AE-969 (Revised)

RADON
IN NORTH DAKOTA

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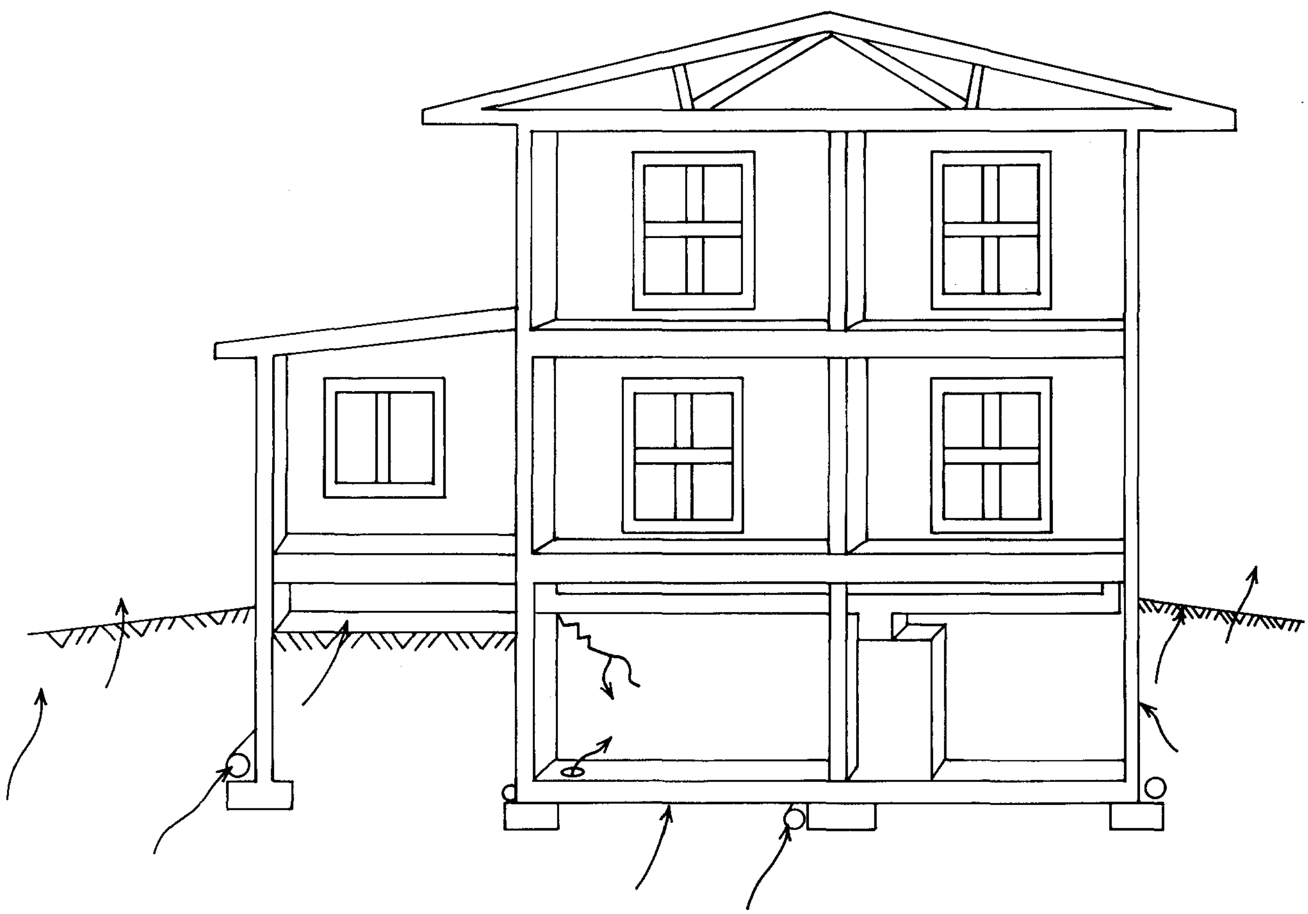

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Radon has been found at elevated levels in 63 percent of North Dakota homes in an Environmental Protection Agency (EPA) study. The term "elevated levels" means that the levels exceeded 4 picocuries per liter of air (pCi/l) which is the EPA recommended guideline for an acceptable level of risk. While there does not seem to be any pattern with respect to location in the state or type of home which might have a problem, it has been determined that there is a higher probability of having elevated radon levels in homes with basements.

