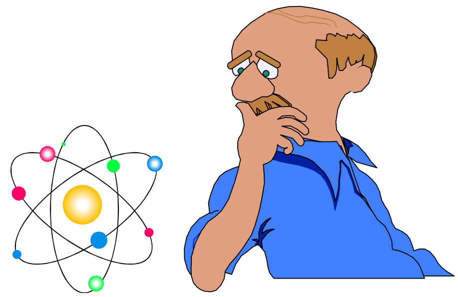
RADON

In Search of Answers



New Hampshire Office of Community and Public Health
Bureau of Environmental & Occupational Health
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Radon is a naturally occurring, colorless, odorless, non-chemically reactive, radioactive gas. It is also a Class A carcinogen, i.e., it has been determined to cause cancer in humans, specifically, lung cancer. The purpose of the radon program at the Bureau of Environmental & Occupational Health is to assess the extent of radon occurrence in New Hampshire and to educate the residents of the State as to the risk it presents and options available for avoiding that risk.

During the past ten years this office has received well over 12,000 telephone calls pertaining to radon, its origin, health effects and options for testing and removal. There are several questions about radon in air and in water that continually arise in the course of our discussions with homeowners, home buyers, realtors and builders. We have assembled a list of these questions along with their respective answers to help the State's residents better understand the radon issue.

If you do not find the answer to your question amongst those listed below, please do not hesitate to contact the New Hampshire Bureau of Environmental & Occupational Health at (603) 271-4764. Alternatively, you may dial 1-800-852-3345 extension 4764 (in New Hampshire only). In addition, radon publications of the United States Environmental Protection Agency (EPA) may be accessed at http://www.epa.gov/radon/pubs.

Persons interested in comparing the relative risks of radon in indoor air with those of radon in the drinking water should consult the Unified Radon Relative Risk Model available at EPA's website, http://www.epa.gov/region01/eco/wrsdp.html. Users of the model are cautioned that the model requires input variables that represent the annual average radon concentration in the water supply and the whole house annual average airborne radon concentration, not simply the short-term radon concentration from any one location within the home or from a single water sample. Further, the transfer ratio that predicts the contribution that the water supply will make to the airborne radon concentration of the house may vary widely between houses. The model is a much more reasonable predictor of relative risks when applied to large numbers of houses than to individual dwellings. Users of the model are encouraged to review the extensive HELP files associated with the model in order to better understand its function and limitations.

TABLE OF CONTENTS

THE ORIGIN OF RADON AND ITS DISTRIBUTION IN NEW HAMPSHIRE

"Doesn't radon come from granite?"

Sometimes. Radon is one of the transient radioactive isotopes created during the decay of uranium-238; radon's immediate parent is radium-226. Whether or not a particular type of granite emanates radon is dependent on the geochemistry of that particular granite, some are a problem, notably the two-mica granites and some biotite granites and tonalites. Radon can also be associated with some of the metamorphic rock in southeastern New Hampshire. In other parts of the country radon is associated with certain black shales, clays, silts, soils above limestones, and phosphatic rock. To read more about the geology of radon and its distribution around the country the reader is directed to reference the U.S. Department of the Interior / U.S. Geological Survey's homepage at http://www.usgs.gov and type **radon** into the search engine.

"Do homes in some parts of New Hampshire have more radon than others?"

Yes. High indoor radon concentrations are more frequently found in the northern, eastern, and southeastern parts of the State. However, values in excess of the US Environmental Protection Agency's 4.0 picocurie per liter (pCi/L) action guideline have been found in nearly every community in New Hampshire.

Values exceeding 100 pCi/L have been recorded in at least eight of New Hampshire's ten counties. The highest indoor radon reading in New Hampshire that we are aware of is greater than 1200 pCi/L; higher values probably exist.

The following table indicates the distribution of indoor radon concentrations around the State as indicated by more than 15,000 short-term radon tests conducted by homeowners. Most tests were conducted between November and April, by resident homeowners of single-family dwellings, in the lowest level of the home suitable for occupancy... often the basement.

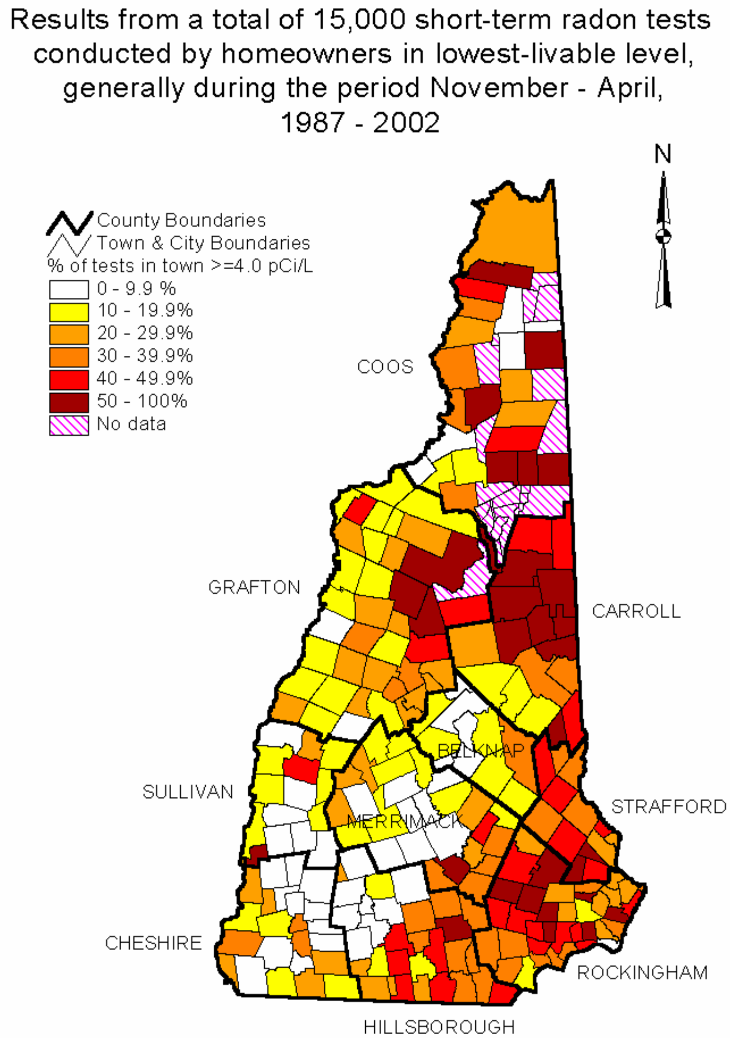
Summary Table of Short-term Indoor Radon Test Results from Single Family Homes
New Hampshire's Radon Database
11/14/03

†Summary Data by County (radon values in picocuries per liter)

County	# Test Results	‡Geometric Mean (~ median)	Maximum Conc. reported during survey	% of tests > 4.0 pCi/L	% of tests > 12.0 pCi/L
Belknap	774	1.3	22.3	14.1	1.3
Carroll	1,042	3.5	478.9	45.4	18.0
Cheshire	964	1.3	131.2	15.6	2.3
Coos	1,072	3.2	261.5	41.0	17.0
Grafton	1,286	2.0	174.3	23.2	5.2
Hillsborough	2,741	2.1	203.3	29.6	6.8
Merrimack	1,961	2.0	152.8	25.2	6.0
Rockingham	3,909	3.0	155.3	40.0	9.5
Strafford	1,645	3.4	122.8	44.0	13.0
Sullivan	466	1.4	29.4	15.7	2.1
Statewide	**15,860 tests**	**2.4 pCi/L**	**478.9 pCi/L**	**32.4 %**	**8.6 %**

† In a random sampling of radon levels in homes, radon concentrations are known to approximate a lognormal distribution. Although the sampling regime used to select homes is not strictly random, the size of the database and the lack of any intentional bias in the selection process justified use of the geometric mean, rather than the arithmetic mean (average), as the appropriate measure of central tendency.

