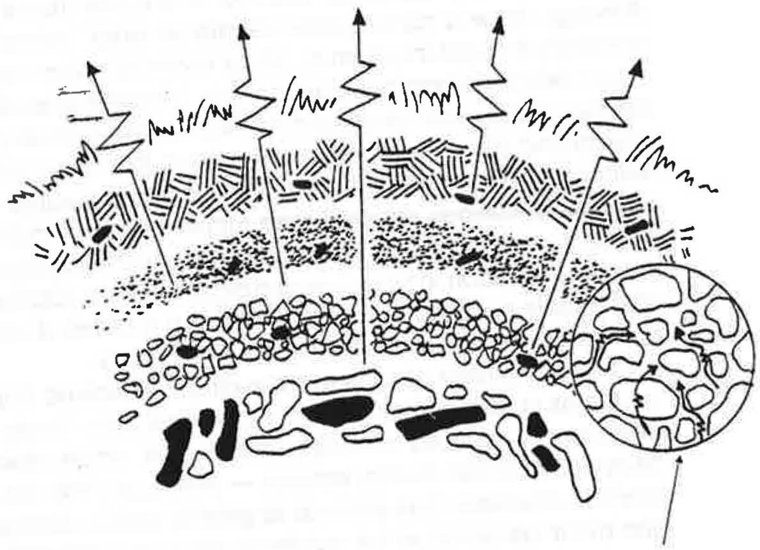

Fig. 2. This cross-section of the Earth's crust shows how radon and other soil gases travel through the soil.

Since uranium is present all over the earth, its radioactive gas, radon, is present everywhere. Outdoors, the radon gas that makes its way up through the soil disperses into the air and the concentration remains very low. When radon gas gets trapped indoors, however, concentrations build up.

Radon is only one of the many problems associated with "soil gases." When you build a house, any openings in the structure that are in contact with the soil allow soil gases to make their way into the house, radon among them. Openings include untrapped floor drains, sumps, underground service entries, cracks in concrete floors, and hollow block walls. Once the radon gas gets into a basement, it is carried into the rest of the house by internal air circulation. In some houses, radon concentration in the air can reach a level that presents a clear health hazard for the occupants. Exposure to radon in such an environment over a long period of time may lead to lung cancer.

Studies done on uranium miners over many years demonstrate that the greater the exposure of individuals to elevated levels of radon, the greater their risk of developing lung cancer. Recently, levels of radon concentration higher than those permitted in uranium mines have been measured in some houses. The implication is that a person living in such a house runs a higher risk than normal of developing lung cancer.

This does not mean that everyone exposed to high levels of radon will get lung cancer. The risk depends on the level of concentration of radon and the length of time of the exposure. Personal factors also play a part in determining risk. Lifestyle can have a significant impact on the result. For example, it has been shown that the risk of developing lung cancer as a result of long exposures to elevated levels of radon increases for people who smoke. It has been estimated that 5-10 percent of lung cancers are caused by radon. See fig. 3.

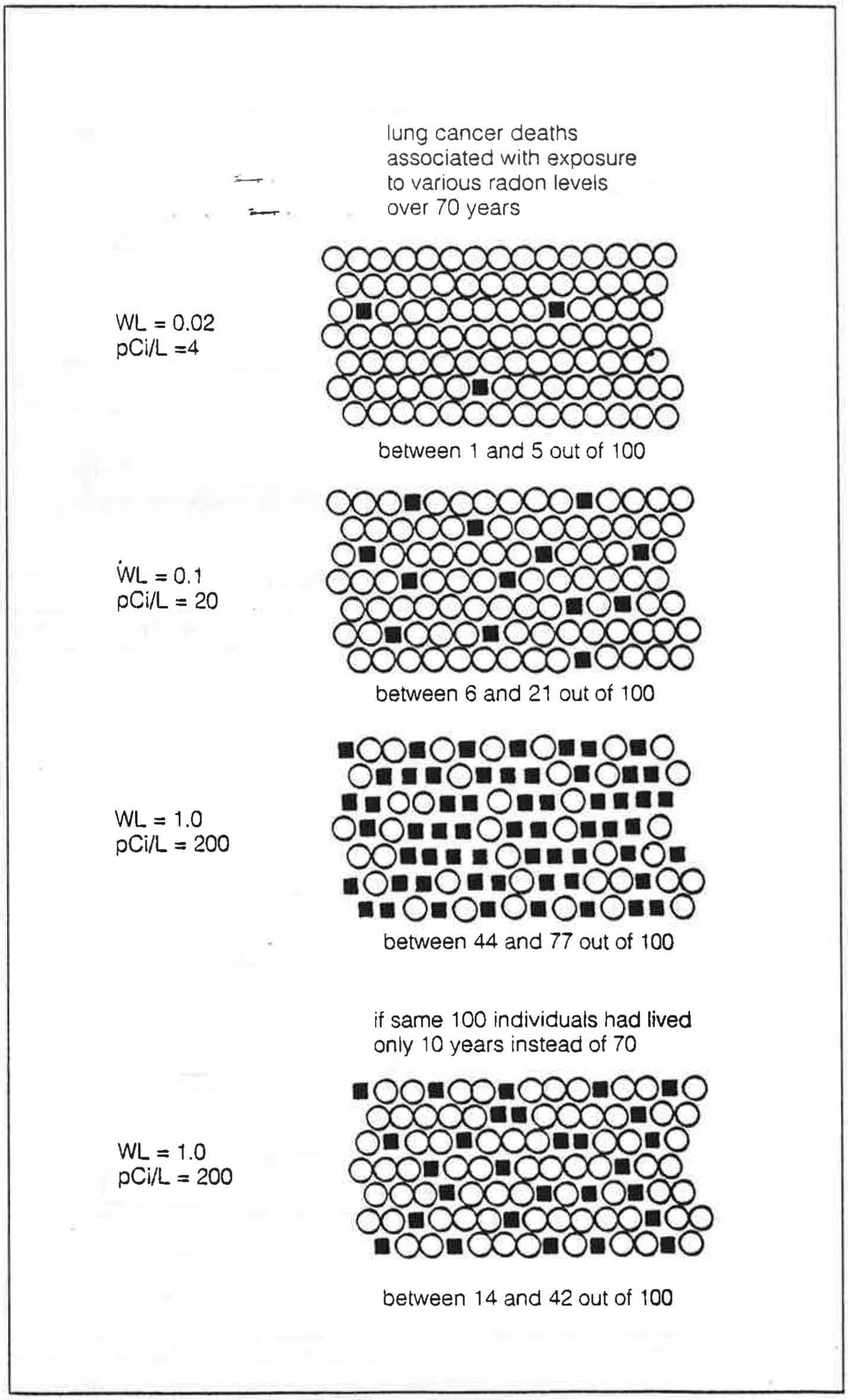

Fig. 3. Illustration of how the length of exposure to radon affects the risk factor for lung cancer. Note that these figures are estimates for the entire population; an individual's risk is greatly affected by individual lifestyle.

How do high levels of radon build up in a house?
There are two mechanisms that control radon levels in indoor air: the flow of radon into the house, and the rate of exchange of air between the inside of the house and the outside. How much radon gets into the house is influenced by a number of factors: the amount of radon in the soil around the house, the type of soil, the number and size of entry paths for the radon gas to enter the house, and the pressure difference between the air inside the house and the soil around the house. See figs. 4 and 5.

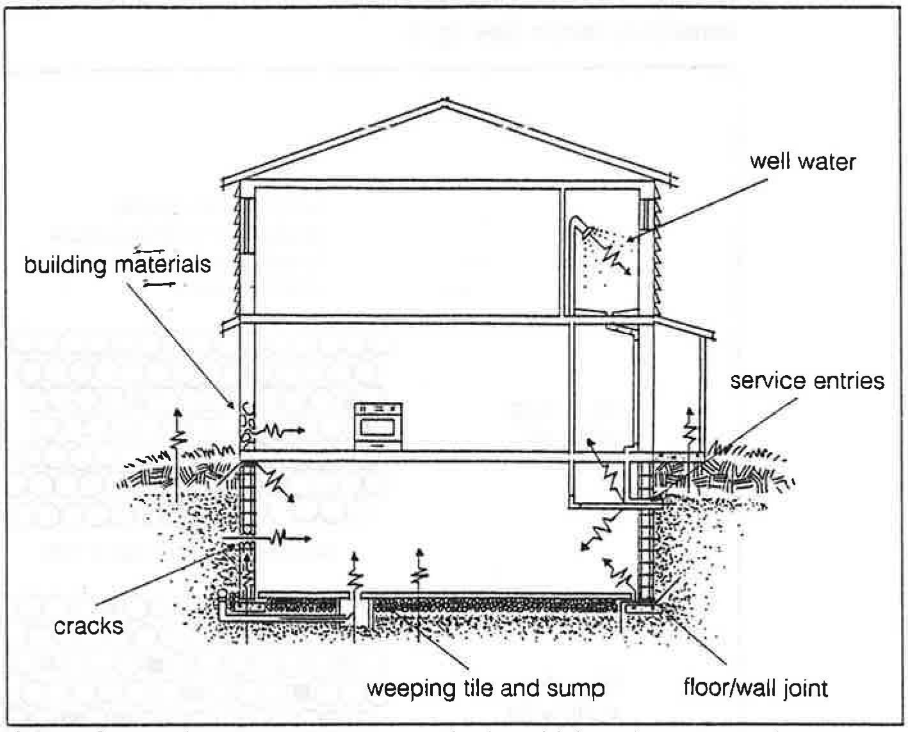

Fig. 4. Some of the most common paths by which radon enters a house.