In the EPA study, a random test of 1,596 homes in North Dakota, 4 percent of the homes tested exceeded 20 pCi/l, 59 percent were between 4 and 20 pCi/l and 37 percent were below 4 pCi/l. The highest level in the study was 184 pCi/l. Three homes were above 100 pCi/l and seven homes were between 50 and 100 pCi/l. The average for the homes in the test was 7 pCi/l.

There has been no pattern to where houses might have higher levels. Two houses adjacent to each other can have greatly differing levels of radon depending on the soil type, construction details and the living habits of the occupants.

Radon is a colorless, odorless, tasteless radioactive gas that is formed as radium decays (Figure 1). The radon decays to form polonium. The polonium also decays, with the process continuing until lead is formed. During the decay process alpha particles are given off. Normally alpha particles are not a health problem. However, if the decay occurs inside the body, it is possible that a cell next to the atom might be damaged. If cell damage occurs, it is possible that it could develop into cancer.

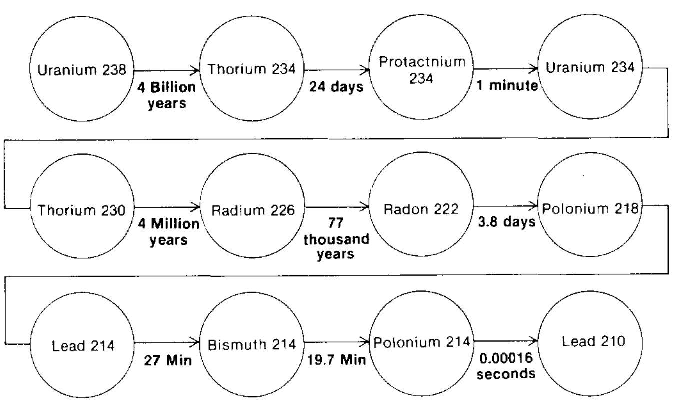


Figure 1. The decay of uranium. During each step radiation is given off. The number between elements is the time needed for one half of the material to decay to the new material. The number after the name is the atomic weight.

The major health concern involving radon is not the radon itself, but its decay products. Some of the decay products become attached to dust particles and others remain in the unattached state. Either can be inhaled. If the dust particles are small enough they can get deep into the lungs and become trapped there. Some studies have suggested that the unattached decay products yield a greater radiation dose to the lungs based on the assumption that they may be deposited in the more vulnerable portions of the lung. At the present time there is little experimental evidence to determine whether these theories of lung exposure are correct.

Measurement Units

The standard method of measuring radon is picocuries per liter (pCi/l). A radon level of 15 pCi/l has about the same risk of causing lung cancer as smoking a package of cigarettes a day (Figure 2).

The measurement for the decay products is called a working level (WL). A WL of 1 is about equal to a radon level of 200 pCi/l. Because of the expense involved in testing for the decay products and the great variability with time, most measurements will be made for radon and this measurement used to determine if steps should be taken to reduce the radon level.

Measurement Techniques

Two types of testing can be done to determine whether a home has elevated levels of radon. One is to use a worst case screening test and the second is a longer test that involves checking the level in the living space throughout the year.

For a screening test, the test equipment is set up in the lowest habitable space (usually the basement). The house is kept closed up as much as possible during the test. Since radon levels vary seasonally, the screening should be performed during the cooler months of the year (Figure 3). Charcoal cannister test kits require from one to three days for an accurate reading (Figure 4). An alpha track detector test kit will require at least seven days, but a longer test will be needed for accurate results under low radon conditions.

If the screening test shows that under the worst case there is no radon problem, no further testing is recommended. With a reading that exceeds 4 pCi/l, further testing will be needed to determine if there is sufficient radon in the living space to require action to reduce the level.