‡ This table reflects only data collected as part of state-run surveys and in no way should be considered to represent the full range of values found in the respective counties.



"Since the radon level in the air is so high, does that mean I will also have radon in my water?" (and vice versa)

No. Although it is tempting to speculate that high levels of radon in either the indoor air or in the drinking water will also mean there will be high levels in the other, it simply isn't true ... at least not with the level of certainty upon which one would like to rely. Radon in drinking water supplies derived from drilled wells is entirely dependent on the geochemistry of the bedrock or sands and gravels into which the well is drilled and the recharge rate of the bedrock fractures or the sand and gravel aquifer. Radon entering homes through the foundation may be influenced by the geochemistry of the bedrock, but it is also a function of soil chemistry and the ease with which gases can move through the soil, various construction aspects of the house itself, the integrity of the foundation floor and walls, and by those appliances within the house whose operation reduces the air pressure within the house, e.g., combustion appliances and fans that exhaust air to the outside.

RADON IN INDOOR AIR

HEALTH RISK

"A note to the reader about risk estimates."

The reason any of us are concerned about radon in the environment is because of the risk it presents to human health. Throughout the following text are numerous references to increased lung cancer risk resulting from exposure to radon at various concentrations for various periods of time. It is very important for the reader to understand that the science of assessing risk as a function of exposure is fraught with uncertainty. Risk estimates are based on the average characteristics of people in the population. The uncertainty of the prediction is reasonably small when large populations are involved; uncertainty increases as the size of the sample population becomes smaller.

Trying to quantify and think about the precise risk to any one particular individual, each with his/her own individual age, habits and genetic traits invokes enormous uncertainty. The best any of us can do is to consider the risk to the average member of the population and recognize that for a variety of reasons our individual risk may be somewhat more or less than the risk to the average person in a large population.

"What is the health risk associated with radon in the air?"

Radon is a Class 'A' carcinogen. This means it has been determined to cause cancer in humans. Regardless of whether the source of the airborne radon is soil gas entering through the foundation or radon out-gassing from the water supply, the **only** health risk presently attributed to **inhaling** radon is lung cancer. Radon **ingested** in the drinking water may result in a slight increase in the risk of developing a stomach and other whole-body cancer**,** but this ingestion risk is comparatively small (11 percent for the general population) in comparison to the lung cancer risk (89 percent for the general population) associated with inhaling radon that out-gasses from the water supply.

In February, 1998, the National Academy of Sciences (NAS) released a summary of the findings of a four-year investigation by their committee on the Biological Effects of Ionizing Radiation (BEIR). The report focuses on the health risks associated with radon in indoor air and is generally referred to as the BEIR VI report, the Executive and Public Summaries are available at http://www.epa.gov/iaq/radon. The committee concluded that radon was a significant health risk and depending on which of two separate models the committee used, their best estimates of the extent of the risk posed to the general population by residential radon in the United States were 15,400 or 21,800 radon-related lung cancers deaths each year. These numbers represent 10 percent - 15 percent of all lung cancer deaths in the United States each year. The committee also concluded that smokers and former smokers are at substantially more risk of developing a radon-related lung cancer than those who have never smoked.

In June of 2003, EPA, building on and refining the information provided by NAS' BEIR VI committee, calculated that of the 157,400 lung cancer deaths nationally in 1995, 21,100 (13.4 percent) were attributed to radon exposure. The following table provides estimates of lung cancer death from lifetime exposure to radon in homes at various constant radon concentrations.

Radon Level (pCi/L)	Lifetime Risk of Lung Cancer Death from Radon Exposure in Homes		
	†Never Smokers	‡General Population	Current Smokers
20	3.6%	10.5%	26.3%
10	1.8%	5.6%	15.0%
8	1.5%	4.5%	12.0%
4 (EPA Action Guideline)	0.7%	2.3%	6.2%
2	0.4%	1.2%	3.2%
1.25 (national average indoor level)	0.2%	0.7%	2.0%
0.4 (average outdoor level)	0.1%	0.2%	0.6%

† "Never Smokers" is defined as someone who has smoked less than 100 cigarettes in their lifetime.

‡ "General Population" refers to the risk for the population as a whole, regardless of individual smoking history.

"Former Smokers" are at more risk than "Never Smokers" and less risk than "Current Smokers," the actual risk for "Former Smokers" will be determined, in part, by the length of time since they stopped smoking.

Additional information on the health risks associated with radon can be found at Iowa State University's "Virtual Hospital" website, by typing "**radon**" into the search engine at http://www.vh.org.

"Has it ever been proven that someone in New Hampshire died from radon exposure?"

There is no definitive "proof" that anyone has died of a radon-induced lung cancer. Current estimates of expected deaths from radon exposures are based on statistical models that assume a certain level of cellular damage and consequent cancer occurrence from a certain level of radon exposure. The models are based on observations of deaths among underground miners who worked in high radon environments.

"I have read that in some places people sit in caves to breathe large amounts of radon to improve their health. Is this true?"

Yes. In some portions of the world, e.g., Montana and Austria, there is a practice of going into caves to breathe radon to improve health. The practice is related to a phenomenon known as hormesis, a perceived health benefit derived from exposure to small doses of substances known to be harmful in larger doses. This is not the same as building immunity to some toxic substance from a series of tiny doses over a prolonged period such as might occur with snake venom. Rather, it is the notion that small doses of some things, such as radiation, may actually stimulate the body's immune system in a manner that helps the body ward off the effects of disease. The scientific literature concerning hormesis is extensive and the effect is well documented, although not well understood.

As the hormesis affect applies to radon exposure, the contention is that limited exposures to high doses of radon or prolonged exposure to small doses act to stimulate the immune system and provide for a generalized overall health benefit. This is seemingly in direct contradiction to the position held by EPA and the National Academy of Science, that the relationship between radon exposure and lung cancer is linear and there is no minimum threshold value below which radon is not harmful. This is referred to as the "linear no threshold" (LNT) position.

