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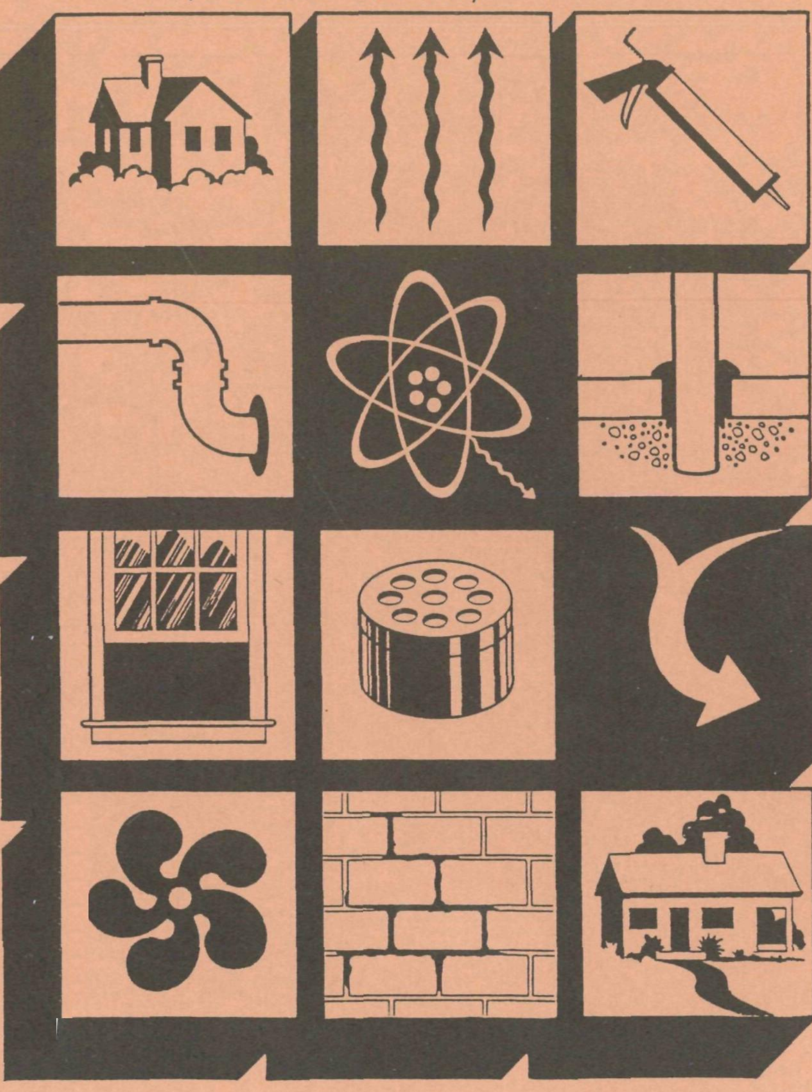
Research and Development

EPA

Radon Reduction Methods

A Homeowner's Guide

(Second Edition)



EPA Study

The U.S. Environmental Protection Agency (EPA) is studying the effectiveness of various ways to reduce high concentrations of radon in houses. While our work is far from complete, we have gained some information which may be of immediate use to homeowners. We are publishing this booklet to share what we have learned with those whose radon problems demand prompt action.

The booklet describes methods that have been tested successfully—by EPA and/or other research groups—on houses with high indoor radon levels. The information presented here is concerned primarily with radon which enters a house from the underlying soil. *Additional information will be* published as it becomes available.

Unique Problems

The first lesson to learn about radon reduction is this: No two houses are alike. Even houses that look the same have small differences in existing conditions that can affect radon entry and the design and effectiveness of reduction techniques. Underlying soils also vary greatly, even among houses which sit close together. These differences will affect the results obtainable from using the radon reduction methods described here.

General Information

This booklet is intended primarily for homeowners who already have had their homes tested for radon and have decided that they need to take some action to reduce radon levels. If you are uncertain of the meaning of such test results, or if you need general information about radon in houses, read the EPA booklet, *A Citizen's Guide to Radon: What It Is And What To Do About It* (OPA-86-004). To get a copy, contact your state radon program office (see list at the end of this booklet).

Performing screening and *follow-up* measurements prior to a decision to mitigate (that is, to reduce radon levels), is strongly encouraged. The results of follow-up measurements will enable the homeowner to make a *well-informed decision* about health risks and the need for remedial action. As mitigation often entails spending a significant amount of money, follow-up measurements should be reliable estimators of the actual maximum potential exposures of the occupants.

Using Contractors

Many radon remedies require the skilled services of a professional contractor who is experienced in radon reduction procedures. (EPA and the states are currently working to increase the number of experienced contractors.) Due to the skills required, do-it-yourself *efforts are recommended only for* homeowners with these special skills.

This booklet does not attempt to give the homeowner detailed instructions for corrective action. But, the information here should help you make informed decisions on what type of remedy is needed, and may assist you in evaluating proposals from contractors.

We cannot overemphasize the importance of carefully selecting a contractor and reviewing any proposal for radon reduction work at your house. Asking for business references and checking with your local Better Business Bureau or Chamber of Commerce will help you ensure that a contractor is reputable. Many states will provide lists of contractors doing radon mitigation work, and some states have certification programs for radon measurement and mitigation.

Getting a second opinion from another contractor or from one of your state's radiological health officials can help you decide if a proposal is reasonable. You should be certain to get a written estimate of costs which stipulates the work to be done. Because radon reduction work is so new, most contractors will not guarantee a reduction in radon levels.

A few contractors may be willing to guarantee a radon concentration of less than 4 pCi/L (picocuries per liter);

however, for a contractor to make this promise he should first thoroughly evaluate the potential for radon reduction methods to work in your home.

Technical Information

Those homeowners who are confident they have the tools, equipment, and skills to do the job themselves may want to read EPA's more detailed manual, *Radon Reduction Techniques for Detached Houses: Technical Guidance* [EPA/625/5-86/019]. Single copies can be obtained by writing:

U.S. EPA
Center for Environmental Research Information
26 West St. Clair Street
Cincinnati, Ohio 45268

Methods

This booklet describes various methods which may reduce the level of radon in your house—either by preventing its entry or by replacing contaminated indoor air. Some of the methods are simple, some are complex, and some are much more expensive than others.

The effectiveness of any one method will depend upon the unique characteristics of each house, the level of radon, the routes of radon entry, and how thoroughly a job is done. No one can guarantee that these methods will work as they did in the test houses.

Sometimes a single method may be sufficient, but often—especially where levels are high—several methods will need to be combined to achieve acceptable results.

Mitigation Follow-up

Once an action (or combination of actions) has been performed, it is important that you have further testing done to determine the level to which radon has been reduced. Some states provide this service. If the radon levels have not been satisfactorily lowered, additional mitigation steps may be taken, and the testing process repeated. All tests should be performed in exactly the same manner as the test which confirmed the high radon levels in your house.

Due to the many factors affecting the performance of any reduction technique, a trial-and-error approach often will be necessary to achieve lasting radon reductions. If short-term testing indicates that radon has been reduced to an acceptable level, you may wish to test on a long-term basis.

Before Choosing a Radon Reduction Method

The selection of appropriate and cost-effective radon reduction techniques for a specific house depends on how well the source of the indoor radon problem is understood, how house characteristics affect radon entry rates, and how candidate radon reduction systems influence the radon entry process. Definition of these factors is possible through a series of diagnostic observations and measurements made before, during, and after radon reduction systems are installed.

Diagnostics begin with a house survey. This involves visual inspection to identify possible radon entry routes and any construction features which could influence the design of later radon reduction techniques. Diagnostics should also include an evaluation of the ease of soil gas movement underneath the concrete slab if sub-slab soil ventilation is a potential control option. If ventilation techniques are to be considered, the natural air infiltration rate also should be measured. The measurement of radon levels in well water is a good way to learn whether water is an important contributor to the airborne radon level. Similarly, measuring gamma levels inside and outside the house can help identify the possibility of building materials as a radon source.