Figure 2. Radon Risk Evaluation Chart.

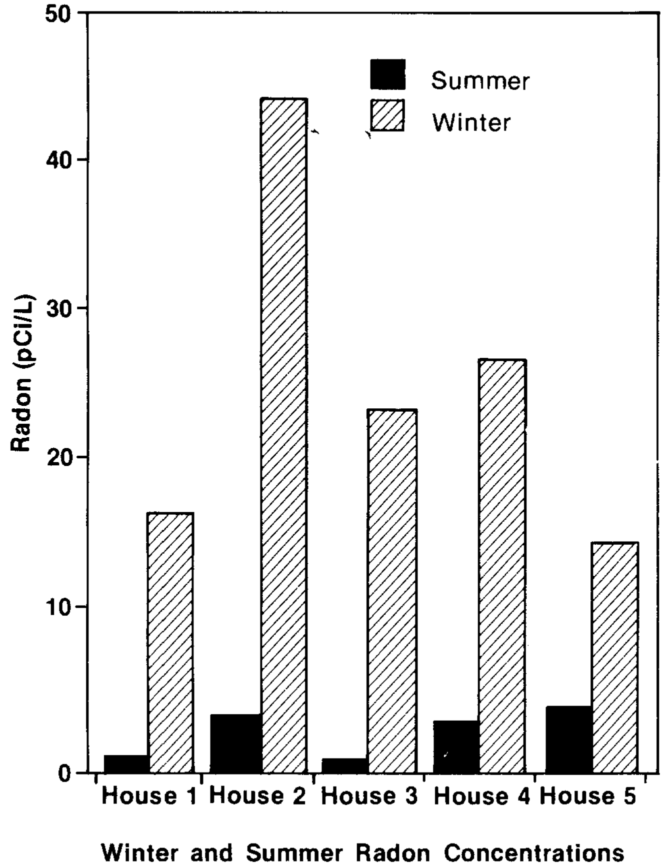
pCi/l	WL*	Estimated number of lung cancer deaths due to radon exposure (out of 1,000)	Comparable exposure levels	Comparable risk
200	1	440-770	1,000 times average outdoor level	More than 60 times non-smoker risk
				4 pack-a-day smoker
100	0.5	270-630	100 times average indoor level	
40	0.2	120-380		
20	0.1	60-210	100 times average outdoor level	2 pack-a-day smoker
				1 pack-a-day smoker
10	0.05	30-120	10 times average indoor level	
4	0.02	13-50	average for houses tested in N.D.	5 times non-smoker risk
2	0.01	7-30	10 times average outdoor level	
1	0.005	3-13	Average indoor level	Non-smoker risk of dying from lung cancer
0.2	0.001	1-3	Average outdoor level	

Followup testing would involve placing alpha track detectors in the spaces where people would be spending most of their time, such as the living room, family room, kitchen or bedrooms. The length of the followup tests will depend on the levels of radon found in the screening test. For levels between 4 and 20 pCi/l, a one-year followup test is suggested. For levels above 20 pCi/l, a three-month test is recommended.

If the followup testing shows that the radon is not getting into the living spaces, no further action would be needed. Periodic followup tests at five- to 10-year intervals are a good idea to be sure that no change has taken place that would increase the levels in the living space.

If followup testing shows that elevated levels of radon are reaching the living space, then some action should be taken to reduce the radon levels as far below 4 pCi/l as possible. The type of action taken and the time in which the action should be taken will depend on the amount of radon present (Figure 5). At levels between 4 and 20 pCi/l, action should be taken within the next few years. For levels between 20 and 200 pCi/l action should be taken within the next several months, while at levels above 200 pCi/l action should be taken as soon as practicable (usually within a few weeks).

After efforts to reduce the radon levels have been completed, followup testing should be done to ensure that the levels have been reduced. This would be similar to the followup tests that were done prior to the mitigation efforts. About every five to 10 years another followup test should be done to ensure that the mitigation equipment is working satisfactorily.