Although there are several details that are relevant to an examination of the conflicting opinions, a few points are worth considering:

- First, exposure to radon in caves is also likely to involve exposure to other forms of radiation, notably, gamma radiation emitted from the decay of other radionuclides that occur in the same radioactive decay chain as radon. Whereas radon only emits alpha radiation, and alpha radiation cannot penetrate the body except through the unprotected lining of the lungs and esophageal airways, gamma radiation can easily penetrate all parts of the body. So, if the body's immune system is reacting to a radiation dose it is just as likely, perhaps more likely, to be a response to gamma exposure than the alpha radiation resulting from radon exposure. Also, many of the claims regarding a health benefit from time spent in "radon caves" involve diseases that are autoimmune in nature (arthritis, lupus, etc.), so an enhancement of the immune system would logically result in an increase in symptoms. It is all very curious.
- Second, early work relating radon exposure to increased incidence of lung cancer was conducted amongst mine workers. It seems reasonable that if increased doses of radon from times spent in caves had a beneficial influence on health, including a reduction in the likelihood of developing lung cancer, there would have been no relationship between radon exposure to miners and the incidence of lung cancer to start with … but there was.
- Third, while the body's immune system may increase its activity in response to cellular damage from exposure to radiation, it is well accepted that at some point the exposure results in cellular damage beyond the body's ability to compensate. So the question becomes, even if there were some health benefit associated with small doses of radon/radiation, at what point does the damage outweigh the body's ability to compensate.
- Finally, the alleged benefits from "radon therapy" pertain to the state of health of the individual at the time of the exposure, e.g., reduced discomfort from arthritis and other existing conditions; it does not speak to cellular damage being done by the exposure that may result in the occurrence of disease several years into the future. For radiation induced lung cancer, the average latency period between initial cellular damage and mortality is 10 - 15 years. There are certainly persons with no smoking history who have undergone radon inhalation therapy (visited radon caves) that nonetheless developed lung cancer. One cannot help but wonder whether they would have developed lung cancer if they had not undertaken radon "therapy."

"Are there any studies that relate incidence of lung cancer in New Hampshire to radon concentrations in homes?"

No. Although it is reasonable to think that this is an obvious relationship to investigate, the truth is that it is a very difficult relationship to make. Such an investigation would require long-term information on radon concentrations throughout all levels within the home (not just readings in the lowest lived-in level), daily occupancy times and duration of residence, smoking history and population mobility, as well as any other variables which might influence the incidence of lung cancer. This data is simply not available in New Hampshire, the best we can do at the moment is to extrapolate average whole-house concentration data from our limited database of short-term readings and use existing estimates for the other variables.

The reader may access the most recently compiled data on cancer incidence in New Hampshire by visiting the website of the New Hampshire Bureau of Health Statistics at http://www.dhhs.state.nh.us/dhhs/healthstats.

"I'm pregnant and we have young children, am I or my children at any greater risk from radon?"

The U.S. Environmental Protection Agency requested that a National Academy of Sciences' committee reviewing the risks associated with radon in drinking water, also comment on the evidence pertaining to the risks from radon on potentially sensitive subpopulations. Because the risks from radon entering through the water supply are largely attributable to radon out-gassing from the water supply and subsequently being inhaled, this consideration of risk encompassed both inhaled and ingested radon. The committee was unable to identify any definitive information to indicate that pregnant women, fetuses or young children were at appreciably greater risk from radon than members of the general population.

"If radon is such a problem in houses now, why hasn't it been a problem in the past?"

There are probably several reasons, some of which are as follows:

First, no one measured radon in houses before the mid-1980's so we don't really know what role it may have played in lung-related illnesses. Also, there was a generic grouping of respiratory illnesses, many of which may have been cancers, some of which may have been radon-related.

Second, in the past, homes were draftier and one might expect that radon concentrations were diluted. Also, a larger portion of the population was involved in agricultural pursuits that allowed for less time to be spent indoors.

Third, after a cell is damaged in a manner that starts it on the road to lung cancer it may take several years before the consequences of that process become evident. In the past, the national average life expectancy was shorter than it is today. In the past 100 years the average life expectancy of a child who reached the age of ten has increased about 17 years. One of the consequences of this extended lifespan is that there is now more time to incur the necessary cellular damage and more time for a cancer that initiates later in life and develops slowly to become enough of a problem to be detected and ultimately be the cause of death.

"What is a "pCi /L"?"

Radioactivity has traditionally been measured in units called "Curies" (**Ci**). The prefix **"p"** stands for "pico" (pronounced, pea-co) (1 trillionth part of some quantity). The "**/L"** is the abbreviation for "per liter." So the whole phrase is "picocuries per liter." The term is a measure of the concentration of radon in air or in water.

Outdoors, the national average radon concentration is estimated to be 0.4 pCi/l. The US Environmental Protection Agency recommends taking steps to reduce radon in indoor air when the average indoor concentration equals or exceeds 4.0 pCi/l, ten times the average outdoor concentration.

"So, if I have less than 4 picocuries per liter of radon in the air of my home I'm safe, right?"

No, not necessarily. Initially there is the question of whether the test was conducted correctly. Apart from that question there are really three issues:

First, the linear, no-threshold model for radon risk used by the National Academy of Sciences and the EPA to estimate risk from radon assumes that every radon atom we inhale or ingest represents some level of risk, regardless of how small that risk may be. The same logic applies to the two alpha-emitting radon decay products, Polonium-218 and Polonium-214. So, there is not really a "safe" level of radon, it is simply a matter of ***the less you are exposed to, the smaller your risk***. At some point the risk becomes too small to be concerned with, but at what point (concentration) this might be is an individual decision. EPA commonly uses a risk level in the range of 1-to-3 additional cancers for every 10,000 persons exposed as a maximum allowable lifetime risk for some contaminants, for some contaminants the allowable risk might be as small as 1 additional cancer per million (1,000,000) people. In any event, it is impossible to reduce indoor radon concentrations to zero because the ambient outdoor air that continually infiltrates homes is estimated to contain some small amount of radon that varies from place-to-place and time-to-time, but is usually considerably less than 1.0 pCi/l. The best available estimate of the national average value for outdoor ambient radon concentration is 0.4 pCi/l.

Second, it is important to understand that EPA's recommended action level of 4.0 pCi/l is a technology driven standard that originated in the mid-1980s, and not a health dependent standard. At that time the forces driving radon entry into a house were not as well understood as they are today, nor was the technology as efficient at preventing radon entry. In those early days of radon reduction technology, homes with more than 4.0 pCi/l could almost always be brought down to significantly less than 4.0 pCi/l; however, radon concentrations in homes that started with less than 4.0 pCi/l could not always be reduced significantly. Therefore, 4.0 pCi/l was determined to be the most reasonable point at which to make a recommendation to mitigate. Four pCi/l still represents appreciable risk. The National Academy of Science's most recent estimate of the general population's risk of developing a radon-induced lung cancer from lifetime exposure to 4.0 pCi/l of airborne radon is approximately 23-24 cancers per 1000 persons, but may range between 7 and 39 cancers per 1000 persons, depending on an individual's smoking history.