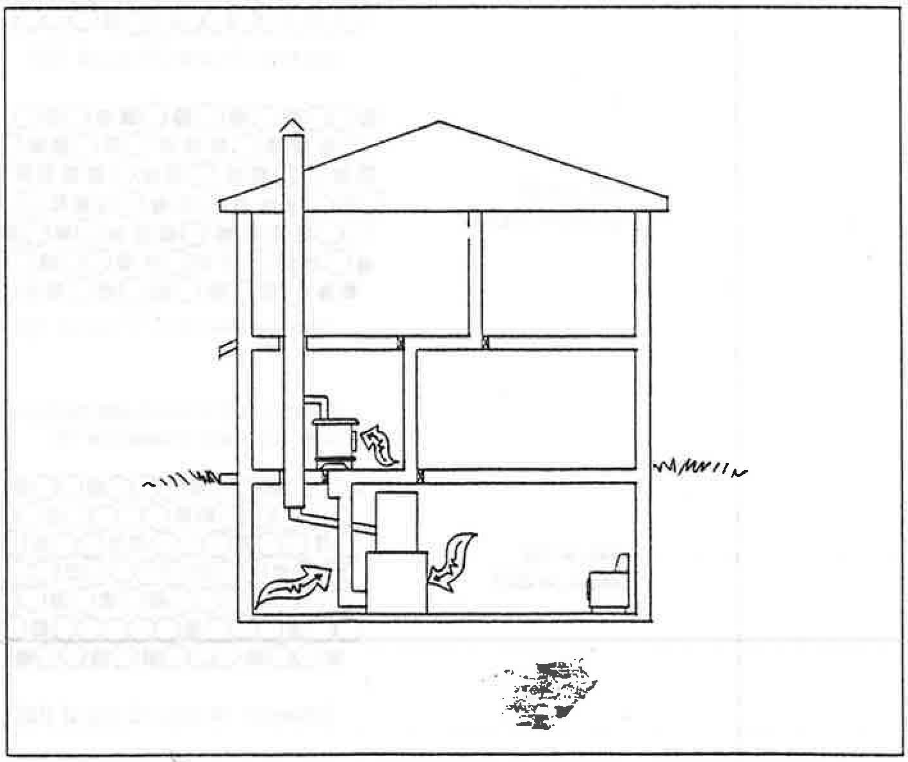

Fig. 5. If too much air is drawn from inside the house without a system to introduce new air from the outside, house depressurization will occur. This can result in more radon being drawn from the earth into the house.

What are some of the most common ways for radon to get into a house?

Radon enters a house from the soil as part of a flow of soil gas into the basement or any part of the house in contact with the soil. Radon is also brought into houses in water in some areas of Canada where well water is high in radon. The amount released from mineral building materials, such as stone, bricks or concrete blocks is usually negligible. The real concerns for the builder are the parts of the house that will be in contact with soil. Because radon is a gas, even a small path of entry, such as a crack, can allow measurable quantities into the house.

Likely paths for radon to enter the house are shown in fig. 4. These paths are drains, sump pumps, cracks, holes and control joints in concrete floors and in concrete or hollow block walls below ground level, and any areas of exposed earth in contact with the inside of the house.

The rate of air exchange between the inside of the house and the air outside is a question of ventilation. This booklet deals with two problem areas: radon entering the house, and lack of adequate air exchange within the house which causes radon to build up to high concentrations.

Building techniques, design considerations and construction practices have been developed and tested to help builders avoid the problem of high radon concentration in the houses they build. Some of these measures are described in the booklet.

Avoiding Radon Problems in New Houses

Only a few areas in Canada are known to have a significant number of houses with high radon concentrations.

The diversity of factors that contribute to radon build-up in a house are so many that it is impossible to speak of a typical problem house. The best approach is to consider as many possibilities as practical and build accordingly. In most cases, adherence to the building code and good building practices will reduce problems. A few modifications to standard building practices for those areas with radon problems are suggested below.

It is worth noting that many of the techniques and procedures highlighted here are specified by the national and most provincial building codes. If the methods outlined are followed carefully, they should prevent most soil gases from entering the house.

Problem

Radon entering the basement.

Cause

Perimeter weeping tile connected to floor drains.

Weeping tile can act as a major collector of radon gas. This should not pose a problem where the weeping tile system connects directly to the municipal storm sewer. However, in older homes and in neighbourhoods with combined storm and sanitary sewers, the weeping tile are often connected to the floor drain, creating a potential passage for radon entry (fig. 6).

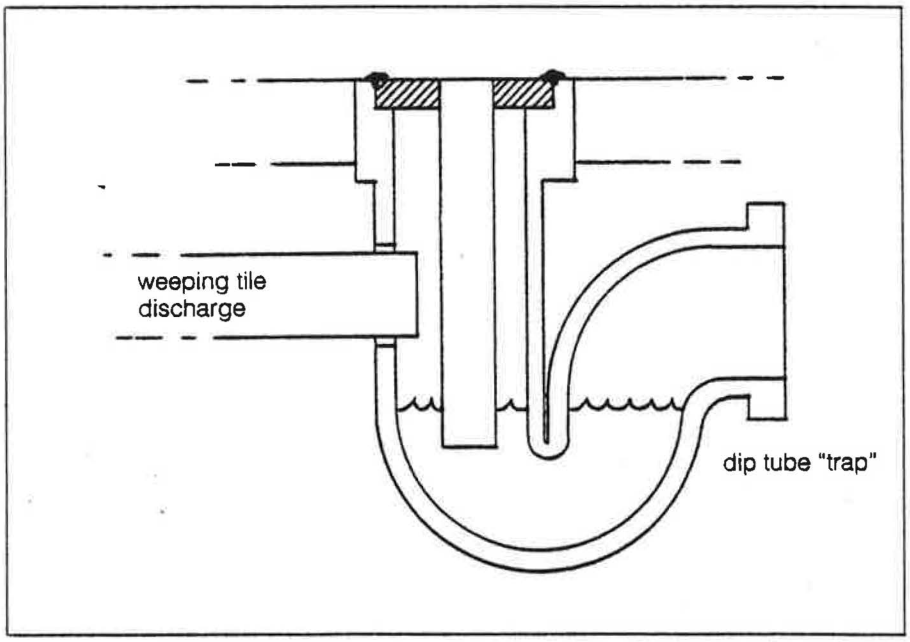

Fig. 6. A major entry point for soil gas.

Solutions

Perimeter drains

- Trap all floor drains. The trap must be kept filled with water to prevent the entry of radon. Instruct homeowners to fill the trap periodically or install a self-priming drain by connecting to a cold water line in a similar manner to a furnace humidifier feed.

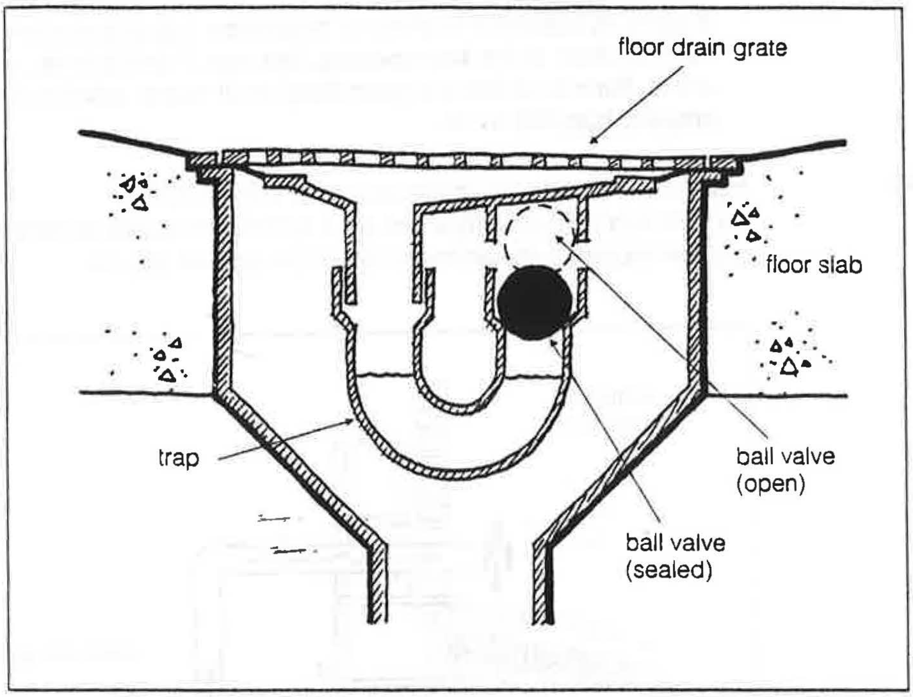

Fig. 7. Self-sealing floor drain (gas trap).