As with radon reduction techniques, the skills needed to perform radon diagnostics are beyond the capabilities of most homeowners. Diagnostic methods are mentioned here only as supplemental information to assist homeowners when working with radon diagnosticians and mitigators.

New Construction

If you are planning to build a new home and are concerned about the potential for elevated indoor radon levels, you should consider measures to prevent radon entry into the house. It is typically less expensive to build a home that resists radon entry than to reduce a radon problem after construction.

A recent EPA document, *Radon Reduction in New Construction: An Interim Guide* (OPA-87-009), is available to assist home builders and others interested in potential radon prevention alternatives in new construction. The suggestions contained in this guide represent current knowledge and experience gained primarily from radon reduction tests and demonstrations on existing houses.

Until some of these techniques have actually been applied during the construction of new homes, the applicability, cost-effectiveness, radon-prevention effectiveness, and durability of the techniques cannot be fairly assessed. Ongoing EPA-sponsored field testing of radon prevention techniques in new construction should provide a better evaluation of radon prevention alternatives. The results of these studies will be published in future technical guidance documents.

Radon in Water

The potential concern with radon in water is the airborne radon released when water is used. The amount of radon that is given off from water depends on the amount in the water initially. The amount given off will increase as the temperature of the water increases and as the surface area exposed to air increases.

In the home, activities and appliances that spray or agitate heated water (showers, dishwashers, and clothes washers) create the largest release of waterborne radon. However, the level of radon in household water must be very high to significantly influence the overall level in the air within a house. As a rule of thumb, 10,000 pCi/L of radon in the incoming household water is equivalent to 1 pCi/L of radon in the indoor air.

In some areas, especially in the northeast and west, water from private wells or small community water systems can contain sufficient radon to contribute significantly to elevated levels within a house. Water from large community water supplies releases most of its radon before it reaches individual houses.

Two techniques can be considered to remove radon from water. The first requires either spraying water into a contained air space, introducing air bubbles into the water, or storing water in a tank until the radon has decayed. The second uses granular activated carbon (GAC) to remove radon from the water. The GAC method has been more widely tested and is more commonly used in individual homes. Radiation buildup in the unit itself may cause exposure and disposal problems.

For more detailed information on radon in water see the recent EPA booklet, *Removal of Radon From Household Water* (OPA-87-011).

Air Cleaners

The radon reduction methods discussed in this booklet concentrate on methods of removing radon gas or preventing radon gas from even entering the house. Since the radon health hazard is associated with the products of radon decay (which are chemically active), and not the radon itself (which is an inert gas), it is appropriate to ask whether it is feasible to remove the radon decay products without removing the radon gas itself.

Air cleaners are devices which either filter or electrostatically remove particles—such as dust or radon decay products—from the air. Air cleaners are commonly used to condition indoor air for a variety of health and comfort reasons, and there have been attempts to market air cleaners to reduce radon decay products. **At this time, EPA does not endorse the use of air cleaners as a method of reducing radon decay products in indoor air because this technology has not been demonstrated to be effective in reducing the health risks associated with radon.**

Although air cleaners will remove some of the radon decay products, many questions remain concerning the relative health effects of the decay products that are not removed and the potential impacts of the undiminished source of radon decay products. Until more is known, EPA believes that the available data do not warrant discontinuing the use of air cleaners already installed, nor can we suggest installing air cleaners to reduce your risk of exposure to radon and its decay products.

Some people also ask whether the radon gas itself can be removed from the indoor air. While some limited research has been done on using charcoal to filter the air, it appears that extremely large quantities of charcoal would be required. This is not yet a demonstrated or even clearly feasible approach.

Natural Ventilation

How It Works

Replaces radon-laden indoor air with outdoor air and neutralizes pressure. This is most often achieved by opening windows.

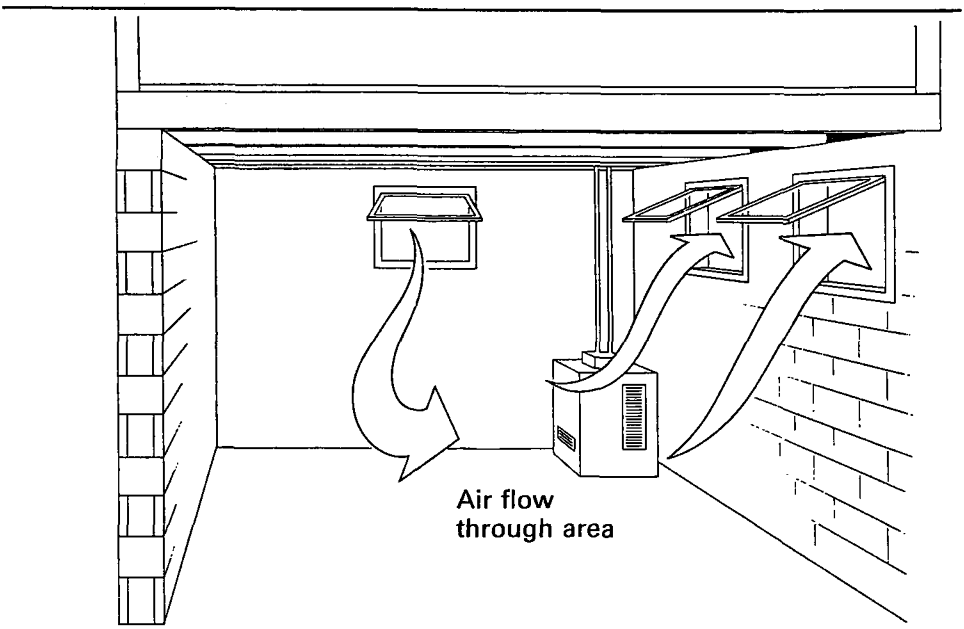
Some natural ventilation occurs in every house as air is drawn through tiny cracks and openings by temperature and pressure differences between indoor and outdoor air. In the average American house, outside air equal in volume to the inside air infiltrates about once every hour. In technical terms, this is called 1.0 ach (air changes per hour). Newer houses, which are generally "tighter," may have air exchange rates as low as 0.1 ach (one-tenth that of the average house). The rate in older houses, on the other hand, may be more than twice the average (2.0 ach).

Cost

There are no installation costs unless devices must be purchased to hold windows or vents in an open position, or to detect or prevent unauthorized entry through these openings.

Use of natural ventilation in cold weather will increase your heating costs substantially. For example, if you were to increase the air exchange rate to eight times its normal level in your basement and still maintain comfortable temperatures there, your annual house heating bill could be as much as three times greater than normal.

If you normally run an air conditioner in hot weather, your cooling costs will be similarly greater.



Reductions

The *opening of windows, doors, and* vents is a very effective, universally applicable radon reduction technique that can be readily implemented by the homeowner. If done properly, natural ventilation is consistently capable of high reductions, probably above 90 percent if a sufficient number of windows and vents is opened. High reductions result because natural ventilation both reduces the flow of soil gas into the house, by neutralizing the pressure difference between indoors and out, and dilutes any radon in the indoor air with outdoor air.

Limitations

The primary shortcoming of natural ventilation is that extreme weather makes this technique impractical year-round in most parts of the country, due to discomfort and/or increased heating and cooling costs. Open windows can also compromise the security of the house.

Procedure

You should ventilate the lowest level of your house, where it is in direct contact with the primary source of radon: the soil. If you have a basement or crawl space, that is the area to ventilate. (If you ventilate your basement, you may find it more economical or comfortable to close it off and limit its use.) If your house sits on a concrete slab, then your only choice is to ventilate the living area. Opening windows around all levels of your house (including the main living area) is recommended whenever outdoor conditions permit.

As noted earlier, radon is drawn into your house when the air pressure in the basement or lowest level is less than the air pressure in the surrounding soil. Therefore, it is imperative that any ventilation system does not further reduce the air pressure within your house and increase this "pull." To guard against this, be certain to open vents or windows equally on all sides of the house. Also, avoid the use of exhaust fans.