Third, a person should not assess their individual risk based on a reading from a single location within a house. Apart from being aware that radon concentrations may vary with the season of the year, it is also important to understand that one's individual risk is a composite of the time-weighted exposures one encounters as they move throughout the house. The following is an example of how a radon reading from the basement might give the wrong impression about an individual's risk.... this **fictitious example** is for a house with a very high level of radon in the water supply, occupied for an average of 18 hours each day:

2.25 hours spent in a 12 pCi/l basement
(*used for laundry, workshop, game/exercise area) = ...……….......... 27 pCi/l hours

8.0 hours spent in a 2 pCi/l bedroom on the second floor = ...…………..... 16 pCi/l hours

*0.75 hours spent in a 20 pCi/l bathroom = ...………….......... 15 pCi/l hours

5.5 hours spent in 4 pCi/l rooms on the first floor
(living room, dining room, family room, but not the kitchen) = ... 22 pCi/l hours

1.5 hours spent in an 8 pCi/l kitchen = ...………….......... 12 pCi/l hours

* The risk from airborne radon in the bathroom or in a laundry room is very difficult to assess for reasons that have to do with the decay rate of radon. The example provided above is a very simplistic model designed to illustrate a point about the effect of cumulative differential exposures and is acknowledged as a representation that is likely to overestimate the risks posed by exposure in areas of heavy water usage.

Health risk estimates are based on an average daily occupancy of 18 hours for an entire lifetime, estimated to be approximately 75 years. In this particular scenario the time-weighted average exposure to radon in the indoor air for these 18 hours would be 5.1 pCi/l (assuming that the radon concentrations in the various parts of the house remained constant, which they do not). If this exposure were indicative of the occupancy cycle for a period of an entire lifetime, this would represent a lifetime risk estimate less than half that which would be calculated using only a reading taken in the basement, but still appreciable (according to the most recent NAS risk assessment, approximately 10 - 50 fatal lung cancers per 1000 persons, depending on the smoking history of the occupants).

TESTING

"My house is built on a slab and doesn't have a basement so I won't have a radon problem, right?"

Homes built with slab-on-grade construction techniques may seem less likely to have radon problems, but even these homes can have elevated radon levels. Data collected during State-run surveys over the past several years indicate that nearly 20 percent of the slab-on-grade homes in New Hampshire have radon concentrations greater than 4.0 pCi/L during the winter months. The highest reading recorded in a slab-on-grade home during these surveys was 120 pCi/L.

In homes built with this construction technique, radon contributed to the air by the water supply may have a greater influence on the airborne radon reading on the first floor than one would typically expect when measuring airborne radon in the basement of some other home. This differential contribution may be particularly important when making a determination concerning the need to mitigate radon entry through the foundation based solely on readings of radon in the air.

"Are radon levels higher in a house if the house has been closed up for some extended period?"

No, not appreciably. Buildings continually have infiltration of new air, as air from within the building escapes to the outdoors through various cracks and openings. Certainly it seems reasonable to suspect that the rate of movement of air into and out of a house would increase when the house was occupied, but this process continues even in the absence of occupants, albeit at a slower rate.

If you are uncomfortable with the idea of testing a home that has been closed for some extended period, then simply open the windows for a short while, then close all the windows for a period of at least twelve hours before conducting a radon test that must last for at least 48 hours.

NOTE: There is one consideration that is often overlooked when airborne radon concentrations are measured in unoccupied houses. The measured radon concentration will not reflect any additional radon contributed to the air through use of the household water supply once the house reaches normal occupancy. Another related consideration is that even when houses are occupied, radon tests conducted in the basement may not adequately reflect the contribution that waterborne radon makes to the air of the house on those floors where water use is frequent. Of course the opposite can also be true if the laundry is in the vicinity of the test location and is in frequent use during the testing period. EPA guidance for conducting radon tests specifies that tests should not be conducted in laundry rooms.

"How do I test my house for radon?"

There are a variety of testing devices available for determining the radon concentration in air: devices that utilize the radon absorption characteristics of activated carbon, some that rely on tiny indentations left on plastic chips by the impact of alpha particles released during the decay of radon atoms, and others that utilize the ionization characteristics of alpha radiation to alter the electrical charge stored on a Teflon wafer. All are easy to use, are suitable for use by the homeowners, home inspectors, or by radon testing professionals. Provided the devices were made, maintained and stored with appropriate quality control they should all work well if proper testing conditions are maintained.

Essentially, the devices simply require opening, setting out in the desired location for a pre-specified length of time, recording time and date when test was started and ended, and prompt mailing of the device to the laboratory for analysis. Different devices are suitable for different testing periods, those utilizing activated carbon are the most common and are suitable for testing periods between and two (2) and seven (7) days, depending on the particular detector.

For the purposes of real estate transactions the US EPA recommends taking two tests in the same location, either simultaneously or sequentially, and basing a decision concerning mitigation on the average of those two readings. Outside of real estate transactions EPA also recommends using multiple tests, but the absence of a time constraint allows for options that include taking long-term tests when an initial short-term test value is between 4 and 10 pCi/l, for further guidance in the use of multiple tests consult A Citizen's Guide To Radon and Protocols For Radon and Radon Decay Product Measurement in Homes at EPA's radon publication website http://www.epa.gov/radon/pubs.

If one wants a radon professional to conduct the test in order to assure quality of the procedure, the homeowner may wish to select an individual certified by one of the two national organizations offering certification programs for radon service providers, the National Environmental Health Association (www.neha.org), or the National Radon Safety Board (www.nrsb.org). Professional radon testers may have an additional type of radon testing device, a continuous monitor that records radon concentrations at brief sequential time intervals and averages those readings over extended periods.

"Where should the radon test be conducted?"

For the purposes of a real estate transaction, this question is best answered by language taken directly from the July, 2000 edition of the EPA publication, Home Buyer's and Sellers Guide to Radon, page 6, EPA doc. 402-K-00-008:

"EPA recommends that testing device(s) be placed in the lowest level of the home **suitable for occupancy**. This means testing in the lowest level (such as a basement), which a buyer could use for living space without renovations. This means testing in the lowest level that you currently live in or a lower level not currently used, but which a buyer could use for living space without renovations. The test should be conducted in a room to be used regularly (such as a family room, living room, playroom, den or bedroom); do **not** a kitchen, bathroom or laundry room or hallway. Usually the buyer decides where to locate the radon test, based on their expected use of the home."

Unfortunately, EPA has not defined the extent of work that would constitute a "renovation." Neither have they set a length of present or projected daily or weekly occupancy time that might differentiate between "lived in" space and that which is used less frequently, other than a definition they used for "living space" during the National Residential Radon Survey (circa (1990), that classified basements as "living space" if they were occupied for an average of at least one hour per day or were determined by the occupants to be living space. Therefore, whether a basement is a reasonable place to conduct a radon test because one might now or at some future time have a workshop, exercise area, or casual game room in that space without undertaking "renovations" is largely a negotiated issue between the buyer and the seller. The general practice seems to be to consider those spaces as habitable, however, in assessing future risk it may be prudent to also test the first floor of the home as in most instances that space may be used more frequently than basement space.

The reader may access the text of this publication at http://www.epa.gov/iaq/radon/pubs/hmbyguid.html.

When radon testing is done outside the confines of a real estate transaction there is time to conduct long-term tests in multiple locations within the building. That is the most reliable means of estimating average exposure and the associated risk.