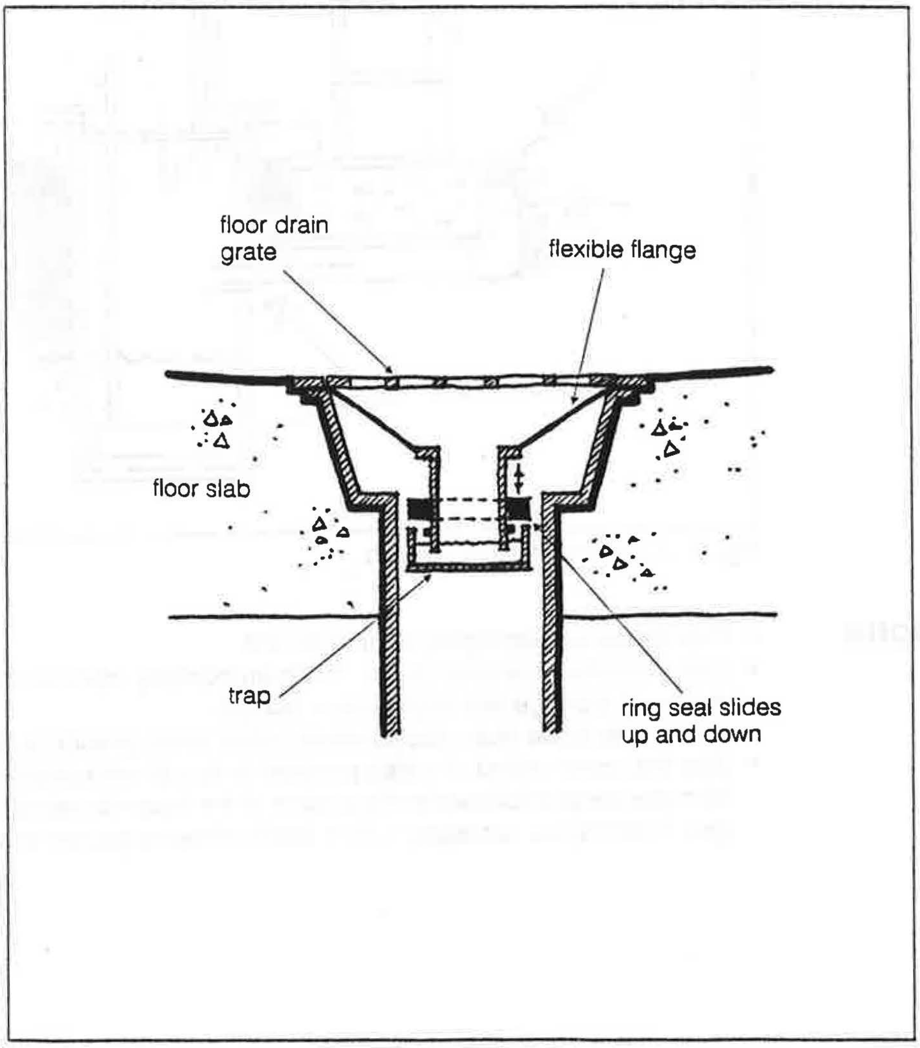

Fig. 8. Self-sealing floor drain (gas trap).

- If the weeping tile connects to the floor drain above the trap, then the trap is being bypassed and offers no protection. Install a special gas trap in the floor drain at the floor opening. See figs. 7 and 8 for how a gas trap works. Such a device is a good idea for all drains, whether they are properly trapped or not.

Cause

Perimeter weeping tile connected to an interior sump.
As with floor drains, sumps can be a significant source of radon since they are connected to the perimeter drainage system (fig. 9).

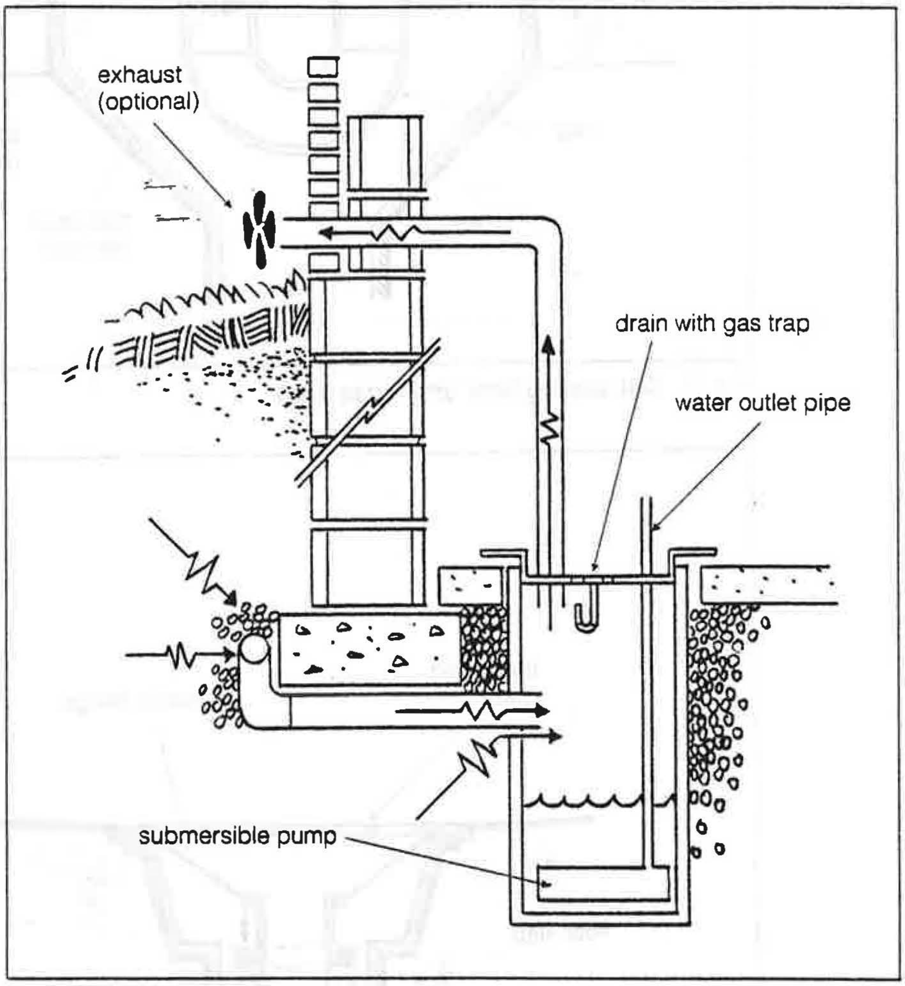

Fig. 9. A sump ventilation system.

Solutions

- Provide sumps with tightly sealing covers.
- Use a submersible sump pump. The high humidity inside a covered sump will damage non-submersible pumps.
- If the sump cover must also serve as a floor drain, provide a gas trap.
- With the cover sealed, it is also possible to run an exhaust pipe with a fan from the sump enclosure to the outside of the house to redirect the radon gas. This may be necessary if high levels of radon gas are encountered.

Cause

Gap between floor slab and wall.
As the floor slab cures, it shrinks away from the walls. The gap between the hardened floor and the wall (wall/floor joint) is a major entry path into the house for soil gases carrying radon. This gap is made wider by the usual steps taken to prevent floor cracking — use of a bond breaker between the floor slab, wall and footings (fig. 10).

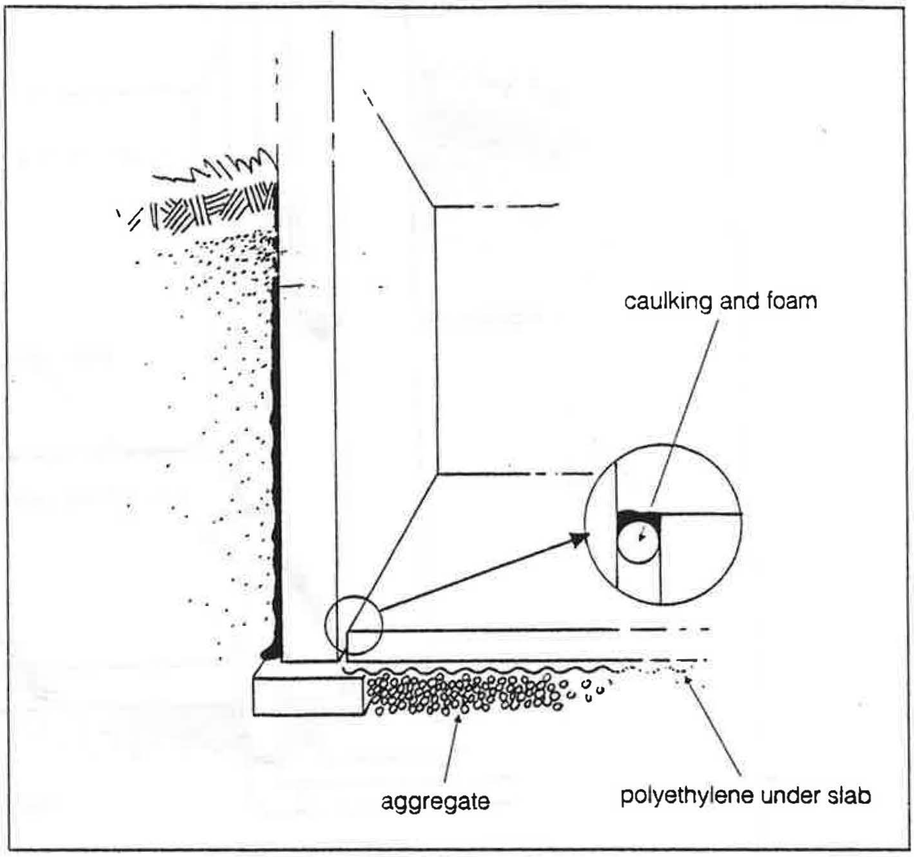

Fig. 10. The wall/floor joint and control joints can be a major path by which radon enters the house. Proper sealing will reduce the entry of radon into the house; it will also contribute to the effectiveness of ventilation methods introduced to reduce radon levels.