When ventilating unheated areas, be sure to take precautions to prevent pipes from freezing.

Forced Ventilation

How It Works

Replaces radon-laden indoor air with outdoor air and neutralizes pressure if the fan is big enough. Uses fans to maintain a desired air exchange rate independent of weather conditions. (Much of the information in the preceding section on "Natural Ventilation" is applicable to "Forced Ventilation" as well.)

Rather than relying on natural air movement, forced air fans can be used to provide a controlled amount of forced ventilation. For example, a fan could be installed to continuously blow fresh air into the house through the existing central forced-air heating, ducting, and supply registers with windows and doors remaining closed. Alternatively, fans could blow air into the house through protected intakes through the sides of the house, or could be mounted in windows. A fan could also be installed to blow outdoor air into a crawl space.

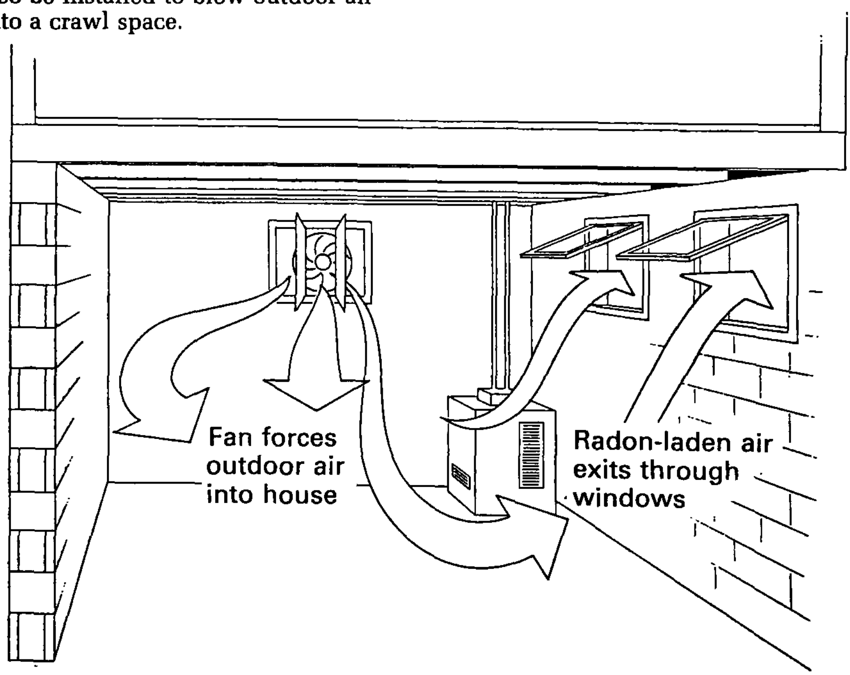
Cost

The installation costs for forced-air systems ranging from simple window fans to elaborate heating, ventilation, and air conditioning (HVAC) systems will range from $25 to as much as $1,000.

The additional cost of electricity for forced-air systems will vary depending upon the size of the fans, the number of fans used, and the amount of use. A single window fan can have electricity costs as low as $20 per year, while a central furnace fan may cost $275 a year to operate.

Use of forced ventilation throughout cold weather will substantially increase your heating costs. As with natural ventilation, if you were to increase the air exchange rate to eight times its normal level in your basement while maintaining comfortable temperatures there, your annual house heating bill could be as much as three times greater than normal.

If you normally have an air conditioner running in hot weather, your cooling costs will be similarly greater.



Reductions

As pointed out in the preceding section, "tight" houses with low air exchange rates are likely to benefit more from ventilation increases than are houses with high exchange rates. In a typical house, to achieve a 90-percent reduction of radon you will probably need a 500 to 1,000 cfm (cubic feet per minute) fan.

Limitations

Forced ventilation, like natural ventilation, can be employed in most houses, but, in many cases, the trade-off in decreased comfort and/or excessive heating or cooling costs may prove unacceptable. This approach may be useful as an interim measure with very high radon levels.

Procedure

You should ventilate the lowest level of your house. (Closing off and not using a basement may also be advisable.) Ventilating all levels is recommended whenever outdoor conditions permit. Air should be blown **into** the house and allowed to exit through windows or vents on adjacent or opposite sides. In many homes, blowing air in through an existing central furnace is quite practical. **The use of an exhaust fan to pull air out of the house may decrease the interior air pressure and draw more radon inside.** The use of whole-house fans is not recommended because they typically operate in the exhaust mode.

Air distribution and ventilation rates can be controlled by the sizing and location of fans and the use of louvered air deflectors. EPA's experience suggests that you should install two or three fans rated at twice the air moving capacity calculated to be needed for the desired increased ventilation.

When ventilating unheated areas, be sure to take precautions to prevent pipes from freezing.

Method

Heat Recovery Ventilation (HRV)

How It works

Replaces radon-laden indoor air with outdoor air.

A device called a "heat recovery ventilator" (sometimes referred to as an "air-to-air heat exchanger") uses the heat in the air being exhausted to warm the incoming air. In an air-conditioned house in warm weather, the process is reversed: The air being exhausted is used to cool the incoming air. This saves between 50 and 80 percent of the warmth (or coolness) that would be lost in an equivalent ventilation system without the device.

Installation

Ducted units are designed, installed, and balanced by experienced heating/ventilation/air conditioning contractors. Wall-mounted units are generally less complex, and can sometimes be installed directly by the homeowner.

Cost

Installation costs (materials and labor) will range from $800 to $2,500 for ducted units and are roughly $400 for wall-mounted units.

The cost for electricity to operate one of the larger units with two 200-cfm fans is about $30 per year.

Using a heat recovery ventilator could save you 50 to 80 percent of the increase in heating and cooling costs that would result from achieving a comparable amount of ventilation without heat recovery.

Reductions

A radon reduction of 50 to 75 percent can be achieved in houses of typical size and infiltration rate, assuming between 200 and 400 cfm of HRV capacity. Reductions can be greater in tight houses. Reductions will vary throughout the house, depending on ducting configurations.

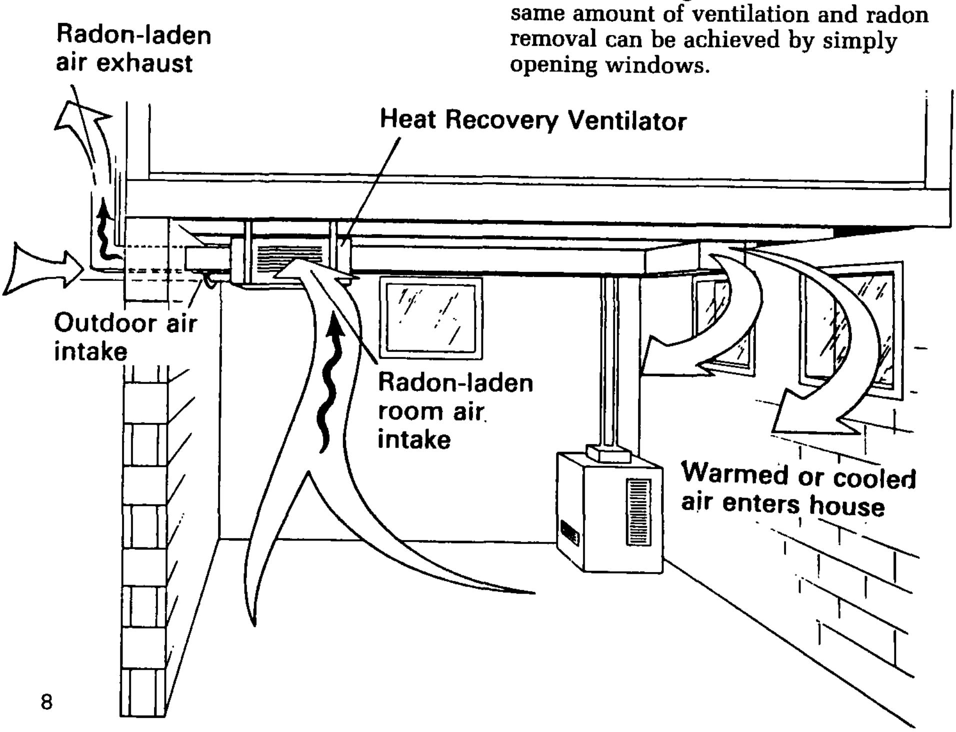
Limitations

The applicability of HRVs for radon reduction will likely be limited to situations where only moderate reductions are needed and where winters are cold. If an HRV is intended to serve as a stand-alone measure to achieve 4 pCi/L in a house of typical size and infiltration rate, the initial radon in the house could be no greater than 10 to 15 pCi/L. Greater reductions can be achieved in tight houses.