"Where can I get a radon test kit?"

Radon detectors may be purchased from some building supply stores, possibly from radon testing companies, from many laboratories that manufacture and read the devices and through the National Safety Council by calling their Radon Helpline at (800) 5576-2366. If you choose to obtain a device through a hardware store or some other common retail outlet, we advise that you try to determine whether the device is certified by one of the two national certification organizations, the National Environmental Health Association and the National Radon Safety Board.

"How accurate are short-term radon tests?"

Devices produced by manufacturers who participated in EPA's radon proficiency program were supposed to have read within 25 percent (+/-) of the true value; generally the device error was no greater than 10 percent - 15 percent. That program is no longer in place, however the two national organizations that certify individuals to do radon measurements and the laboratories/manufacturers that produce radon test devices advocate the same protocols with respect to the accuracy of radon detectors.

A more frequent source of discrepancy between, or misinterpretation of test results stems from a lack of understanding that radon concentrations in homes fluctuate not only from place-to-place within the home, but also from hour-to-hour, day-to-day and month-to-month. The short-term testing devices most often used in real estate transactions are only capable of providing a reading representative of the radon concentration for the time and place the test was conducted. That reading may, or may not, be representative of the annual average concentration throughout the house. In general, the longer the testing period the more closely the result is likely to reflect the average annual concentration at that location. The one proviso is that for long-term test results to mimic annual average concentrations care should be taken to see that the specific testing period contains equal durations of the home heating season and the non-heating season.

With any testing device, the reliability of any measurement as a representative estimate of the radon concentration in the air can only be as good as the level of adherence to the protocols for proper placement of testing devices and maintenance of the "closed-house" testing conditions. Even with proper placement and maintenance of testing conditions it is always possible for a radon test to yield an inaccurate estimate of the radon concentration. For that reason, duplicate testing is recommended as a means of ensuring against spurious readings. Very large differences between duplicate measurements conducted in the same location at the same time would indicate a device error; it would be impossible to determine which reading was correct and a new test would be recommended.

More information about radon measurements in homes can be found in EPA publication, EPA 402-R-93-003, June 1993, Protocols for Radon and Radon Decay Product Measurements in Homes (see http://www.epa.gov/radon/pubs The information contained in this document is applicable to practices currently endorsed by both private organizations currently certifying radon service providers.

A particularly important associated question that should be asked, but frequently is not, is whether one should act upon the result of any particular radon short-term test result. Recommendations regarding the desirability of taking steps to reduce radon in indoor air are based on the presumption that the radon test was conducted in a specific manner under a certain set of conditions. For the short-term, passive type detectors commonly used to measure radon in indoor air during real estate transactions (activated carbon, alpha trac, and electret detectors) those conditions include: duplicate tests in the same general location of the house, maintenance of closed-house conditions during the entire test period **and for twelve (12) hours prior to starting the test**, proper placement of the detectors, and a few other criteria. If these protocols are not followed, then the validity of the recommendation to take steps to reduce radon concentrations when they equal or exceed 4 pCi/L may not be applicable.

Many radon tests are conducted by home inspectors who have no direct knowledge of whether closed-house conditions were maintained during the twelve (12) hours prior to setting out the detectors. Failure to adhere to the 12-hour closed-house condition prior to testing may result in a test result being somewhat different than if the conditions had been adhered to. Although one might expect such a deviation in testing protocols to result in a somewhat lower test result, there is the possibility that opening a window in the house may result in an increase in the natural stack effect in the house, a depressurization of the basement space and a subsequent increase in the radon concentration. There is no way to predict the extent of the error introduced by failure to comply with the closed-house conditions prior to testing, it depends on a number of factors including the extent of prior ventilation, the actual time it took the radon concentration to in the tested space to reach equilibrium after closed-house conditions were imposed, and duration of the actual test. As a practical matter, this may be particularly important during real estate transactions in which radon mitigation is a negotiation point and the reported test result is near the 4.0 pCi/L EPA Action Guideline.

"Are tests conducted with continuous monitors more accurate than tests done with passive measuring devices?"

In theory, no. If the devices (any devices, passive or active) are made, read and operated in accordance with the requirements of either of the two national certification organizations, the National Environmental Health Association and the National Radon Safety Board, then they are all subject to the same quality control standards. However, continuous monitors do have some advantages that go along with their higher cost of use. They measure radon at brief time intervals to produce a continual "real time" record of the radon concentration. This supplies the user with a picture of radon fluctuation within the house which may be useful in helping to determine the source of the radon and may also provide information concerning whether the testing conditions were maintained during the testing period and/or whether the test result may have been adversely influenced by weather conditions.

There is one significant exception to this "equality" between test devices. Short-term radon tests conducted with granular activated carbon commonly used in the real estate industry have a bias towards the radon concentrations present at the end of the test period. This is because the migration of radon into the carbon grains is a dynamic process that can move in both directions. The carbon grains contain large numbers of pores and radon migrates from the air into the pores and over time tries to come to an equilibrium condition between the concentration in the pore and the concentration in the air surrounding the pore, i.e, the room. When there is a strong adverse change in the weather during the testing period the concentration of radon in the home will frequently rise, and with it the concentration of radon in the pores of the carbon grains. When the weather abates to a more normal condition radon concentrations in the home will drop and radon will drift back out of the pores in the carbon grains as it continues to try to reach equilibrium with its surroundings. If an adverse weather event causes radon concentrations to increase during the latter half of a short-term test conducted with an activatred carbon radon detector there may be insufficient time for the radon concentration in the pores of the carbon grains to return to a more normal condition. This circumstance would yield a radon test result biased to the high side and not representative of the more common "average" for the space in question.

With any radon testing device the key is to be sure that the test was conducted under appropriate conditions and to understand what the measurement represents.

An average of duplicate measurements (simultaneous or consecutive) taken at the same location will help to reduce uncertainty.

NOTE: As with all radon testing devices, tests with continuous monitors need to employ a minimum 48- hour test period in order to comply with EPA testing protocols. However, when using a continuous monitor the first 4 hours of data collected by the monitor may be discarded or incorporated into the result using specified system correction factors. This is to allow for a four-hour interval while the monitor's sensing device comes to equilibrium, usually referred to as "ramp up time." With continuous monitors there must be **at least 44 contiguous** hours of usable data, other than the 4-hour ramp up time, to produce a valid average.

More information about radon measurement in homes can be found in EPA publication, EPA 402-R-93-003, June 1993, Protocols for Radon and Radon Decay Product Measurements in Homes. Included in this publication is information pertaining to technologies directed at reducing the likelihood of device tampering aimed at biasing the result of a radon test. The information contained in this document is applicable to practices currently endorsed by both private national certification organizations.

"We had a radon test done on a property we are trying to buy and it differs greatly from a subsequent test conducted by the homeowner, how can that be?"

Widely differing results between tests conducted by the buyer and the seller is an all too frequent scenario. Often the circumstance is one in which the buyer hires a home inspection firm to conduct a radon test and the result comes back high, whereupon the seller doesn't believe the result, conducts a test of their own and gets a much lower reading. Of course the reverse can be true in the case of post-sale testing. This leads to a feeling of mistrust, antagonism and uncertainty between the parties ... a situation obviously detrimental to the successful completion of the sale.