Solutions

- Seal the opening around the perimeter of the floor at the wall/floor joint as follows:
  - place flexible expansion joint material such as fibre board around the wall before pouring the slab. This will create a space when it is removed after the floor has hardened. A wider space is easier to fill and makes it easier to achieve a reliable seal.
  - fill the gap with caulk to produce a high grade seal. In most cases a water-resistant polyurethane or elastomeric caulking material will work best. Fit a foam backer rod in the opening first to control the caulking depth and provide a base to tool against. This is illustrated in fig. 11.
- As an alternative, carry the moisture barrier (usually polyethylene) up and caulk it to the wall. This procedure is being proposed for the 1990 National Building Code.

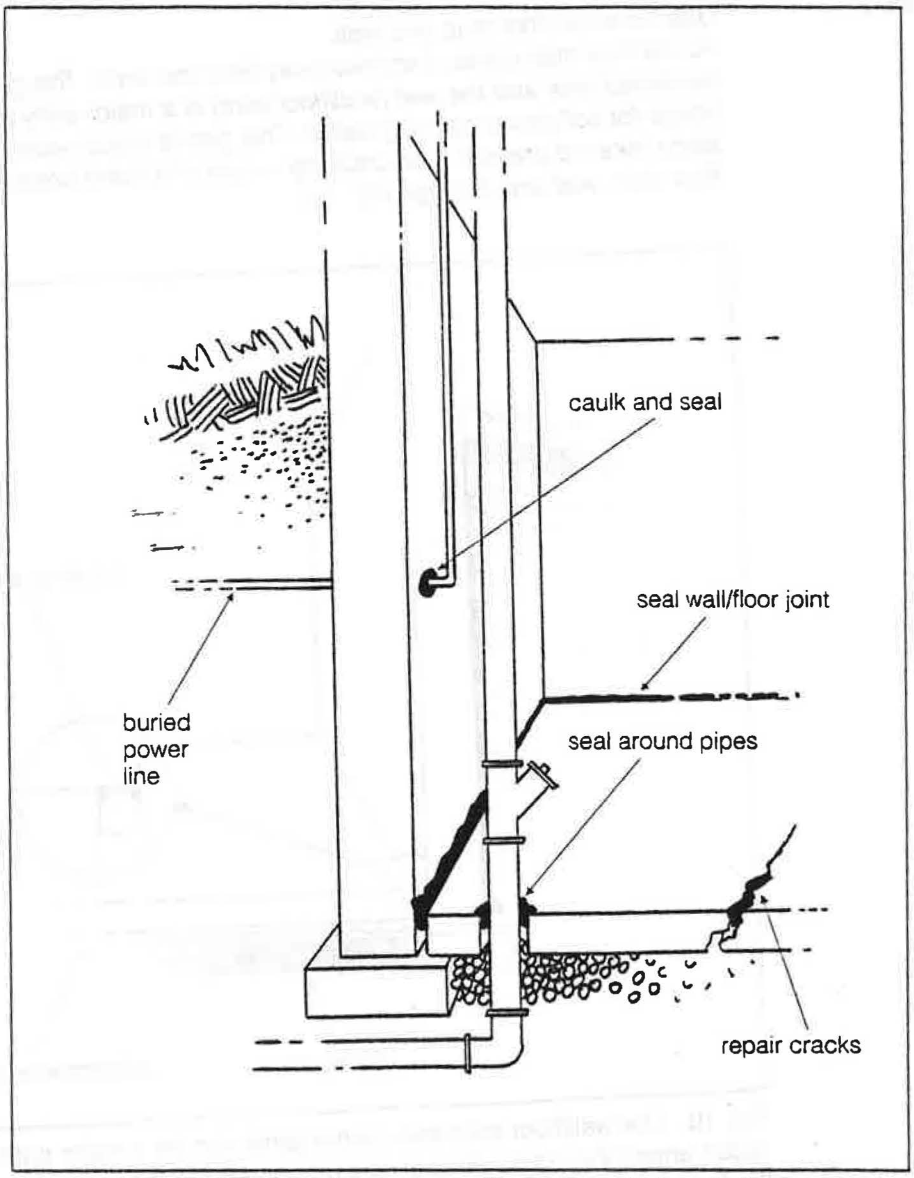

Fig. 11. Systems for excluding radon will be more efficient if all entrances into the house from the soil are properly caulked and sealed.

Cause

Openings around drains and utilities in floors and walls.
Materials are packed around pipes and conduit cables (buried power lines) to keep them clear when concrete is poured. These materials provide gaps that allow soil gases to freely enter the house. Hollow steel house jacks that pass through floors also let radon into the basement.

Solutions

- Remove packing materials around drains, including those under basement bathtubs and toilets.
- Pour a sealant into large openings around pipes.
- Close small openings around utility pipes with a polyurethane caulk.
- Use house jacks with a fully welded bottom plate to make them airtight.

Cause

Cracks in a basement floor or slab on grade floor.
Radon enters into the house through floor cracks. The most common of these are the cracks caused by shrinkage after the concrete cures. The causes include the slab's not being able to separate from the footings during shrinkage, lessened slab strength because of fast setting, and improper curing or too much water in the mix.

Solutions

- Place a bond breaker between the slab and the footing. This will allow the slab to slide along the footing the few millimetres needed to prevent shrinkage cracks. Use polyethylene or sand.
- Use a mix low in water content to reduce shrinkage. Avoid adding water to the mix on site.
- Cure the concrete properly to delay shrinkage until the slab has some strength. Cover the slab while it is drying to slow the process and improve the curing quality. This will help minimize cracks.
- Add a plasticizer to the mix to give high slump without jeopardizing the slab strength.
- Install control joints in large areas and seal between the joints with a polyurethane caulk.
- Provide an airtight barrier such as 0.15 mm (6mil) polyethylene below the slab to prevent the upward infiltration of radon gas. Overlap joints 100 mm (4") and caulk. Protect the barrier with a 50 mm (2") layer of sand.

  Two publications that provide more technical detail on concrete techniques are CMHC's *Concrete Foundations* and the Portland Cement Association's *Concrete Floors on Ground*. See Additional Reading for details.

Causes

Cracks and other unintentional openings in poured concrete walls. Hollow block wall cavities connected to footing/wall joint.
Basement walls may develop cracks from shrinkage, stresses and other causes. In hollow block walls, the blocks themselves permit the passage of soil gases as does the mortar between the blocks. Furthermore, in hollow block walls, any soil gas coming into the block cavities at the wall/footing joint can easily travel through the cavities and enter the house through any opening in the interior wall. It is often this section of the exterior that is not as completely or carefully parged or waterproofed as the upper parts of the wall.

Solutions

- The best protection against cracking is to follow proper concrete building practices. Weak, over-watered concrete is more prone to cracking. Proper curing is essential to reducing cracks. Keep forms on poured concrete as long as possible and keep newly poured concrete protected in hot or cold weather
- Proper dampproofing on walls should prevent soil gases getting into the house through the walls. The three most important elements of good dampproofing are surface preparation, extending the wall-coating material over the exterior wall/footing joint, and backfilling after the coating has dried. CMHC's publication *Concrete Foundations* is a good reference work for specific techniques. See Additional Reading.
- Clean walls of scale, dirt, dust and oil.
- Patch any holes on the exterior of the wall, such as snap tie holes, with grout.
- For concrete block walls, cover the entire wall surface and the footing with a thick parge. Spread two coats of dampproofing materials over the parge on block walls and the footing cover. Extend over the footing as shown in fig. 12.
- The use of semi-rigid fibrous insulation on the exterior of foundations may help prevent the entry of radon through walls.