Procedure

To simplify the necessary ducting runs to different parts of the house, the heat recovery ventilator unit, consisting of the core and fans, can be located in an inconspicuous part of the house—such as an unfinished basement or utility room. Care must be taken to keep fresh air supply registers well-removed from return air withdrawal points, locating the radon-laden air returns in the basement or lowest level. It is crucial that the flow–rates in the fresh air intake duct and the radon-laden air exhaust duct be balanced. If more air is exhausted than is brought in, the house will become depressurized and even more radon may be drawn into the house. Be sure the balancing is done with no pressure difference between indoors and outdoors, since the unit will tend to maintain any pressure difference that exists when it is balanced.

Heat recovery ventilators are usually cost-effective only if operated during cold weather or in hot weather if the indoor versus outdoor temperature difference is large. At other times, the same amount of ventilation and radon removal can be achieved by simply opening windows.



Covering Exposed Earth

How It Works

Reduces the flow of radon into the house.

Exposed earth—in basement cold-rooms, storage areas, drain areas, sumps, and the like, as well as in crawl spaces—is often a major entry point for radon.

Installation

Requires installation by competent, experienced contractors or highly skilled homeowners.

Cost

Covering or sealing small areas (and ventilating covered air spaces as necessary) often costs under $100. Pouring a new slab would cost considerably more in a large unpaved area.

The annual cost for operating a fan would be about $30.

Reductions

Since radon can seep through any small opening, the degree of radon reduction achieved by sealing any particular area cannot be predicted. Effectively blocking a major entry point, however, should result in some reductions of the overall radon level in your house. In houses with marginal radon problems, covering exposed earth, along with sealing cracks and openings, may be a sufficient remedy.

Covering exposed earth is also likely to enhance the effectiveness of most other radon reduction methods, such as block-wall ventilation and sub-slab suction.

Limitations

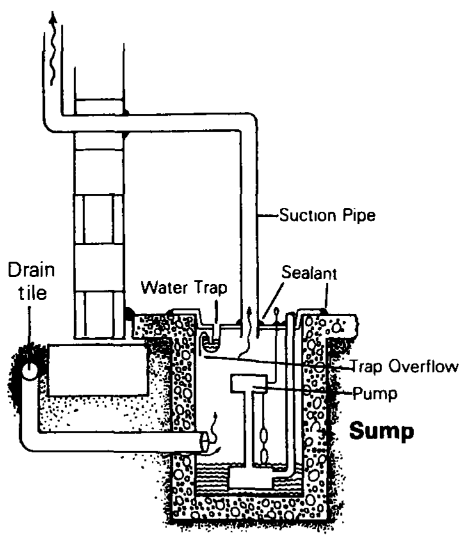
As a house settles and reacts to external and internal stresses, covered areas can open again. Therefore, periodic checking and maintenance are required.

Procedure

Any basement earthen floor should be excavated as necessary and a poured concrete floor installed. Before the concrete is poured, four inches of crushed stone should be placed over the earthen floor to permit easy radon reduction by sub-slab suction if needed at a later date. All joints must be carefully sealed. When the covering encloses an air space, such as that around a sump pump, a small fan should be installed to exhaust the air to the outside, preferably at roof level.

A crawl space connected to a basement can be covered, ventilated, and/or sealed off from the basement.

A crawl space not connected to a basement can be ventilated (as discussed in the section on natural ventilation), or the earthen floor can either be covered with a gas-proof liner (with passive vents to the outside) or covered with concrete.



Sealing Cracks and Openings

How It Works

Reduces the flow of radon into the house.

Radon is a gas that can pass through any opening in a floor or wall which touches the soil. It can enter your house through: openings around utility pipes, joints between basement floors and walls including perimeter (French) drains, other floor drains (especially those that discharge to dry wells), the holes in the top row of concrete blocks, and tiny cracks and openings (such as the pores in concrete blocks). Sealing such cracks and openings is often an important preliminary step when other methods are used. For houses with marginal radon problems, sealing alone may be sufficient.

In some houses, certain areas will be difficult, if not impossible, to seal without significant expense. These include: the top of block walls, the space between block walls and exterior brick veneer, and openings concealed by masonry fireplaces and chimneys.

Installation

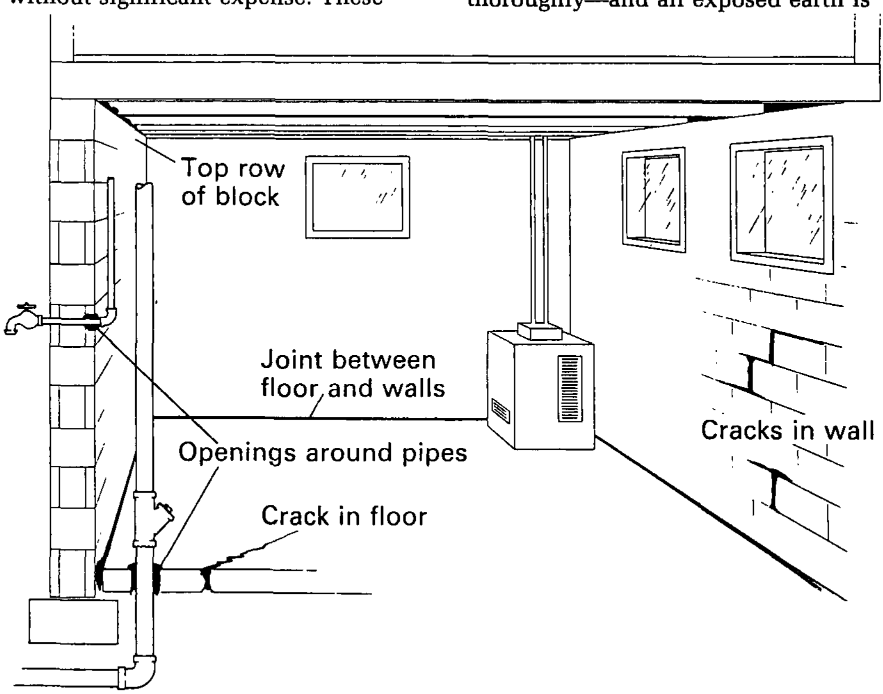
Since effective sealing generally requires meticulous surface preparation and carefully controlled application of appropriate substances, the work is often most effectively done by experienced and competent contractors or highly skilled homeowners.

Cost

Costs are highly variable. Do-it-yourself closure of accessible major entry points can be low in cost. Putting traps in drains and covering sumps can be low to moderate in cost. Applying membranes and coatings can be expensive.

Reductions

When sealing is used alone, you should expect only low to moderate reductions in radon levels. If sealing is done thoroughly—and all exposed earth is



covered—reductions may be sufficient in some houses. Sealing is required for block-wall ventilation and some sub-slab suction systems to work effectively.

Limitations

It is very difficult to find all the cracks and openings in your house. This method may have little effect on radon entry unless nearly all the entry points are sealed. Furthermore, settling of the house and other stresses may create more cracks as time passes. Also, the openings in the top row of concrete blocks in a wall are often inaccessible or otherwise difficult to seal tightly. As a house settles and reacts to external and internal stresses, old seals can deteriorate and new cracks can appear. The aging process ultimately ends the ability of sealants to block out soil gases. Therefore, checking and maintenance are required at least yearly.