Source: LBL

Figure 3. Radon concentrations vary by season. Some of the variation is due to differences in ventilation.

Figure 4. Minimum sampling times for screening measurements. (Made in lowest livable area under closed-house conditions)

Instrument	Sampling Times
Charcoal Canister	2 days
Alpha Track Detector	1 month
Time Integrating Unit	3 days minimum, 7 days preferred
Continuous WL Monitor	6 hours minimum, 24 hours or longer preferred
Continuous Radon Monitor	6 hours minimum, 24 hours or longer preferred

Mitigation Procedures

There are a number of things that can be done to reduce the level of radon in a home; however, all of them might be rejected for one reason or another. For example, opening the windows and doors will quite likely reduce the level of radon in the home, but it will also make the house extremely hard to keep warm during the winter months (Figure 3). Also, if the ventilation is not done properly, it can actually increase the radon levels by increasing the suction on the lower level of the house. For best results, there should be more windows open on the windward side of the house than on the downwind side.

Figure 5. EPA recommendations for action based on follow-up measurements.

Based on currently available information, EPA believes that levels in most homes can be reduced to about 0.02 WL (4 pCi/L).

If results are about 1.0 WL or higher, or about 200 pCi/L or higher:
Exposures in this range are among the highest observed in homes. Residents should undertake action to reduce levels as far below 1.0 WL (200 pCi/L) as possible. The EPA recommends that you take action within several weeks. If this is not possible, determine in consultation with appropriate state or local health or radiation protection officials if temporary relocation is appropriate until levels can be reduced.

If results are about 0.1 to about 1.0 WL, or about 20 to about 200 pCi/L:
Exposures in this range are considered greatly above average for residential structures. Action should be taken to reduce levels as far below 0.1 WL (20 pCi/L) as possible. We recommend that action be taken within several months.

If results are about 0.02 to about 0.1 WL, or about 4 pCi/L to about 20 pCi/L:
Exposures in this range are considered above average for residential structures. Action should be taken to lower levels to about 0.02 WL (4 pCi/L) or below. It is recommended that action be taken within a few years, sooner if levels are at the upper end of this range.

If results are about 0.02 WL or lower, or about 4 pCi/L or lower:
Exposures in this range are considered average or slightly above average for residential structures. Although exposures in this range do present some risk of lung cancer, reductions of levels this low may be difficult, and sometimes impossible, to achieve.

Remember: There is increasing urgency for action at higher concentrations of radon. The higher the radon level in the home, the faster action should be taken to reduce exposure.

Source: EPA

The mitigation procedure that has produced the most consistent results in research has been a combination using sub-slab suction and crack sealing.

Sub-slab suction is accomplished by drilling a hole through the basement floor if one does not already exist. With a crushed rock or sand fill placed under the floor before the concrete was poured, all that needs to be done is to place a pipe through the hole and caulk it into place. A suction fan is connected to the pipe and the air is pulled from under the floor. It is recommended that the fan be placed outside the living space and the air be exhausted above the roof of the home to minimize the possibility that the radon laden air will reenter the home or accumulate where children might play (Figure 6, 7, and 8).

The fan should be able to move from 80 to 200 cubic feet of air per minute (cfm) in free air. It should be able to develop a static pressure of 2 inches water column (WC). A centrifugal fan is usually required to get this type of performance. You will need to check the manufacturers performance curves to ensure that the fan has the capability that you need.