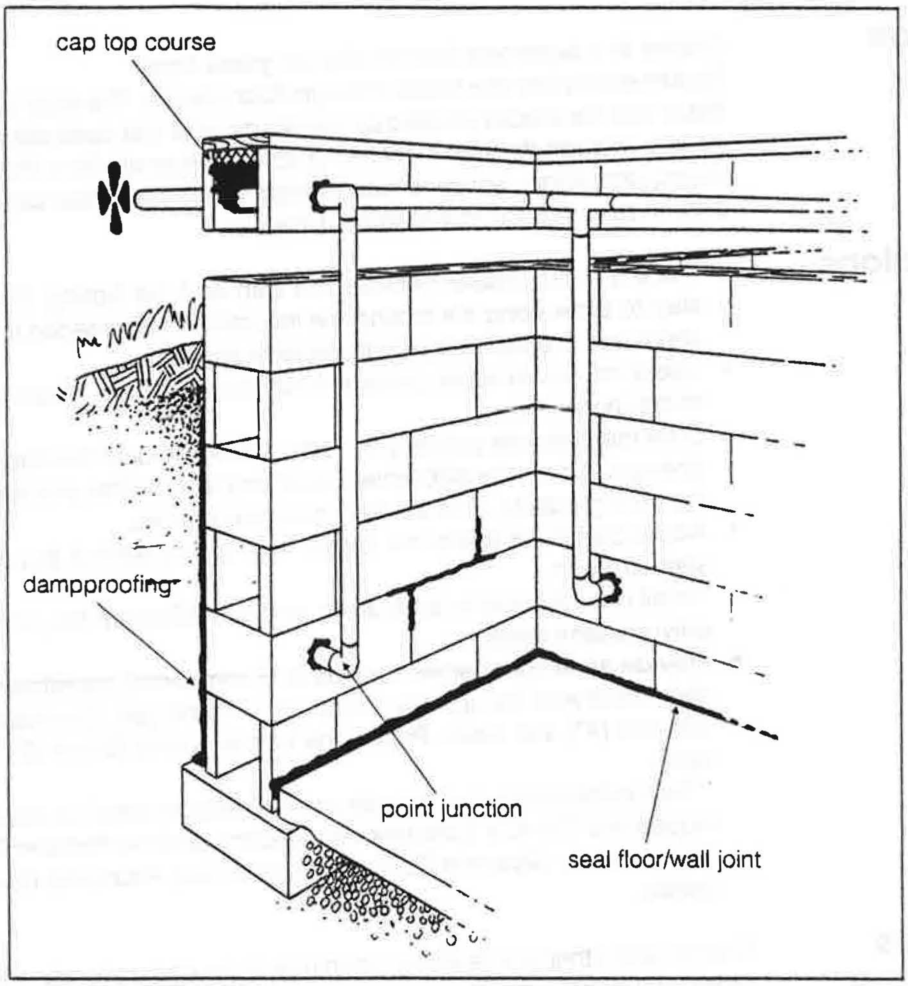

Fig. 12. How to treat hollow-block walls.

Cause

Radon entering through preserved wood foundations.
While plywood can be regarded as impermeable to radon gas, the joints provide a potential entry point.

Solutions

- Ensure that all joints between the wall panels are caulked. Dampproof coatings may provide better protection than polyethylene, since polyethylene on PWF walls is usually left unattached at the base of the wall.
- Install a concrete floor slab or caulk all plywood joints in a wood sleeper floor. The polyethylene below the floor should be sealed to the wall's sill plate.
- If a suspended wood floor is used, the space below can be treated as a crawl space. See below, Crawl Space Construction.
- Follow all the precautions given regarding openings in the floor and perimeter drainage tile described in the section for concrete floors.
- Caulk and seal all underground service entrances and other openings.

Note: Very little is known about the penetration of soil gases into houses with wood foundations.

Cause

Crawl space construction.
If soil gas is allowed to penetrate the crawl space, radon can easily enter the living space above.

Solutions

- Leave no exposed earth in the crawl space.
- Cover the ground with an airtight barrier such as polyethylene, lap and

caulk all joints, and seal it to the foundation wall. Protect the barrier with a layer of sand.

- A more durable solution is to cover crawl spaces with a concrete slab over polyethylene. The good concreting practices outlined in the section on basement slabs should be followed to minimize shrinkage cracks. Seal the gap between the crawl space slab and the foundation wall, as described earlier.
- Polyethylene can also be carried up the interior of the crawl space foundation wall and sealed at the top.
- A good practice is to provide approximately 125 mm (5″) of crushed stone or coarse gravel below the polyethylene, in case sub-slab ventilation is required later. See the section on sub-slab ventilation.
- An alternative solution in milder climates is to ventilate the crawl space mechanically at the rate, approximately, of two air changes per hour. An airtight barrier should be provided at the main floor. Such an approach requires dependable fans rated for continous operation. In colder climates, this alternative is likely not feasible, since crawl spaces will be heated to protect plumbing and heating systems.

Cause

Slab-on-grade construction

Solutions

- Provide an airtight barrier below the slab, such as polyethylene. Lap and caulk all joints. Protect the barrier with a 50 mm (2″) layer of sand. Ensure that the exterior edge of the slab is also sealed with polyethylene or with a coating.
- Alternatively, provide an airtight membrane or coating on top of the slab, below the finished flooring.
- Follow good concreting practices, as outlined earlier, to reduce cracks.
- Seal all penetrations through the slab, such as floor drains or underground services, similar to basement slabs.
- Avoid casting ductwork into the thickened slab edge, since hidden cracks which could provide a potentially serious entry point for soil gas would be difficult to correct.

Problem

Build-up of radon inside a house.

Cause

Lack of ventilation.
Any source of radon entering the house will eventually reach high concentrations if there is not an adequate air exchange between the air inside the house and "fresh" air from outside.

Solutions

- The National Energy Building Code specifies that ventilation systems must have the capability for 1/2 air changes per hour. However, this will not prevent radon build-up if the occupants do not use the ventilation system. Educate homeowners on the need for ventilation and install a system which is as "user friendly" as possible:
  - continuous low-velocity air flow
  - simple controls
  - tempering of fresh air to avoid drafts
  - balanced exhaust and supply.
- If a forced-air heating system is being built, ensure adequate make-up air. If a hydronic or radiant system is being built, consider adding a dedicated ventilation system.
- Provide operable basement windows for natural ventilation during warm weather. See fig. 13.
- Refer to CMHC's publication *Ventilation: Health and Safety Issues* for more details.

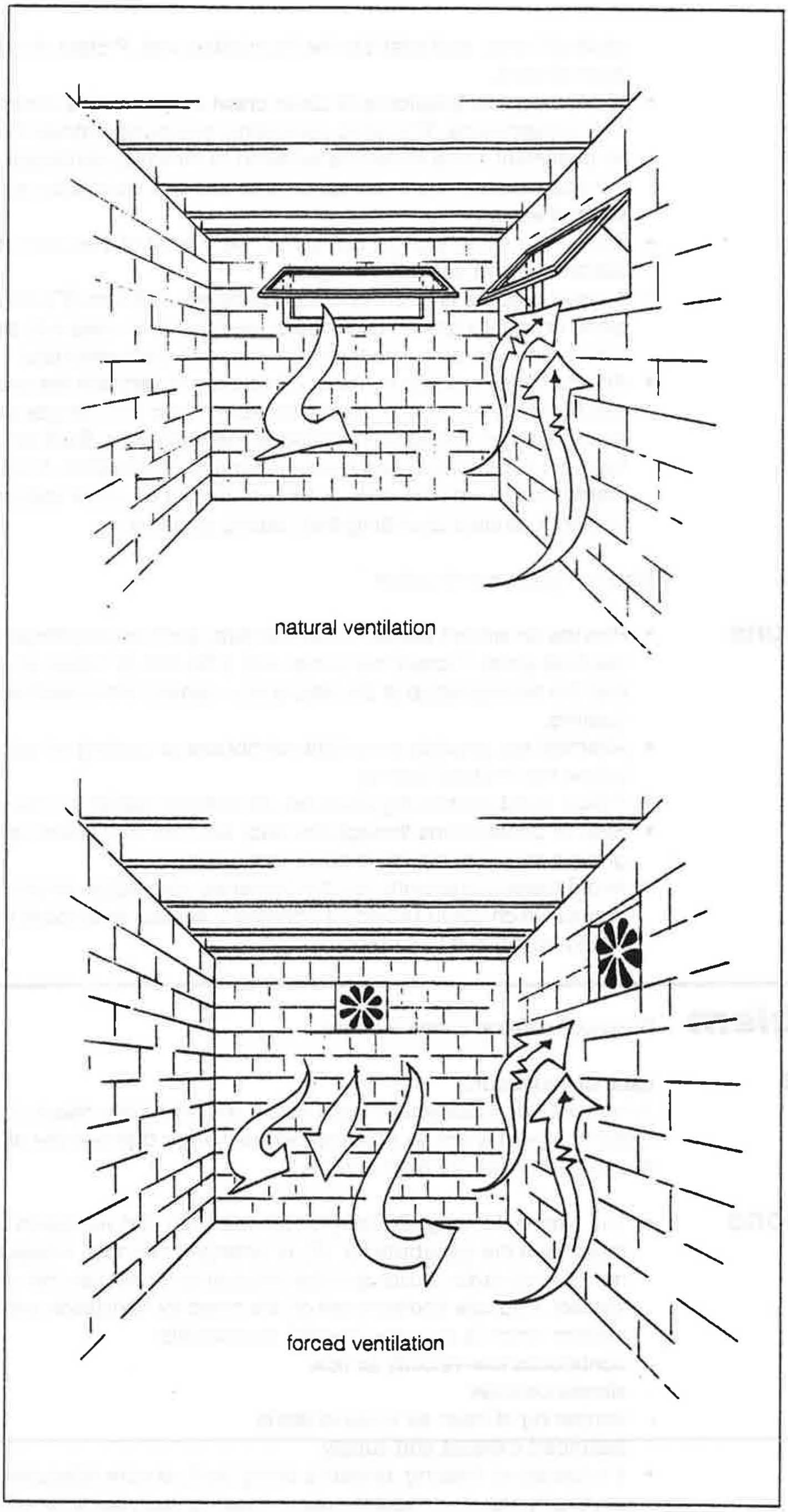

Fig. 13. Natural ventilation helps lower radon concentrations but it is not a permanent solution. A ventilation system should balance air exchange between the inside and the outside of the house.