Procedure

If possible, the holes in the top row of concrete blocks in the basement walls should be sealed with mortar or urethane foam.

Seal wall and floor joints with flexible polyurethane membrane sealants.

Cracks and utility openings should be enlarged enough to allow filling with compatible, gas-proof, non-shrinking sealants.

A water trap should be installed in floor drains connecting to drainage or weeping-tile systems. Water traps allow water that collects on basement floors to drain away but greatly reduce or entirely eliminate entry of soil gas, including radon. Water traps must be kept filled with water to be effective.

Perimeter drains (French drains) should be filled with a urethane foam; however, some alternative plan for water drainage should be provided.

Porous walls (especially block walls) require the application of waterproof paint, cement, or epoxy to a carefully prepared surface.

Drain-Tile Suction

How It Works

Water is drained away from the foundation of some houses by perforated pipes called drain tiles. Drain tiles are rarely completely filled with water. If these drain tiles form a partial or continuous loop around the house, they may be used to pull radon from the surrounding soil and vent it away from the house.

Installation

Normally requires installation and testing by competent, experienced professionals. Some homeowners, however, might be able to install a drain-tile suction system themselves (particularly where work inside the house does not require removing concrete).

Cost

Installation costs (labor and materials) would be between $700 and $1,500 for an exterior drain system and between $800 and $2,500 for a system that drains into a sump. The actual cost will largely depend upon the amount and location of piping and the fan location. For simple exterior installations, the cost of materials (fan, plastic piping, and some incidentals) should not exceed $300.

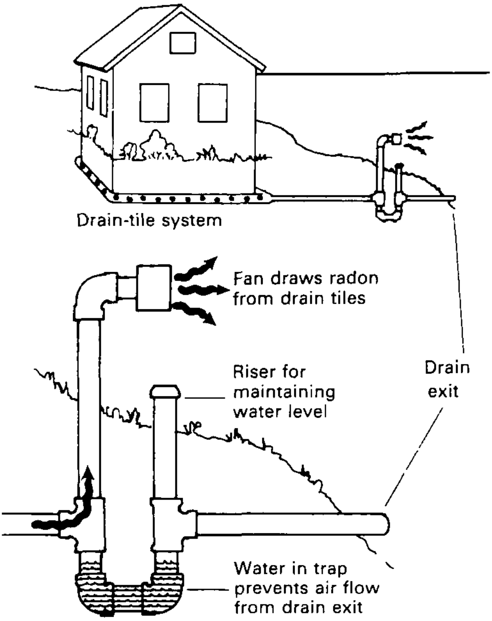
Operating costs should be roughly $30 per year for fan electricity and $100 per year for the heating penalty resulting from increased house ventilation.

Reductions

In some houses, the installation of a drain-tile suction system has resulted in radon reductions of over 99 percent.

Limitations

The primary disadvantage of drain-tile suction is that many houses will not



have complete drain-tile loops. Installation of drain tiles in houses that do not have them is sometimes not cost-effective. If some portion of the perimeter footing does not have drain tiles beside it or if the tiles are damaged or blocked, that portion of the perimeter might fail to be effectively treated. It is very difficult to determine how extensive the drain tiles are around a house. If drain tiles are likely to form a large portion of a complete loop, the advantages of the drain-tile suction approach may make it more cost-effective to try this approach first before attempting a more expensive technique.

Procedure

Water collected by drain tiles normally flows through a pipe to a drainage area away from the house or into a sump. Radon can be pulled from the soil beneath a house by attaching an exhaust fan to the collection pipe or to the sealed sump (see page 9).

To prevent outside air from being drawn from the end of the collection pipe, a water-filled trap should be installed in the pipe beyond the point where the fan is attached. This trap (similar to the trap beneath a kitchen sink) must be placed below the freeze line. The trap must be kept filled with water in order to be effective.

Method

Sub-Slab Suction

How It Works

The lowest floor of most houses, other than those built over crawl spaces, consists of a concrete slab poured over the earth or on top of crushed rock (aggregate). Radon can be drawn from under the slab and vented away from the house.

Installation

Installation of a sub-slab suction system is not an easy "do-it-yourself" job, but some installations might be successfully completed by a homeowner with the necessary skills. A do-it-yourself installation might be most logically attempted when it is known that a good layer of aggregate underlies the slab.

Cost

Installation cost for a multiple-pipe, through-the-slab system would be about \$900 to \$2,500 if completed by a professional. Material costs for a fan, piping, and incidentals would be about \$300. Typical operating costs would be roughly \$30 per year for electricity and \$100 per year for the heating penalty resulting from increased house ventilation.

Reductions

Installation of a sub-slab suction system can reduce indoor radon levels by 80 to 99 percent. In many cases, reductions of 95 to 99+ percent have been achieved when good permeability exists beneath the slab.

Limitations

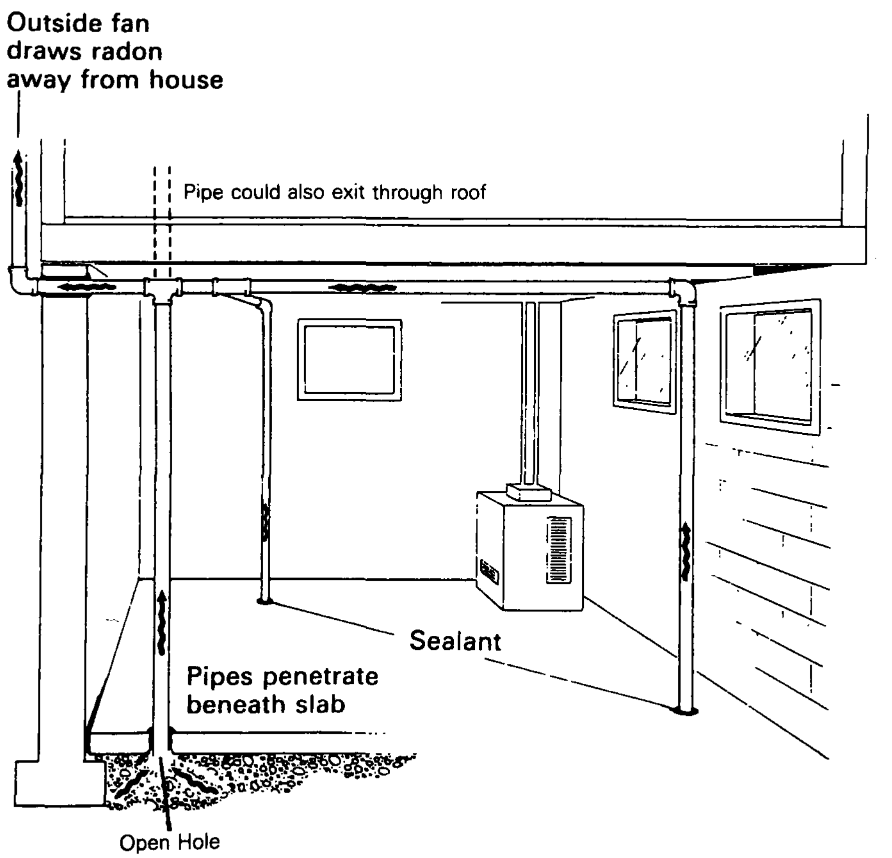
Sub-slab suction has been one of the most widely used and successful radon reduction techniques. It is most useful with foundations built on good aggregate or on highly permeable soil.

When permeability under the slab is not so good, sub-slab suction will often still be applicable. If permeability is less than desirable, more suction pipes might be needed. Positioning of the suction pipe also may become more important.

Sub-slab suction systems require both a fan capable of maintaining at least 0.5 to 1.0 inch pressure and closure of accessible openings in the slab.