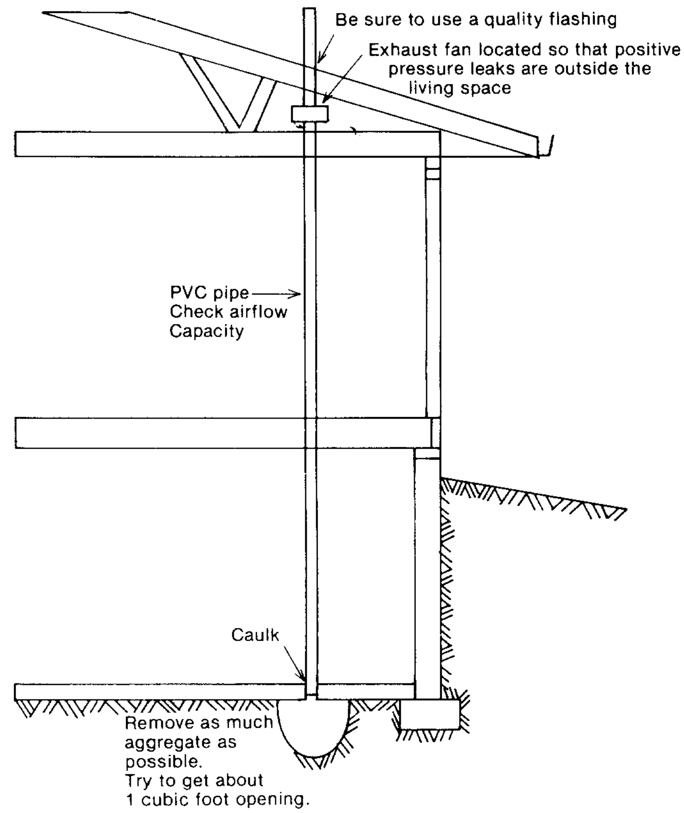


Figure 6. Depressurization of the soil by applying suction to the aggregate below the slab.

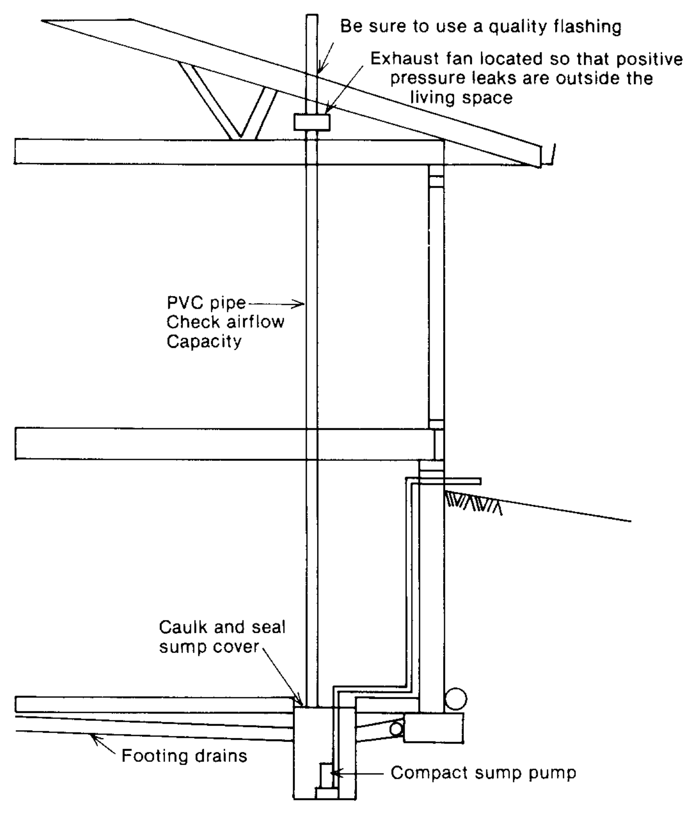


Figure 7. Soil depressurization by suction on sump hole.