There can be a number of reasons why test results done by the buyer and seller in the same general location, but at different times, can vary widely. Although non-maintenance of closed-house testing conditions is usually the first reason that occurs to the buyer, other reasons may include:

- use of testing devices with unacceptable levels of quality control,
- placement of devices in different locations,
- inaccurate recording of exposure durations,
- normal variation in the accuracy with which devices measure radon concentrations (+/- 25 percent of reality is acceptable),

- sometimes a differential contribution from the water supply (usually only an issue if the home's water source is a private well with very large radon concentrations),
- and a very common cause, extreme differences in the weather conditions during the two testing periods (stormy versus calm).

When differences of this nature occur, buyers and sellers frequently agree to have the test redone with what they perceived to be a more accurate device, an electronic continuous radon monitor. In actuality, in order to be certified by the National Environmental Health Association (NEHA) or the National Radon Safety Board (NRSB), **all** radon devices must undergo the same quality control tests and respond within the same range of accuracy and precision. Continuous monitors offer an hourly history of the radon concentration for the entire test period, sometimes accompanied by barometric, moisture and temperature readings, all of which help provide an explanation for the hourly fluctuations in radon concentration and hopefully divert any previous allegations of device tampering. When interpreted by a qualified radon measurement specialist the resultant average reading usually is one that both parties can agree on.

One can have a reasonable expectation of avoiding the mistakes that may be associated with conducting a radon test properly by engaging the services of an individual that is certified by either of the two national certification organizations, the National Environmental Health Association or the National Radon Safety Board.

"Should I do another test?"

This question comes up frequently with respect to radon concentrations in the air and in the water; specifically, when a properly conducted test yields a result close to the action level and also when the reading is so high that the individual feels the result "must be a mistake." The appropriate answer in both instances is related to the individual's confidence in the methodology used for the first test and in their understanding that radon levels vary through the year. If the individual has little confidence in the methodology used to conduct the test or collect the sample, a retest is always appropriate.

One testing scenario that frequently leads to the question of whether a retest is warranted is when the results of two simultaneous, side-by-side tests yield indicate radon concentrations on either side of the 4.0 pCi/L action guideline. In this instance the protocols initially established by EPA and later adopted by the two national certification bodies indicate that a new round of testing is appropriate when the higher test result is twice as large, or more, than the lower test result.

MITIGATION

"How do I lower the radon level in my house?"

The most common approach is the use of sub-slab depressurization. In its simplest form the technique involves drilling a hole in the basement floor, excavating some dirt through that hole, inserting a 3" or 4" PVC plastic vent pipe, venting that pipe above the eave of the roof by routing it either through the body of the house (similar to the stack vent for the plumbing) or through the shell of the house and upward along the exterior of the house (similar to the down pipe of a drain gutter). The pipe is fitted with an in-line fan that exhausts outward and depressurizes the area under the basement slab, thus diverting the radon.

In New Hampshire, costs for this service normally range from $1000 - $2000, although this range may vary depending on the distance the contractor may have to travel, complexity of the job and normal market pressures.

An alternative radon removal technique involves the use of a Heat Recovery Ventilator (HRV), sometimes called an air-to-air heat exchanger. An HRV unit exchanges internal air for external air and lowers the radon concentration through simple dilution.

One downside of HRVs is that they cause an increase in household heating and cooling costs. This option would not normally be feasible for initial radon concentrations greater than 15 pCi/L.

Note: Some professional radon mitigators have ceased installing HRV units to reduce radon concentrations because of the potential for moisture problems to develop within the home. Other contractors report no such difficulties.

"Would caulking the cracks in the cellar floor take care of the problem?"

Probably not. The house is always under negative pressure and unless you seal every conceivable entry point, when you fill one crack you may increase the volume of air moving into the cellar through another opening. Of course sealing openings will probably help some, it just should not be thought of as a “stand alone” procedure, but rather a procedure to use in conjunction with sub-slab ventilation or other radon reduction techniques.

Caution: Urethane caulks give off organic compounds during curing. Some of these may represent health hazards. Users are reminded to obtain and read the Manufacturers' Data Sheets for any chemical they use. These sheets identify hazardous aspects of the product's use.

"Can't I reduce the radon entry by just painting the basement floor and walls?"

Possibly. In most instances the predominant pathway for radon entry into basements is through cracks and other openings in the floor and walls and also the seam where the floor abuts the wall, not through advective flow directly through the concrete. There are concrete sealants on the market that might reduce diffusive migration of radon directly through concrete and through very small cracks in the concrete. Experimental data concerning a dozen different sealants indicate they all reduced advective flow by 60 percent or more and that two reduced diffusive flux by more than 97 percent (epoxies: "no filler" and "polysulfide"). However, the same report noted that several of the sealants tested exhibited unfavorable adhesion characteristics that may negatively influence long term performance.

Please be advised that neither the US Environmental Protection Agency, nor the NH Bureau of Environmental & Occupational Health recommend sealing as a "stand alone" permanent solution for reducing radon in homes. For those persons who want to try this approach we suggest you consult professionals at paint or masonry supply stores for the product that may most closely meets your need; alternatively, you may wish to ask radon removal specialists to share their experience with such products.

As with all chemical usage, the user is advised to read and adhere to the recommendations noted on any Manufacturers Data Sheets associated with the products.

It should be noted that EPA document EPA/625/R-93/011, Radon Reduction Techniques for Existing Detached Houses, 3rd Edition, has a section that addresses sealing techniques in the context of installation of active soil depressurization systems, page 176 - 183.

"Can I lower the radon level by installing a HEPA filter?"

The short and technical answer is "no," but that is not the entire answer. The question one really wants answered is whether a HEPA filter installed on a continuously operating air circulation system will reduce radon-related risk and since risk is really associated with the inhalation of radon decay products, polonium-214 and polonium – 218, the question becomes whether a HEPA filter will capture these decay products.

HEPA filters are designed to capture small particles in the air, such as dust and pollen, a task they accomplish by simple filtration through a material with very tiny pores for air to pass through. The pores are large enough to allow air passage, but small enough to restrict passage of all but the very tiniest particles. Because radon's decay products are electrically charged particles and will attach to microscopic particles and aerosols in the air (which we may eventually inhale), the removal of particles from the air (along with any attached radon decay products) might technically reduce the actual radiation dose delivered to the lungs. It all depends on how deep into the lungs the various airborne particles go, and that is principally determined by the size of the particles. Current thinking is that the airborne particles we inhale are too small to be filtered out by a HEPA filter. If this is true, then even though a HEPA filter will remove some radon decay products from the air, these are the ones that are attached to dust particles that are too large to make their way deep into the lung and thus are not the ones that are carrying the decay products that actually do the damage.

"Will an electrostatic pricipitator/filter attached to an air circulation system lower my radon levels?"