Procedure

A fan is used to ventilate soil gas away from the foundation by means of individual pipes which are inserted into the region under the concrete slab. The pipes can be inserted vertically downward through the slab from inside the house, as illustrated, or can be inserted horizontally through a foundation wall at a level beneath the slab. This latter approach is more practical for slabs poured near the surface of the ground. Pipes should exhaust at roof level, away from windows and vents that could permit the gas to re-enter the house.



Block-Wall Ventilation

How it Works

Draws radon from the spaces within concrete block walls before it can enter the house ("wall suction") or blows air into block walls so that radon is prevented from entering the walls ("wall pressurization").

The concrete blocks used to construct many basement walls contain hollow spaces which are connected both horizontally and vertically. Radon from the soil—which enters the wall through joints or tiny pores and cracks—can travel through these connected spaces and enter the basement through similar openings on the interior side or through the openings in the top row of block.

Installation

Requires installation and testing by competent, experienced professionals or highly skilled homeowners.

Cost

The installation of a series of exhaust pipes in an unfinished basement would cost from $1,500 to $2,500. A baseboard collection system in a similar basement would cost about $2,000 or more to install.

Annual operating costs would typically be $30 to $60 for electricity and $200 to $400 for additional heating costs.

Reductions

Very effective (up to 99 percent radon reduction) in houses with good closure and sealing of all major wall openings. In other houses, radon reduction will be significantly less.

Limitations

Applicable only to houses with hollow block basement walls. Block-wall suction may not be successful if you cannot seal the top of the walls, the space between the walls and any exterior brick veneer, and openings that could be concealed by masonry fireplaces or chimneys. Noticeable cracks and openings should be sealed.

Block walls dividing the interior of a basement sometimes penetrate the floor and touch the underlying soil. Exhaust pipes must be installed in all such walls.

Procedure

There are two basic approaches to block-wall ventilation.

Although this method can be used for any radon level, it is best suited to levels above 0.2 WL (40 pCi/L). The easiest approach is to insert one or two pipes into each wall and use fans to draw radon out of the walls and vent it outdoors, or use fans to pressurize the walls to prevent radon entry. The other approach involves the installation of a sheet metal "baseboard" duct around the perimeter of the basement. Holes are drilled behind the duct into the hollow spaces within the blocks. This second approach produces more uniform ventilation and may be more pleasing in appearance.

In houses which have channel drains cast in the concrete floor next to the block walls, the baseboard approach should work particularly well, since it would ventilate the drains as well as the walls.

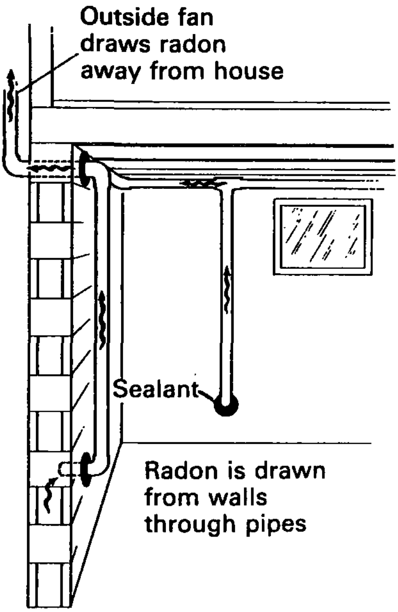
For either wall-ventilation approach to work, all major holes (especially the tops of the blocks) must be sealed. As we pointed out previously, this might be difficult—if not impossible—to do in certain places. (Both of the approaches are shown below in the "suction" mode.)

Pipes should exhaust at roof level away from windows and vents that could permit the gas to re-enter the house.

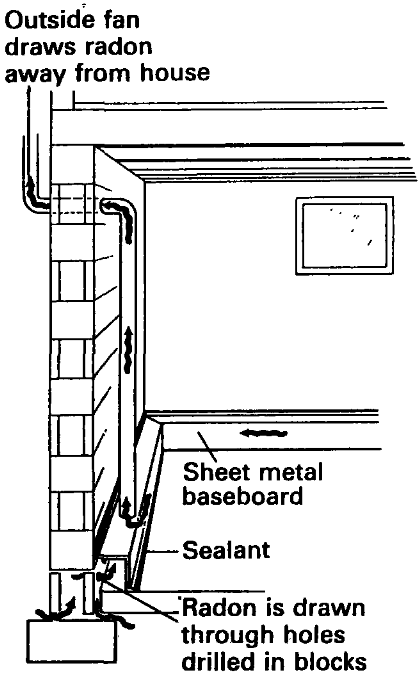
Method

Prevention of House De-pressurization

Pipe-in-wall approach



Baseboard approach



How It Works

Reduces the amount of radon drawn *into your house.*

Some exhaust fans and combustion units (such as woodstoves and fireplaces) can lower the air pressure in your house by consuming air and/or exhausting it to the outside. The lower the air pressure in your house, compared to that in the soil, the more radon-laden air may be drawn inside from the underlying soil.

Installation

If exhaust fans must be used, slightly open windows near the fans. Likewise with windows near fireplaces, woodstoves, and other combustion units. Doing so will facilitate the flow of make-up air from outdoors. Install a permanent system to supply outdoor air to household combustion units. For central, forced-air heating and cooling systems, seal off any cold-air return registers that are located in the basement. This reduces leakage of basement air into ducts.

Close air-flow bypasses (openings through the floor between stories) to inhibit air movement up through the house. Close openings through the house shell on upper levels to reduce air outflow from the house.

Note: Many combustion units are designed to accept outside air, but for many others a modification is not only illegal but may be unsafe. Gas furnaces are a prime example. In this case, directing outdoor air to a point near the furnace or enclosing the furnace in a room that is vented outdoors are appropriate measures.

Cost

Some causes of depressurization can be eliminated by the homeowner with little cost.

Installation costs for providing supplemental air will vary greatly depending upon the type and location of the combustion unit being modified. For some, there may be a slight increase in operating cost due to the typically lower temperature of the air being heated.

Reductions

Because each situation is different, it is impossible to predict the reduction in radon levels that can be expected as a result of reducing sources of depressurization in a house. There have been a number of individual applications where radon reduction has been significant.

Limitations

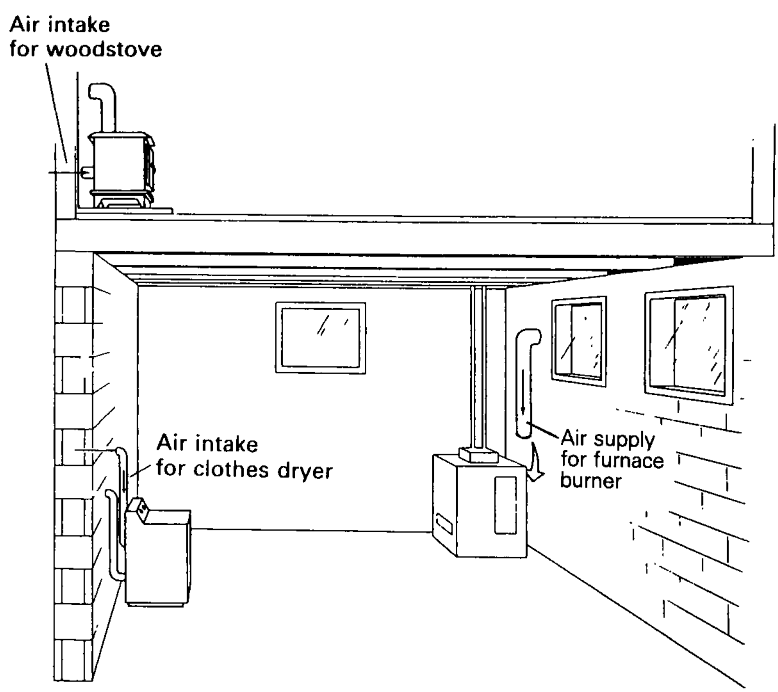
The effectiveness of depressurization reduction techniques for lowering radon levels will be time-dependent. For example, a technique aimed at reducing depressurization by an exhaust fan or a fireplace could have a significant impact when the appliance is being operated; however, the average annual effect will be lower if the appliance is operated for only a relatively small percentage of the year.