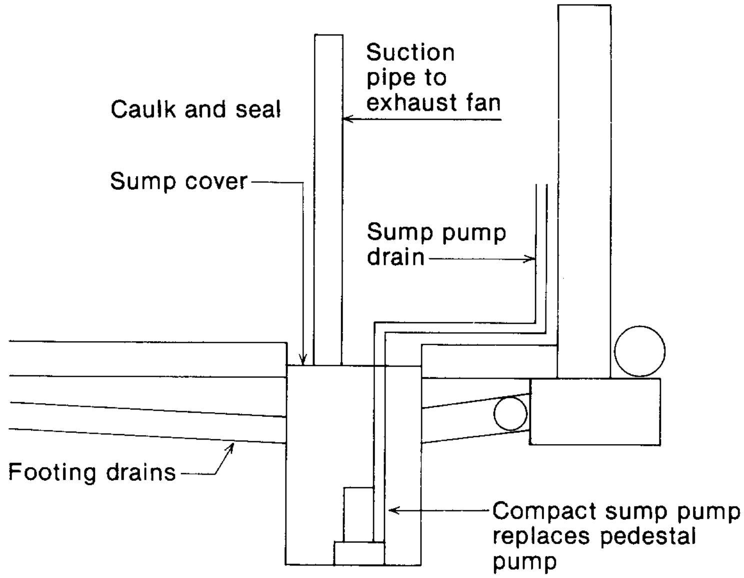


Figure 8. Converting a sump hole into a radon collection sump. Be sure to caulk all joints between materials.

A single suction point is usually sufficient where crushed rock or gravel was used under the slab, continuous footing drains have been installed, or the soil has settled away from the concrete floor. Multiple suction points may be needed in clay soils without drain tile or if there is considerable air leakage from the basement or outdoors to the area under the slab (Figure 9). Drill a small test hole in the slab at the point farthest from the suction hole and do a vacuum test to make sure that the fan is able draw air from under the entire floor. If no air enters the test hole, you will need to either install a larger suction fan and piping or install a second suction point. Which option you choose will be determined by the type of fill under the slab and the cost of fans.

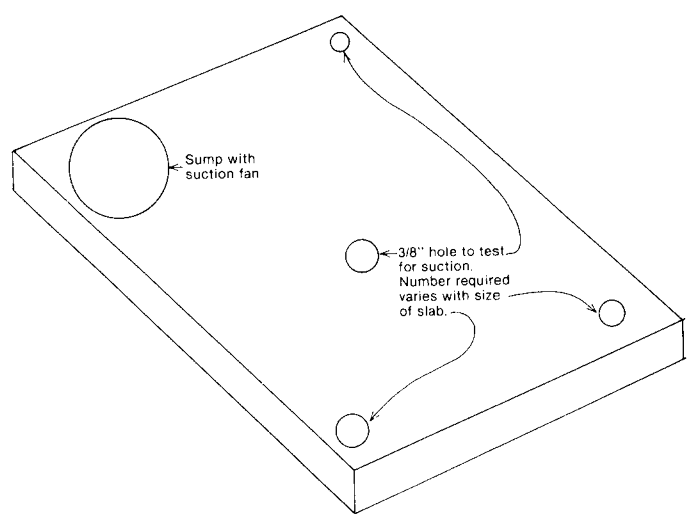


Figure 9. Place test opening at strategic locations around slab to insure that a suction exists at all locations. Be sure to caulk holes after completing the test.

Some of the other factors to consider when selecting a fan include its energy consumption, noise, service life and ease of installation. If the fan can be located outside of the living space, there is less likelihood of radon-laden air being blown into the living space through openings in the fan housing or in the pressurized pipe.

Any good quality rigid pipe can be used. PVC piping is readily available and easy to work with. Select a pipe size that will result in an air velocity of less than 1,000 feet per minute as this will result in very little noise from the air moving through the pipe. As the air velocity increases there will be an increase in noise and power requirements.

Table 1. Pipe size and airflow required to limit velocity to less than 1000 feet per minute.

Pipe Diameter (inches)	Total Airflow (cfm)
2	22
3	49
4	87
6	197
8	349

A 4-inch diameter pipe is frequently used, because it is readily available and it can handle 80 cfm of air at reasonable power requirements. At 80 cfm a 4-inch pipe would have a velocity of 916 feet per minute and a pressure drop of 0.01 inch. A fan that could develop 2 inches of static pressure would be adequate on this system and the noise level should be fairly low.