Building Radon Control Features into a House

The level of radon concentration in a house is virtually impossible to estimate before the house is built. Not only are there many factors in house construction and local environmental conditions that affect radon levels, but the lifestyle of the house's occupants will also have its impact. Houses of similar construction adjacent to each other have been shown to have widely different indoor radon concentration levels. Soil gases move more easily through porous soils than clay soils, so that houses built on clay generally have lower radon levels. For the most part, studies and surveys have not provided consistent results for predicting radon-prone areas. See fig. 14.

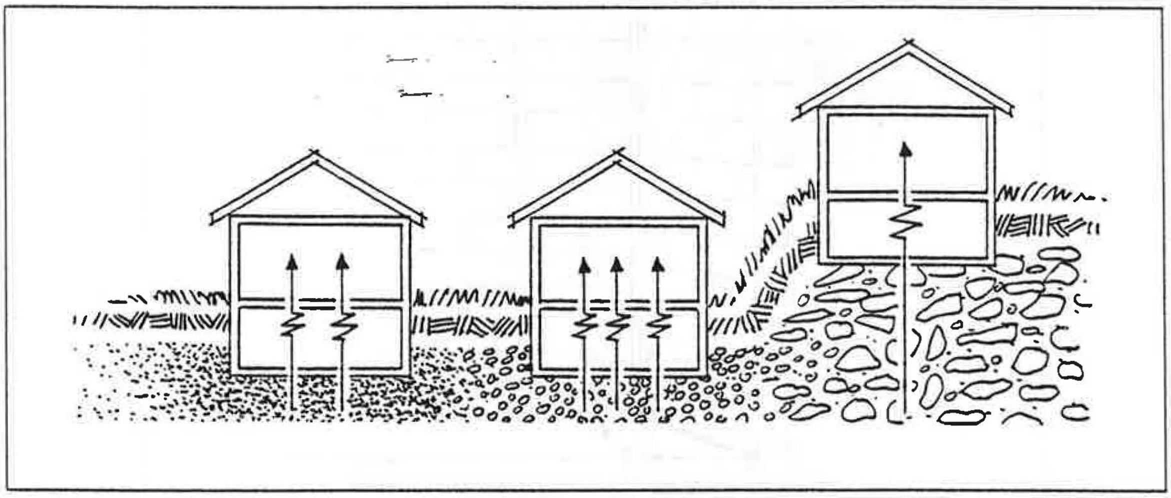

Fig. 14. Houses of similar construction adjacent to one another can have different radon levels depending on such factors as the soil under the house and the location, which may affect the house's air exchange.

Methods are being developed which may give an answer someday, but it is likely that the cost of measuring radon will be higher than the cost of putting in radon-control systems or facilitating features. It is obvious which is preferable.

Health and Welfare Canada has carried out studies to identify areas where radon measurements in existing houses have shown high concentrations. Contact HWC for further information.

Problem

Building in high radon areas.

If you follow the recommendations in this booklet, you will reduce radon concentration in a house. However, if you are building a house in an area known to have houses with high radon levels, you should consider some of the systems specifically designed to help builders construct "radon-resistant" housing in problem areas.

Cause

Lack of sub-slab ventilation.

The largest area for soil gases to enter basements or slab-on-grade houses is from gaps in or around the concrete floor.

Solution

- Draw soil gas and radon out from that space and away from the house. This has proved to be one of the most effective and efficient means of radon control for new and existing houses. See fig. 15 for how the system works.

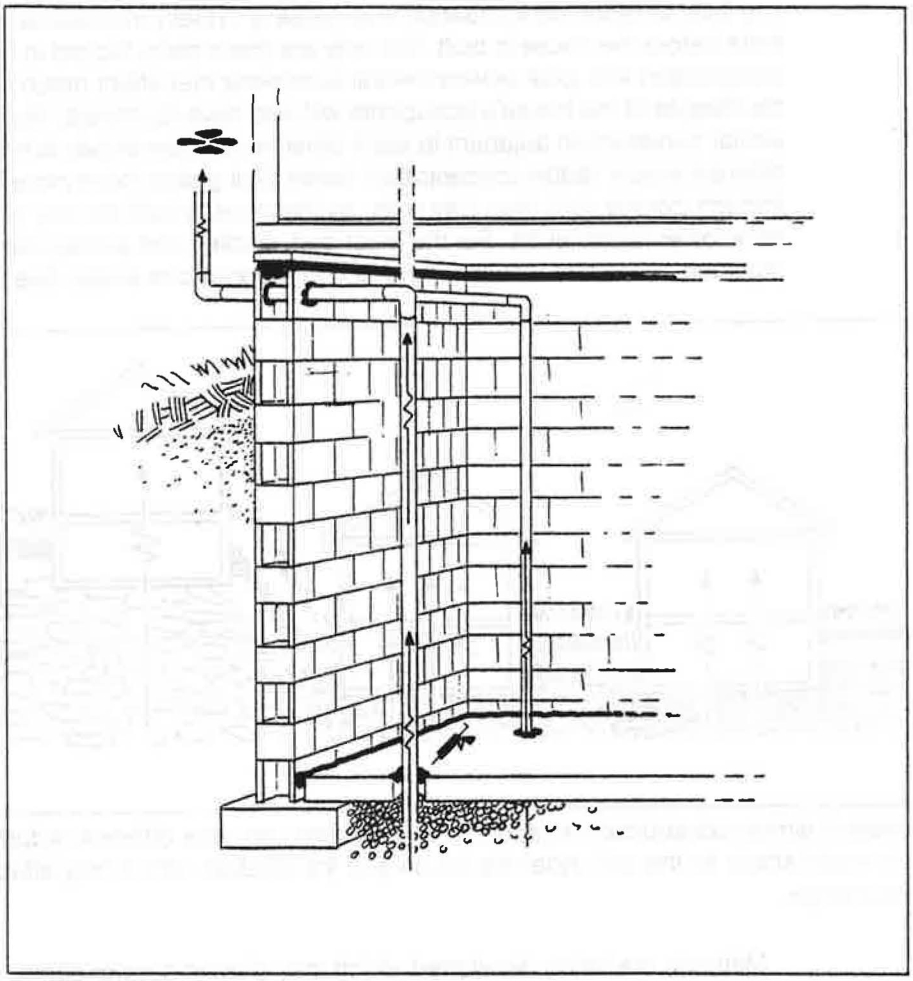

Fig. 15. A sub-slab ventilation system.

There are three basic elements to this system:

1. Use a coarse aggregate under the slab to a depth of at least 100 mm (4″). The aggregate must be coarse to permit the ventilation pipe to collect soil gas under the entire slab from one point. This is the only component of the system that cannot be retrofitted at moderate cost.
2. Install a pipe to carry the gas out from under the slab. The pipe should be at least 100 mm (4″) in diameter, penetrate the slab completely and extend into the aggregate at least 100 mm (4″). The pipe can also be connected to a loop of weeping tile below the basement slab.
Excavate the section around the pipe deeper than usual and provide a minimum aggregate depth of 150 mm (6″) to ensure a free flow of any gases.
Cap the pipe for future use. Tightly seal the area around the pipe and the slab.
3. After completion of the house, test for radon levels in the basement. If levels are high, uncap the pipe and vent to the exterior. If a passive system is used, the vent should exhaust at a point above the roof ridge to ensure upward flow. If a mechanical system is used, install a fan outside the living space (in an attic, crawl space, or on the exterior), so that any leakage in the system will not cause radon to enter the liveable area of the house. The fan should be rated for continuous operation. EPA demon-

strations have used 135 L/s in-line fans successfully. The house should be retested after the system is operational.

Perimeter weeping tile ventilation

- Using a similar approach to sub-slab ventilation, it is possible to draw soil gases away from the basement by depressurizing the drainage tile around the perimeter of the house. This requires a trap between the perimeter tile and the municipal sewer system — otherwise, the ventilation system would be trying to depressurize the entire municipality. This use of a trap has raised questions about possible silting up of the drainage system. As with sub-slab ventilation, the system can be ventilated passively or mechanically, or left capped, depending on the severity of the radon problem.

Sump ventilation

- As above, the weeping tile can be used to draw soil gas from around the basement to the sump pit and exhaust it to the exterior. This again requires a trap between the house drainage system and the municipal sewer.

Remedial Measures

A number of remedial measures to lower the concentration levels of radon in houses are possible depending on the cause. The first step is to find the problem. There are numerous books and guides on the subject, many of which are listed at the end of this booklet.