Procedure

Follow the procedures given under "Installation." When possible, avoid the use of exhaust fans or provide a route for outdoor air entry to compensate for exhausted house air.

Provide outdoor air in the vicinity of combustion units. Ductwork or piping can be run from any suitable exterior wall to the combustion unit. A manual or automatic damper should be placed in such ductwork to prevent entry of cold air when the stove or furnace is not in operation. Screen the outside end of ductwork to bar pests and debris.

Ensure that windows on the downwind side of the house are opened only when windows on the upwind side are also open.



House Pressurization

How it works

Maintains that part of the house which is in contact with the soil at a pressure higher than that of the air in the soil. This prevents soil gas—including radon—from entering the home. The most common application of this method is to blow upstairs air into the basement; however, in some homes, blowing upstairs air into a crawl space may also be applicable.

Installation

Requires installation by competent, experienced contractor or a careful and skilled homeowner.

Cost

Varies depending upon the work required to tighten the basement shell. Installation cost typically would be comparable to a simple wall ventilation system ($1,500-$2,500). Operating costs will include the electricity to run the fan (about $30 to $40 per year) and the heating penalty resulting from increased infiltration upstairs caused by the fan (as much as $400 to $500 per year).

Reductions

Initial results from a few basement pressurization applications indicate that radon reductions of 70 to 90 percent are possible.

Limitations

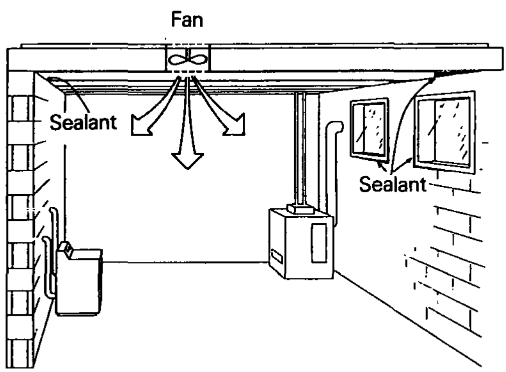
The application of this technique is strictly limited to houses with either basements or heated crawl spaces that are relatively tightly sealed from the living area. Care must be taken to prevent back-drafting of upstairs combustion units. Also, the performance of the system could be completely negated if homeowners open basement doors or windows.

Some homeowners may object to fan noise and vibration if the fan is mounted in the floor of living areas. To overcome that problem, the fan may be mounted on the basement floor and ducted to the living area.

This is one of the least-tested techniques. Structural effects and reliability are not well known.

Procedure

Tighten shell between the basement or crawl space and the upstairs and between the basement or crawl space and the outdoors. Blow upstairs air down in the basement or crawl space. If openings must be made in the upstairs floor, the openings should have a reasonable cross-section to avoid suffering a severe energy penalty.



Comparison of Features

Method	Installation Cost	Operating Cost	Maximum Possible Reductions*	Comments
Natural ventilation:				Useful immediate step to reduce high radon levels.
Basement or lowest floor	Minimal	High to very high	Up to 90+%	
Crawl space	Minimal	Moderate	Up to 90+%	
Forced ventilation:				More controlled than natural ventilation.
Basement or lowest floor	Low to moderate	Very high	Up to 90+%	
Crawl space	Low to moderate	Moderate	Up to 90+%	
Heat recovery ventilation				Air intake and exhaust must be equal. Also, expect lower radon reductions for houses with moderate to high air exchange rates.
Ducted	Moderate to high	Low to moderate	50-75%	
Wall mounted	Low to moderate	Low to moderate	No data available	
Covering exposed earth	Moderate to high	Low	Site specific	Required to make most other methods work.
Sealing cracks and openings	Minimal to high	Nominal	Site specific	Required to make most other method work.
Drain-tile suction	Moderate to high	Low	Up to 99+%	Works best when drain is continuous, unblocked loop.
Sub-slab suction	High	Low	Up to 99+%	Works best with good aggregate or highly permeable soil under slab.
Block-wall ventilation	High	Low	Up to 99+%	Applies to block-wall basements. Sub-slab suction may be needed to supplement.
Prevention of house depressurization	Low to moderate	Low	Site specific	May be required to make other methods work. May see seasonal impact.
House pressurization	Moderate to high	Moderate	Up to 90% (limited data)	Most cost-effective when basement is tightly sealed.

*These represent generally the best reductions that a single method can accomplish. You may get higher or lower reductions depending on the unique characteristics of your house. It is likely that reductions in your house will not be as great as those shown. Especially with high initial radon levels, several methods may have to be combined to achieve acceptable results.

Sources of Information

If you would like further information or explanation about any of the points mentioned in this booklet, you should contact your state radon program office listed at the end of this booklet.

If you have difficulty obtaining needed information, you may call your EPA regional office listed below. The radiation program staff will be happy to provide you with assistance.

EPA Regional Offices

EPA Region 1
JFK Federal Building
Boston, MA 02203
(617) 565-3234

EPA Region 2 (2AIR:RAD)
26 Federal Plaza
New York, NY 10278
(212) 264-4418

Region 3 (3AH14)
841 Chestnut Street
Philadelphia, PA 19107
(215) 597-4084

EPA Region 4
345 Courtland Street, N.E.
Atlanta, GA 30365
(404) 347-2904

EPA Region 5 (5AR26)
230 South Dearborn Street
Chicago, IL 60604
(312) 886-6165

EPA Region 6 (6T-AS)
1445 Ross Avenue
Dallas, TX 75202-2733
(214) 655-7208

EPA Region 7
726 Minnesota Avenue
Kansas City, KS 66101
(913) 236-2893

EPA Region 8 (8HWM-RP)
999 18th Street
One Denver Place, Suite 1300
Denver, CO 80202-2413
(303) 293-1648

EPA Region 9 (A-3)
215 Fremont Street
San Francisco, CA 94105
(415) 974-8378

EPA Region 10
1200 Sixth Avenue
Seattle, WA 98101
(206) 442-7660

State - EPA Region

Alabama	4
Alaska	10
Arizona	9
Arkansas	6
California	9
Colorado	8
Connecticut	1
Delaware	3
District of Columbia	3
Florida	4
Georgia	4
Hawaii	9
Idaho	10
Illinois	5
Indiana	5
Iowa	7
Kansas	7
Kentucky	4
Louisiana	6
Maine	1
Maryland	3
Massachusetts	1
Michigan	5
Minnesota	5
Mississippi	4
Missouri	7
Montana	8
Nebraska	7
Nevada	9
New Hampshire	1
New Jersey	2
New Mexico	6
New York	2
North Carolina	4
North Dakota	8
Ohio	5
Oklahoma	6
Oregon	10
Pennsylvania	3
Rhode Island	1
South Carolina	4
South Dakota	8
Tennessee	4
Texas	6
Utah	8
Vermont	1
Virginia	3
Washington	10
West Virginia	3
Wisconsin	5
Wyoming	8

State Radon Contacts

Alabama
Radiological Health Branch
Alabama Department of Public Health
State Office Building
Montgomery, AL 36130
(205) 261-5313

Alaska
Alaska Department of Health and Social Services
P.O. Box H-06F
Juneau, AK 99811-0613
(907) 465-3019

Arizona
Arizona Radiation Regulatory Agency
4814 South 40th Street
Phoenix, AZ 85040
(602) 255-4845

Arkansas
Division of Radiation Control and Emergency Management
Arkansas Department of Health
4815 W. Markham Street
Little Rock, AR 72205-3867
(501) 661-2301

California
Indoor Quality Program
California Department of Health Services
2151 Berkeley Way
Berkeley, CA 94704
(415) 540-2134