The answer to this question is very much like the answer to the previous question about HEPA filters. Filters that remove particulates from the air by means of applying an electrical charge to the filter material and relying on this electrical charge to attract and capture airborne particles will not have any affect on the radon concentration because radon has no electrical charge that would allow it to be captured by the filter. Electrostatic filters/precipitators will remove some dust particles from the air and along with them will be the electrically charged radon daughter products of polonium-214 and –218 that have attached themselves to these particles. It also seems likely that filters of this type would remove smaller airborne particles than HEPA filters and also some of the electrically charged radon daughter products that are unattached to any dust particle or aerosol, but it remains unclear whether they would trap enough of the radon daughters which had attached themselves to the tiniest airborne particles, or those radon daughters that remained unattached, to actually make a significant reduction to radiation dose that makes its way deep into the lung.

It may be possible to reduce the overall risks from radon through use of these devices and they may be an alternative for mitigating buildings where conventional mitigation techniques are impractical, certainly they can do no harm and it is equally certain that they will reduce the concentration of radon decay prducts in the air. However, one should be aware that many such devices only handle enough air to treat a single room and therefore may be prohibitively expensive to deploy throughout the home.

"Who can I get to correct the problem?"

The State of New Hampshire has no radon-related certification process by which to assess the skills of radon service providers or the quality of the devices they may install. For those who prefer to hire an individual with some form of related certification, we are aware of two radon-related certifying organizations, the National Environmental Health Association (NEHA) and the National Radon Safety Board (NRSB).

Individuals certified by either the NEHA or the NRSB can be identified through their websites at http://www.neha.org or at http://www.nrsb.org, respectively, or by contacting the organizations directly: (NEHA, (800)-269-4174) and (NRSB, (303)-423-2674). Alternatively, one may consult the yellow pages of their telephone directory.

Participation in either of the aforementioned certification programs is voluntary and is not a condition of performing radon-related services in New Hampshire. There is no evidence that certifications offered by either organization represent substantial differences in training or knowledge over that offered by the other organization. For all intents and purposes, certification requirements of either organization for Radon Measurement and Mitigation Specialists equal or exceed those formerly required by EPA's National Radon Proficiency Program.

"I'm pretty "handy," is this something I can do myself?"

Possibly. Although some aspects of installing an active soil depressurization system for the removal of radon may be physically demanding and carry with them risk of personal injury, apart from the determination of appropriate fan size and possibly wiring associated with installation of the fan, there is nothing technically difficult about the actual installation of the apparatus that might be needed: vent pipe, sump pump cover, fan and manometer. **However**, without adequate knowledge of radon measurement techniques and diagnostic methods, flow charts for sizing fans, or the equipment to make the requisite measurements, the effectiveness of the homeowner-installed system may be somewhat less than desired. Further, the homeowner is **cautioned** to **always** test for backdrafting of the furnace or other combustion appliances, notably, gas water heaters and gas dryers that may be caused by putting any such installation into operation. This is best left to a professional furnace service technician. The consequences of installing a radon removal system that interferes with the proper venting of combustion appliance flue gasses may be **fatal**.

If a homeowner in New Hampshire wishes to undertake installation of a radon mitigation system in their home, this agency is aware of at least one text on the subject that is likely to be found in their local public library and may be helpful, Protecting Your Home From Radon, 2nd ed., D. L. Kladder, et. al., 1995. In addition, there are various EPA publications available through the National Service Center for Environmental Publications (telephone 1-800-490-9198; e-mail necepi.mail@epamail.epa.gov) that may be of assistance. Specifically, Radon Reduction Techniques for Existing Detached Houses, technical guidance, 3rd ed., EPA/625/R-93/011, Oct. 1993; there is also a 2nd edition of this text that covers a wider range of radon reduction options, EPA/625/5-87/019, Revised Jan. 1988. A companion document may also prove to be beneficial, Application of Radon Reduction Methods, EPA/625/5-88/024, Aug. 1988.

Companies that sell radon mitigation equipment directly to the homeowner include, amongst others:

Infilted, Inc.; Waynesboro, VA; www.infiltec.com

Professional Discount Supply, Inc; Colorado Springs, CO; www.radonpds.com

"Can the radon problem always be corrected?"

The correct answer is, “almost anything for a price.” Most “fixes”/“mitigations” in single family dwellings are straightforward, very effective and relatively inexpensive (in New Hampshire, on the order of $800 - $2,000), but occasionally with complex jobs, mitigation of commercial structures, mitigation of radon in condominiums, or mitigation of old buildings (particularly those with dirt floors and/or fieldstone foundations) costs may run into the “several thousand” dollar range.

In some instances the radon concentration in the air of the house has a large component that is contributed by radon “out-gassing” from the water supply. In these cases there may be unanticipated costs associated with a need to install both a standard sub-slab depressurization system to remove radon that is entering through the foundation **and** some technology for removing radon from the water supply. Indeed, in some instances eliminating the contribution from the water supply alone is sufficient to reduce airborne concentrations to acceptable levels.

"Do radon vent pipes have to extend above the eave of the roof?"

Yes. If the vent pipe terminates beneath the level of the eave there is a possibility for radon to re-enter the house through open windows. Clearly, the vent pipe should also terminate well away from other windows or openings as well.

"I don't want the radon vent pipe running up the outside of my house, isn't there another solution?"

Assuming that the prospect of routing the vent pipe through the house has been dismissed, there is one other possibility for reducing airborne radon concentrations. Sub-slab depressurization systems remove radon from beneath the basement slab (or from outside the walls) before it ever has a chance to enter the home. When sub-slab depressurization is not feasible or desirable because of aesthetic, structural or design limitations, or because of a high water table, an alternative approach is to use a combination of dilution and increased air pressure to reduce radon levels.

Heat recovery ventilators (HRVs), also referred to as air-to-air heat exchangers, are designed to bring fresh air into the house and exhaust inside air. These devices lower radon concentrations through simple dilution. Further, if the device is set up so the rate of air intake exceeds the rate of exhaust, the resulting increased air pressure in the ventilated space can act as a barrier to reduce the entry of soil gasses, including radon. In combination, dilution and increased air pressure can be an effective means of mitigating radon problems when initial concentrations are less than 15 pCi/L.

As one might expect, a simple exchange of air can result in significant loss of heat from within the home during the winter months and significant heat gains during the summer. HRVs are designed to reduce these seasonal gains and losses by passing the airflows over heat exchange coils that transfer a percentage of the heat from one air flow to the other depending on whether one is trying to conserve heat in the winter or prevent its entry in the summer.

There are significant negative aspects to the use of HRVs. One, of course, is the unavoidable increased heating and cooling costs associated with seasonal heat loss and gain. Another area of concern is maintaining the desired flow rate balance between intake and exhaust. If the intake rate becomes less than the exhaust rate (as might happen if the intake vent becomes clogged with leaves during the autumn, or snow during the winter) the result would be a depressurization of the ventilated space and likely a consequent increase in the rate of radon entry. There is also the possibility of increasing the humidity in the building from introduction of moist air. Further, HRVs may have moisture condensors that will need to be adequately drained.

Any device that brings air into the house should have its intake vent located well away from any sources of airborne pollutants, notably, vehicle exhaust.