A number of retrofit projects can be undertaken. Here is a short list of some of the most common steps to take:

- trap drains and install gas traps
- seal the sump pump
- double check the sealing on all basement walls and floors, especially at the slab/wall intersection and at openings for utilities
- improve ventilation in the house
- depressurize the soil around the basement with sub-slab ventilation, weeping tile ventilation, or sump ventilation.

Building-in Protection for the Future

You may not feel that the addition of specific radon-control systems is appropriate for the house you are building. However, particularly in radon-prone areas, you may want to take measures to build the house in such a way that installing radon control systems later will be easier and much less costly.

Sub-Slab Suction

A good amount of aggregate of a coarse size and a ventilation pipe that penetrates the floor slab will make sub-slab suction an easy task. The pipe must be capped and sealed when not used.

Run ventilation pipes parallel to the plumbing stack or furnace chimney to make it easy to install a suction ventilation system later. Connection to a fan is all that remains to get the system operative.

Install an electrical socket near the point of exit of the exhaust pipe to run a fan in the attic or outdoors; this will make it easy to get the system running.

Perimeter Weeping Tile Ventilation

It is not difficult, during construction, to connect pipes for a ventilation system to the weeping tile drain around the house, and add water-trapping to the drain tile discharge. If left till after construction, digging down to the drain could mean destroying attractive landscaping. See fig. 16.

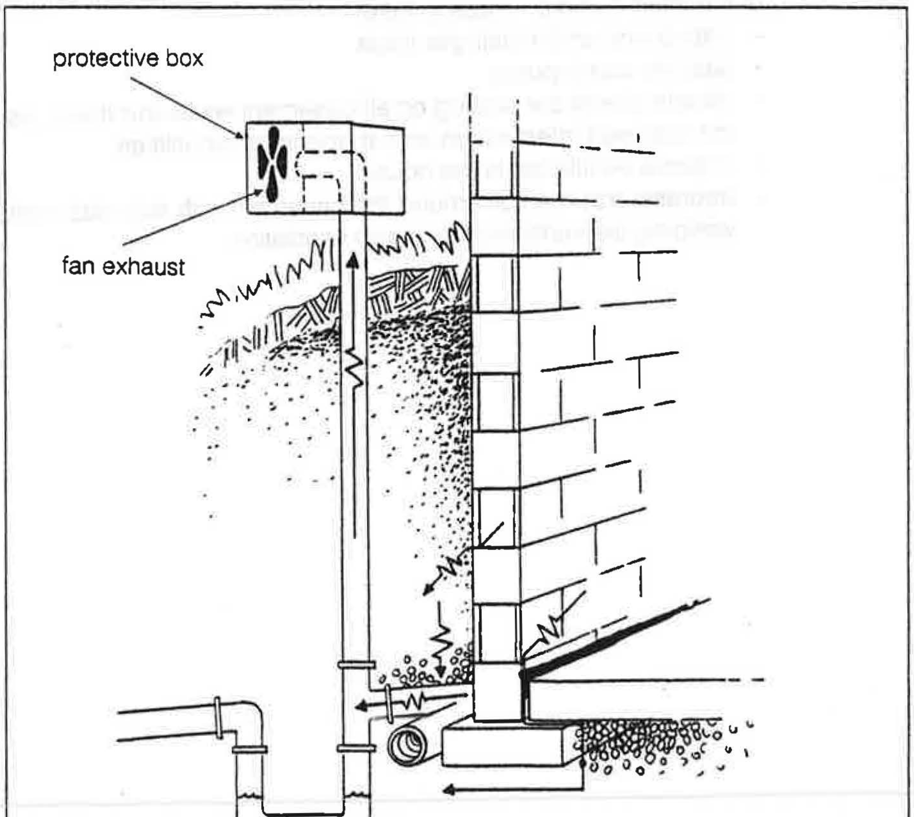

Fig. 16. The perimeter weeping tile drain can be used to draw radon away from the house.

Sump Ventilation

The sump cover sealing and pipe work for a sump ventilation system can be installed at the time of construction. If a radon problem arises later, it is a small job to add an exhaust fan to the pipe to draw radon away from the house. This method is effective. It is not complicated or costly to install and means that systems to combat possible radon build-up in the house are already in place in the house design.

A few additional steps like the ones described above, carried out during construction, could save lots of time and money later if radon problems arise.

Measuring Levels of Radon Concentration

Although the health risks related to radon primarily depend on an individual's personal exposure levels, as a builder you will want to get a measurement of radon gas present in a house. There are two readily available and popular measuring devices for radon gas: alpha track detectors and activated charcoal detectors. You can expose these devices to the indoor environment of the house and have their content analyzed to get a reading of radon levels. Charcoal devices will suit your needs best. Alpha track devices require more time for measuring radon, and are often used as a follow-up to charcoal canister measurements. Alpha track devices need to be in the house for three months or longer to record an approximation of the average exposure to radon a person living in the house would be subjected to over a period of time.

Charcoal detectors consist of containers that allow radon gas to enter and be absorbed by the charcoal. The container is then shipped back to the manufacturing company's lab for analysis. The detector should be placed in the lowest level of the house and the area closed for at least twelve hours before the test. The test lasts from one to three days so that it is possible to get a reading of highest levels of radon. It is wise to remember, however, that radon concentration levels fluctuate significantly at different times of the year, between morning to night, and because of other uncontrollable factors. The quick reading you get from such a test is not necessarily representative of a constant radon level in the house. Radon levels tend to be higher in winter, at night, and after a low-pressure front has moved through. See fig. 17.

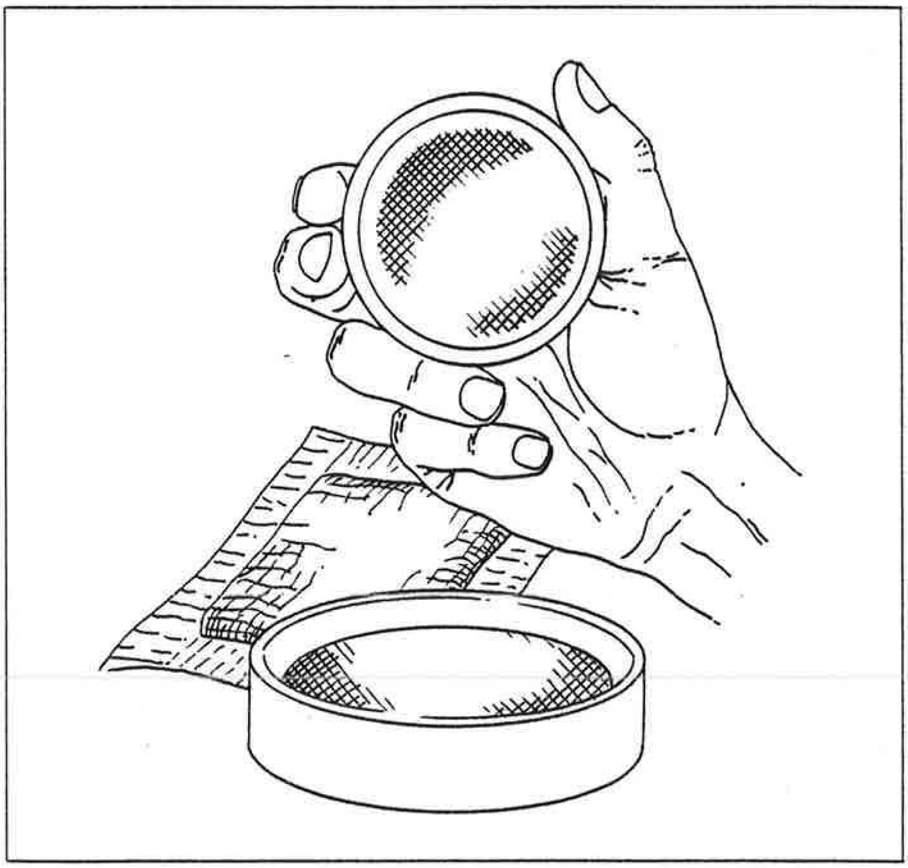

Fig. 17. Activated charcoal measuring devices come in a variety of types. Shown here are a "tea-bag" collector and a charcoal canister.

In alpha track detectors, a small sheet of polycarbonate plastic is damaged by the alpha radiation from the radon to which it is exposed. When the container is returned to the company, the damage marks are counted to reveal the level of radon to which the plastic was exposed. A minimum of three months is needed for the alpha track method, which is best suited to follow-up measurements by a homeowner or in cases where a charcoal detector showed high levels of radon concentration. See fig. 18. There is also growing use of more sophisticated detectors which provide instantaneous direct-count readings. While considerably more expensive, these provide increased accuracy and assist in identifying exactly where radon is entering.