Colorado
Radiation Control Division
Colorado Department of Health
4210 East 11th Avenue
Denver, CO 80220
(303) 331-4812

Connecticut
Connecticut Department of Health Services
Toxic Hazards Section
150 Washington Street
Hartford, CT 06106
(203) 566-8167

Delaware
Division of Public Health
Delaware Bureau of Environmental Health
P.O. Box 637
Dover, DE 19903
(302) 736-4731

District of Columbia
DC Department of Consumer and Regulatory Affairs
614 H Street, NW, Room 1014
Washington, DC 20001
(202) 727-7728

Florida
Florida Office of Radiation Control
Building 18, Sunland Center
P.O. Box 15490
Orlando, FL 32858
(305) 297-2095

Georgia
Georgia Department of Natural Resources
Environmental Protection Division
205 Butler Street, SE
Floyd Towers East, Suite 1166
Atlanta, GA 30334
(404) 656-6905

Hawaii
Environmental Protection and Health Services Division
Hawaii Department of Health
591 Ala Moana Boulevard
Honolulu, HI 96813
(808) 548-4383

Idaho
Radiation Control Section
Idaho Department of Health and Welfare
Statehouse Mall
Boise, ID 83720
(208) 334-5879

Illinois
Illinois Department of Nuclear Safety
Office of Environmental Safety
1035 Outer Park Drive
Springfield, IL 62704
(217) 546-8100 or
(800) 225-1245 (in State)

Indiana
Division of Industrial Hygiene and Radiological Health
Indiana State Board of Health
1330 W. Michigan Street, P.O. Box 1964
Indianapolis, IN 46206-1964
(317) 633-0153

Iowa
Bureau of Environmental Health
Iowa Department of Public Health
Lucas State Office Building
Des Moines, IA 50319-0075
(515) 281-7781

Kansas
Kansas Department of Health and Environment
Forbes Field, Building 321
Topeka, KS 66620-0110
(913) 862-9360 Ext. 288

Kentucky
Radiation Control Branch
Cabinet for Human Resources
275 East Main Street
Frankfort, KY 40621
(502) 564-3700

Louisiana
Louisiana Nuclear Energy Division
P.O. Box 14690
Baton Rouge, LA 70898-4690
(504) 925-4518

Maine
Division of Health Engineering
Maine Department of Human Services
State House Station 10
Augusta, ME 04333
(207) 289-3826

Maryland
Radiation Control
Department of the Environment
7th Floor Mailroom
201 W. Preston Street
Baltimore, MD 21201
(301) 333-3130 or (800) 872-3666

Massachusetts
Radiation Control Program
Massachusetts Department of Public Health
23 Service Center
North Hampton, MA 01060
(413) 586-7525 or
(617) 727-6214 (Boston)

Michigan
Michigan Department of Public Health
Division of Radiological Health
3500 North Logan, P.O. Box 30035
Lansing, MI 48909
(517) 335-8190

Minnesota
Section of Radiation Control
Minnesota Department of Health
P.O. Box 9441
717 SE Delaware Street
Minneapolis, MN 55440
(612) 623-5350 or (800) 652-9747

Mississippi
Division of Radiological Health
Mississippi Department of Health
P.O. Box 1700
Jackson, MS 39215-1700
(601) 354-6657

Missouri
Bureau of Radiological Health
Missouri Deparment of Health
1730 E. Elm, P.O. Box 570
Jefferson City, MO 65102
(314) 751-6083

Montana
Occupational Health Bureau
Montana Department of Health and Environmental Sciences
Cogswell Building A113
Helena, MT 59620
(406) 444-3671

Nebraska
Division of Radiological Health
Nebraska Department of Health
301 Centennial Mall South
P.O. Box 95007
Lincoln, NE 68509
(402) 471-2168

Nevada
Radiological Health Section
Health Division
Nevada Department of Human Resources
505 East King Street, Room 202
Carson City, NV 89710
(702) 885-5394

New Hampshire
New Hampshire Radiological Health Program
Health and Welfare Building
6 Hazen Drive
Concord, NH 03301-6527
(603) 271-4588

New Jersey
New Jersey Department of Environmental Protection
380 Scotch Road, CN-411
Trenton, NJ 08625
(609) 530-4000/4001 or
(800) 648-0394 (in State) or
(201) 879-2062 (N. NJ Radon Field Office)

New Mexico
Surveillance Monitoring Section
New Mexico Radiation Protection Bureau
P.O. Box 968
Santa Fe, NM 87504-0968
(505) 827-2957

New York
Bureau of Environmental Radiation Protection
New York State Health Department
Empire State Plaza, Corning Tower
Albany, NY 12237
(518) 473-3613 or
(800) 458-1158 (in State) or
(800) 342-3722 (NY Energy Research & Development Authority)

N. Carolina
Radiation Protection Section
North Carolina Department of Human Resources
701 Barbour Drive
Raleigh, NC 27603-2008
(919) 733-4283

N. Dakota
Division of Environmental Engineering
North Dakota State Department of Health & Consolidated Laboratories
Missouri Office Building
1200 Missouri Avenue, Room 304
P.O. Box 5520
Bismarck, ND 58502-5520
(701) 224-2348

Ohio
Radiological Health Program
Ohio Department of Health
1224 Kinnear Road
Columbus, OH 43212
(614) 481-5800 or
(800) 523-4439 (in Ohio only)

Oklahoma
Radiation and Special Hazards Service
Oklahoma State Dept. of Health
P.O. Box 53551
Oklahoma City, OK 73152
(405) 271-5221

Oregon
Oregon State Health Department
1400 S.W. 5th Avenue
Portland, OR 97201
(503) 229-5797

Pennsylvania
Bureau of Radiation Protection
Pennsylvania Department of Environmental Resources
P.O. Box 2063
Harrisburg, PA 17120
(717) 787-2480

Puerto Rico
Puerto Rico Radiological Health Division
G.P.O. Call Box 70184
Rio Piedras, PR 00936
(809) 767-3563

Rhode Island
Division of Occupational Health and Radiological Control
Rhode Island Department of Health
206 Cannon Bldg.
75 Davis Street
Providence, RI 02908
(401) 277-2438

S. Carolina
Bureau of Radiological Health
South Carolina Dept. of Health and Environmental Control
2600 Bull Street
Columbia, SC 29201
(803) 734-4700/4631

S. Dakota
Office of Air Quality and Solid Waste
South Dakota Dept. of Water & Natural Resources
Joe Foss Building
Room 217
523 E. Capital
Pierre, SD 57501-3181
(605) 773-3153

Tennessee
Division of Air Pollution Control
Custom House
701 Broadway
Nashville, TN 37219-5403
(615) 741-4634

Texas
Bureau of Radiation Control
Texas Department of Health
1100 West 49th Street
Austin, TX 78756-3189
(512) 835-7000

Utah
Bureau of Radiation Control
Utah State Department of Health
State Health Department Building
P.O. Box 16690
Salt Lake City, UT 84116-0690
(801) 538-6734

Vermont
Division of Occupational and Radiological Health
Vermont Department of Health
Administration Building
10 Baldwin Street
Montpelier, VT 05602
(802) 828-2886

Virginia
Bureau of Radiological Health
Department of Health
109 Governor Street
Richmond, VA 23219
(804) 786-5932 or (800) 468-0138 (in State)

Washington
Environmental Protection Section
Washington Office of Radiation Protection
Thurston AirDustrial Center
Building 5, LE-13
Olympia, WA 98504
(206) 753-5962

W. Virginia
Industrial Hygiene Division
West Virginia Department of Health
151 11th Avenue
South Charleston, WV 25303
(304) 348-3526/3427

Wisconsin
Division of Health
Section of Radiation Protection
Wisconsin Dept. of Health and Social Services
5708 Odana Road
Madison, WI 53719
(608) 273-5180

Wyoming
Radiological Health Services
Wyoming Department of Health and Social Services
Hathway Building
4th Floor
Cheyenne, WY 82002-0710
(307) 777-7956