At 200 cfm, a 4-inch diameter pipe would have an air velocity of 2,290 feet per minute. This would result in a pressure drop through 20 feet of pipe of 1/2 inch (Figure 12) plus the suction on the aggregate. It

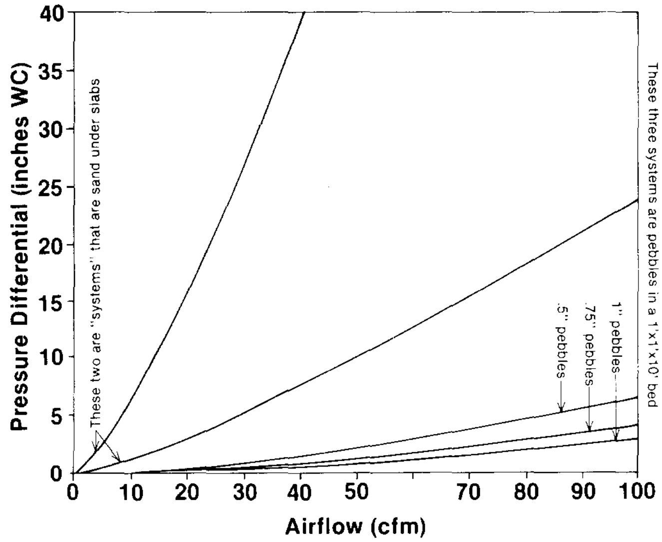


Figure 10. Pressure vs airflow curves for different aggregates.

would be desireable to have a pipe larger than 4 inches or else the fan would need to be able to develop more suction than 2 1/2 inches. Most small fans are not capable of this type performance.

Pipe wall thickness is usually not a major concern unless it must be installed outside, and then a fairly sturdy pipe should be used. Schedule 40 PVC pipe or equivalent would be adequate for most applications outside.

Figure 10 shows some typical airflows through various aggregates. Figure 11 gives some guidelines for the design of soil depressurization systems.

For soil depressurization to be effective, it is important that all air leaks between the soil and the

Figure 11. Design guide for soil depressurization.

Depressurization Location	Pipe Diameter (Inches) Suggested	Minimum	Number of Suction Points	Suction Location	Blower Max. AP (Inches WC)	Max. Flow (cfm)
Sub Slab Pebbles (#2)	4	4	1-2	Anywhere Convenient	1.5-2	180-240
Gravel	4	3	2-4	Slab Edge, Center Wall	2-5	80-150
Sand	3	1.5	1/600 sq. ft.	Slab Edge, Center Wall	4-5	80-150
Air Gap	4	4	Variable	Over Gap	1.5-2	180-240
Block Wall	4	4	1 per wall	Int. or ext. each major wall, or highest radon wall	1.5-2	180-240
Drain Tile	4	4	1-2	Simplest place on int. or ext. pipe	1.5-2	180-240
Sub Membrane	4	4	1-2	Anywhere Convenient	1.5-2	180-240
Baseboard	4	4	1 each zone	Anywhere Convenient	1.5-2	180-240

basement or the outside air be eliminated. Sealing is crucial to achieve a uniform low pressure field with the smallest blower and the lowest operating cost.

Some of the obvious openings include the tops of cement block walls, open sumps, floor and wall cracks and plumbing penetrations.

Small cracks can be filled with caulking materials. A quality caulk should have a long life, good adhesion, good elasticity and should require relatively easy surface preparation. Polyurethane and polysulfide caulks have worked very well. Latex gloves avoid skin exposure to any toxic solvents that might be used with the caulks.

Silicone caulks have not been effective, because they tend to have poorer adhesion. They are good for gasketing type installations such as placing the caulk between the sump frame and the sump cover and then bolting the sump cover into place.

Large cracks may need to be filled with a masonry patch or filled with a backing (backer rod) material and then caulked. Be sure to provide adequate ventilation when working indoors with caulking materials.

Large holes can be sealed with urethane foam or caulk placed over a supporting material. The tops of concrete block walls can be filled with crushed newspaper and then a caulking material or mortar installed over the top. Sealing the tops of concrete block walls is a very difficult and time consuming job.

Pressurizing the basement may work to decrease the radon level in some homes. Usually this works best where the radon levels are fairly low and it is easy to keep the basement at a pressure higher than that of the soil around the house. Caution: during the winter months, this may force water vapor into the basement walls and cause condensation in areas that are difficult to dry out, resulting in increased deterioration of these areas.