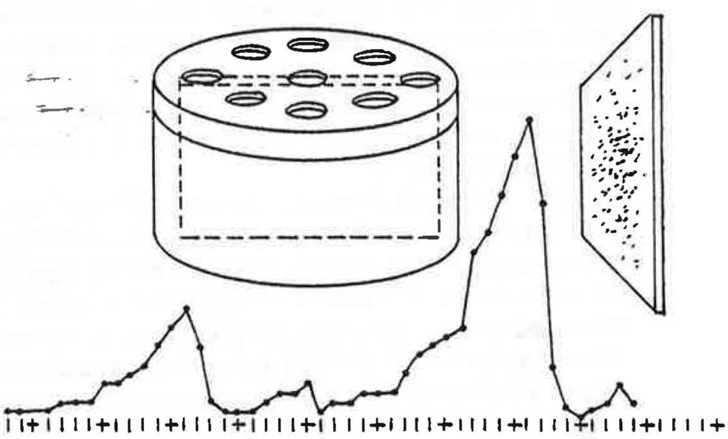

Fig. 18. The alpha track measuring device has a piece of plastic inside it that shows the effects of alpha radiation when the film is developed in the lab.

The results of the measurements you take in the house (and much of the information you read about radon) may be given in one or more of three measurement units: picoCuries per litre, (pCi/L), Becquerels per cubic metre, (Bq/m^3) or Working Levels (WL). These measurements were developed over time in different phases in the study of radon.

Radon was among the first of the radioactive elements to be discovered in the 1890s and there have been a variety of different measurements used since then. The first unit was the Curie (Ci), named for the discoverer of radium. Concentrations in houses are usually expressed in units of (10 to the-12 or one millionth of a millionth of a Curie) picocuries per litre of air, written pCi/L.

Recently, radiation measurements have been standardized to the metric system, and the Ci has been dropped as a special measurement unit. Concentrations are now measured in Becquerels per cubic metre, written as Bq/m^3. One pCi/L equals 37 Bq/m^3.

Measurement of airborne radon daughters was introduced by the uranium mining industry during the 1950s to provide a rapid indication of risk. The unit of measurement was the Working Level (WL) maximum concentration that a miner was allowed to work in. The ratio between radon and its daughters varies with conditions, but in most houses, 800 Bq/m^3 (about 20 pCi/L) produces about 0.1 WL. Much of the available information about radon gives measurements in WL and pCi/L.

There is a great deal of debate over what level of radon concentration inside a house presents how much of a health risk. Lung cancer develops as a result of a person's exposure to elevated levels of radon in the air breathed. How much time an individual spends in a part of the house with high radon concentrations will have a significant impact on the dose of radon delivered to the lungs. How long a person lives in a particular house is another factor. Current research suggests that long periods of exposure to relatively moderate levels of radon may be more dangerous than shorter exposure to higher levels.

The normal radon concentration in average outdoor air is about 8 Bq/m³. There is very little risk to people at this level. Inside a house, radon levels are typically five times as great. However, much higher levels have been found in many areas throughout Canada and thus the concern about radon in indoor air

The time at which to take action, based on the measurement of radon in a house, is a decision that builders or homeowners must make for themselves. There are as yet no standards or legal limits. Health and Welfare Canada recommends that a house with a radon level of 800 Bq/m³ should be treated within twelve months of testing with some method to lower the level. The guidelines suggest that at a radon level of 150 Bq/m³ no remedial action is necessary. See fig. 19.

The Environmental Protection Agency (EPA) in the United States developed the chart shown in fig. 20. It is a convenient way to show the health risks of radon in lung cancer and more familiar causes of lung cancer. In this chart, the WL is given as constant over 70 years. The figures arrived at are based on an individual's being exposed to this environment for 75 percent of the time over those years. You can understand from this why the ranges are so wide and why it is difficult to apply this to any specific situation.

The Department of National Health and Welfare has developed the following radon guideline:

The level at which remedial action is recommended for naturally occurring radon in indoor air is 800 Bq/m³ as an estimated annual average under normal living conditions.

For any house exceeding 800 Bq/m³, remedial action should be carried out within twelve months after confirming measurements.

The Department of National Health and Welfare is of the opinion that at a radon level of 150 Bq/m³, no remedial action is necessary. This level can also be considered as a goal for any remedial action in occupied housing with radon concentrations above this level.

For any radon level, it is acceptable for individuals to apply the principle of "as low as reasonably achievable" taking into account the cost of mitigation or other non quantifiable factors when trying to reduce the level in their homes.

For newly constructed and previously unoccupied buildings, the goal for radon concentration in indoor air shall be 150 Bq/m³ averaged over one year.

For this guideline, 800 Bq/m³ is equivalent to 0.1 WL and 150 Bq/m³ is equivalent to 0.02 WL *(fig. 20).*

Fig. 19. Draft: A Radon Guideline for the Department of National Health and Welfare.

Bq/m³	pCi/L	WL	Estimated number of cancer deaths due to radon (out of 1000)	Comparable exposure levels	Comparable risk
8000	200	1	440-770	1000 times average outdoor level	More than 60 times non-smoker risk
					4 pack-a-day smoker
4000	100	0.5	270-630	100 times average indoor level	
					20,000 chest x-rays per year
1600	40	0.2	120-380		
					2 pack-a-day smoker
800	20	0.1	60-210	100 times average outdor level	
					1 pack-a-day smoker
400	10	0.05	30-120	10 times average indoor level	
					5 times non-smoker risk
160	4	0.02	13-50		200 chest x-rays per year
80	2	0.01	7-30	10 times average outdoor level	
					non-smoker risk of dying from lung cancer
40	1	0.005	3-13	Average indoor level	
8	0.2	0.001	1-3	Average outdoor level	20 chest x-rays per year

Adapted from EPA chart

Fig. 20. The Radon Risk Evaluation Chart compares the estimated risks associated with exposure to radon with the more familiar contributors to lung cancer.

Will Growing Awareness of Radon Problems Affect My Business?

The awareness of the problem is probably very low in most areas, but it is certainly growing. In areas where the problem has been around for a long time and been recognized by the community, concern can be quite high.

Whatever the level of awareness or concern in the area you work, it is to your advantage to help the public get correct information. It is often vague notions about health risks that cause the biggest problems. If people understand the problem of radon in houses, they will understand what can be done to alleviate the problem.

There is as yet no legislation in place today that requires a builder to "radon-proof" houses, except in designated high-radon areas of Ontario (by the Ontario Building Code). However, changes proposed for the 1990 National Building Code will require more airtight basement slab construction, and the prevention of air flow upward from drains and sumps. A proposed Appendix will describe recommendations for sub-slab venting systems.

It is a rare occurrence in Canada for a "radon clause" to be found in a house sales contract. Such clauses are common in some areas of the United States. Some buyers and sellers put radon control money in escrow for a period of a year or other reasonable amount of time for the homeowner to carry out radon measuring.

The builder who addresses the problem honestly with the homebuyer will gain the respect of that buyer and the community. By showing that you are aware of the issue and are taking steps to do something about it, you enhance your professionalism.

Additional Reading

The Canadian Home Builders' Association, *Builder's Note #2: Radon*, Ottawa, Ontario.

CAIRS (Canadian Institute for Radiation Safety), *Radiation Safety Bulletin*, Vol. 4, No. 1, April 1986, Toronto.

Cohen, Bernard and the Editors of Consumer Reports Books, *Radon — A Homeowner's Guide to Detection and Control*, Consumers Union, New York, 1987.

United States Environmental Protection Agency (EPA)

A Citizen's Guide to Radon, What It Is and What To Do About It (with the U. S. Department of Health and Human Services), OPA-86-004, August 1986, Washington, D.C.

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Radon Reduction In New Construction, an Interim Guide, Offices of Air and Radiation and Research and Development, OPA-87-009, August 1987, Washington, D.C.

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Radon/Radon Progeny Measurement Proficiency Program, Cumulative Proficiency Report, Office of Radiation Programs, EPS 520/1-87-015, July 1987, Washington, D.C.

Nazaroff, William W. and Anthony V. Nero Jr., Editors, *Radon and Its Decay Products in Indoor Air*, John Wiley & Sons, Inc., New York, 1988.

Publications on Related Topics and Building Practices

CMHC (Canadian Mortgage and Housing Corporation):
Ventilation: Health and Safety Issues, NHA 5888 08/86, Ottawa, Ontario.
Concrete Foundations, NHA 5892 01/87, Ottawa, Ontario.

The Canadian Home Builders' Association, *Builder's Note #1: CGSB Standard for Polyethylene*, Ottawa, Ontario.

Portland Cement Association, *Concrete Floors on Ground*, Second Edition, 1983, Skokie, Illinois.

Sources of Information

Provincial Offices Available to Answer Questions about Radon

Radiation Health and Safety Services
Occupational Health and Safety Division
Government of Newfoundland and Labrador
Department of Labour and Manpower
Beothuck Building, Crosbie Place
St. John's, Newfoundland
A1C 5T7

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Tel: (306) 787-4486

Radiation Health Branch
Occupational Health and Safety Division
Community and Occupational Health
4th Floor, Donsdale Place
10709 Jasper Avenue
Edmonton, Alberta
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Tel: (403) 427-2691

Radiation Protection Service
British Columbia Ministry of Health
307 West Broadway — Suite 200
Vancouver, British Columbia
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Tel: (604) 660-6630

Other Sources

Ontario Research Foundation
Sheridan Park Research Community
Att: Peter Piersol (Consultants)
Mississauga, Ontario
L5K 1B3

Tel: (416) 822-4111

Canadian Institute for Radiation Safety (CAIRS)
595 Bay St. — Suite 1050
Toronto, Ontario
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Tel: (416) 596-1617

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