Pressurizing of the basement is accomplished by sealing as many of the openings between the basement and the upper levels of the house as possible and then installing a fan that blows the air from the upper levels into the basement.

Radon In Water

At this time there does not seem to be a problem with radon in water in North Dakota. If very high levels of radon are encountered in water supplies (more than 10,000 pCi/l) there may need to be some effort to remove some of the radon from the water to reduce its effect on airborne radon. An activated charcoal filter system has been effective in this regard.

It is possible that as the Environmental Protection Agency sets standards for radon in drinking water some steps may need to be taken to reduce the level. Again, the activated charcoal filter appears to be adequate for this purpose.

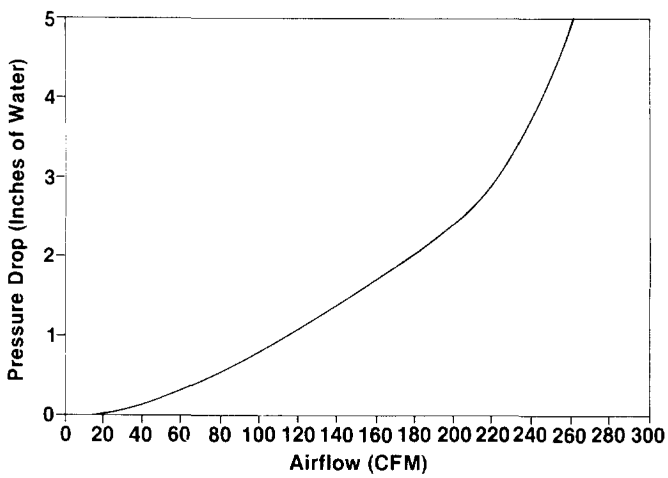
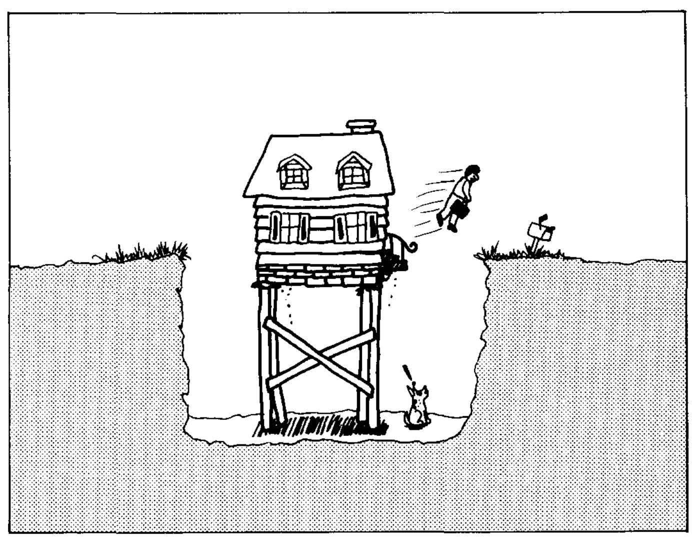


Figure 12. Pressure drop through 100 feet of 4 inch PVC pipe.



The ultimate in radon mitigation techniques. Something similar to this may be needed in extremely high radon areas.

References

The material in this publication is based to a large extent on material which has been published by the Environmental Protection Agency and has been adapted to North Dakota conditions.

A Citizens Guide to Radon, USEPA publication OPA-86-004, August 1986.

Radon Reduction in New Construction, USEPA publication OPA-87-009, August 1987.

Radon Reduction Methods A Homeowners Guide, USEPA publication OPA-87-010, September 1987.

Radon Reference Manual, USEPA publication EPA 520/1-87-20, September 1987.

Interim Protocols for Screening and Followup Radon and Radon Decay Product Measurements, USEPA 520-86-014-1, February 1987.

Radon Reduction Techniques for Detached Houses, USEPA publication EPA/625/5-87/019 revised January 1988.

Reducing Radon in Structures an EPA manual in press.

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