Although we do not keep track of retail costs of these or other devices, one might expect cost of these units sized for residential use to be in the $500 - $1000 range. This does not include the cost of installation.

Note: Some professional radon mitigators have ceased installing HRV units to reduce radon concentrations because of the potential for moisture problems to develop within the home. Other contractors report no such difficulties.

"Do all radon vent systems need fans? If so, do the fans need to run all the time?"

No, and yes. Radon vent systems do not always need fans, sometimes the normal stack effect caused by temperature and pressure differentials is adequate to cause sufficient radon to move upward through the vent pipe on its own. However, if a fan is installed with a sub-slab radon mitigation system, then the fan is likely to be integral to the successful operation of the system and should be allowed to run continuously.

"If I install a system to lower the radon concentration in the air do I still need to treat the water?"

This question presumes the radon concentration in the water was above recommended levels; therefore, generally speaking the answer is, yes.

The sub-slab depressurization system that is usually installed to remove radon in the air is designed to prevent radon entry through the foundation by lowering the air pressure beneath the basement floor and in some cases in the soil outside the basement walls. It does nothing to remove radon that has already entered the house, either through the foundation or through the water supply.

The one exception might be if one attempts to lower the airborne radon concentration by means of an air-to-air heat exchanger (heat recovery ventilator (HRV)). Since HRV's are designed to lower radon concentrations within the building envelope by simple dilution, regardless of the source of the radon, it might be possible to appreciably reduce the contribution emanating from the water supply by judicious placement and operation of HRV units. However, this approach is likely to be more practical in small homes, preferably ranch-style homes without basements used as living space.

HRV units will do nothing to mitigate any risks associated with ingestion of radon in the drinking water.

REAL ESTATE TRANSACTIONS

"Does a house need to be tested for radon before it can be sold?"

Not in New Hampshire. In New Hampshire there is only a notification requirement (NH Revised Statutes Annotated 477:4-a). The seller is under no initial obligation to reduce the radon concentration in the air or in the drinking water. In part, this statute states that the buyer must be notified that radon may "pass into a structure through the ground or through water from a deep well." Also, that "Testing can establish its presence and equipment is available to remove it from the air or water."

"If I test for radon do I have to disclose the result to a buyer?"

From the perspective of New Hampshire State law, the issue of radon notification during real estate transactions is covered under Revised Statutes Annotated (RSA) 477:4-a. In part, this legislation reads:

"I. Prior to the execution of any contract for the purchase and sale of any interest in real property which includes a building, the seller, or the seller's agent, shall provide the following notification to the buyer. The buyer shall acknowledge receipt of this notification by signing a copy of such notification:

Radon Gas: Radon gas, the product of decay of radioactive materials in rock may be found in some areas of New Hampshire. This gas may pass into a structure through the ground or through water from a deep well. Testing can establish its presence and equipment is available to remove it from the air or water."

With respect to the necessity to disclose specific information about a radon test, real estate agents (licensees) are subject to the rules of the New Hampshire Real Estate Commission, RSA 331-A. Under these rules the licensee (the real estate agent) "... shall disclose to a prospective buyer/tenant any material, physical, regulatory, mechanical or on-site environmental conditions affecting the subject property of which the licensee has actual knowledge." Further, "A licensee, when listing a property for sale, purchase or exchange which is served by a private water supply and is used or proposed to be used for a one to 4 family dwelling, shall ask the seller for at least the following information: ... (6) Whether the seller has experienced a problem such as an unsatisfactory water test or a water test with notations."

At least in the circumstance where one engages a real estate agent to market a home, it appears that if a radon test is conducted in the air or in the water the result should be disclosed to the real estate agent, and through the agent to the potential buyer.

"Is it the seller's responsibility to reduce the radon level if it is greater than 4 picocuries per liter?"

Apart from any conditions set out in the terms of the real estate contract itself, in New Hampshire there is no State requirement of either the buyer or the seller to test for radon in the air or in the water of a property; nor, for either party to reduce radon concentrations below some specified amount as a condition of either the sale or occupancy of a property.

"The house I am buying has a high radon level, is this something I need to get fixed before I move in?"

Assuming that this question is aimed at concerns about health risk rather than convenience, each individual situation has its own appropriate response based on the projected occupancy time in the area tested and the measured radon concentration in that area; there is no one answer that fits every scenario. The buyer needs to understand that health risks associated with exposure to radon are dependent on the amount of radon one is exposed to and the duration of that exposure. Estimates of increased cancer risk from exposure to radon are based on an assumption of an exposure period defined as 18 hours per day for 75 years. The estimates infer the anticipated increase in cancer occurrence in a large population, estimates bcome increasingly imprecise as the size of the affected population decreases. At the individual level they contain huge uncertainties. Keeping the high level of uncertainty in mind, at a radon concentration of 4 pCi/L, an individual with no smoking history might expect to incur an additional cancer risk of 7 - 8 chances per 1000 persons if they spend 18 hours per day for 75 years in the tested location. Since the model is linear in nature, a daily occupancy of 18 hours for a period of 1 year would yield 1/75 of the whole risk. Similarly, if one only occupied the area for 1 hour per day for the entire 75-year period, one would only incur 1/18 of the total estimated risk.

A typical circumstance is that the lowest level of the home has a radon concentration that is assessed as being too high. The buyer intends to use that area as a family room, den or bedroom that might be occupied for as many as 9 hours per day. For one reason or another it is not possible to get the radon level lowered prior to closing and it is unlikely that the work will be able to be done for a year. In this case the total risk incurred from exposure obtained in that space over the course of the following year would be estimated to be 1/150 of the total risk one would incur if one spent 18 hours per day in the location for a period of 75 years. If the individual had no smoking history and the radon concentration was 4 pCi/L, the risk incurred during the one-year period would be 7 - 8 chances in 150,000 of developing a lung cancer from the radon exposure. If the radon concentration is 40 pCi/L, the risk incurred in one year would be 7 - 8 chances in 15,000.

Persons with a smoking history are at approximately 5 times greater risk of developing radon-related lung cancer than those with no smoking history.

NEW CONSTRUCTION

"I'm building a new house. Is there something I can do to prevent it from having a radon problem?"

There are a few things one can do during the construction phase to reduce the likelihood of significant radon entry into the structure. These techniques are addressed in EPA documents. One such document, Radon-resistant Construction for New Residential Construction, EPA/625/2-91/032, Feb. 1991, is available through this office. A more recent document, Passive Radon Control Systems for New Construction, EPA/402-95012, May 1995, may be accessed at EPA's website, http://www.epa.gov/radon/pubs, by selecting the document, Building a New Home: *Have you Considered Radon?*. EPA's most recent and comprehensive document on this subject, Building Radon Out: A Step-by-Step Guide on how to Build Radon Resistant Homes, can also be found on this website.

"Is it possible to test a building lot prior to starting construction in order to determine whether a home built on that site will have high radon levels?"

No, not really. Certainly it is possible to test or estimate the potential of the soil or bedrock at a building site to emanate radon and/or allow transport of that radon to the surface; however, many other factors also influence the amount of radon that eventually finds its way into a structure.

WORKPLACE

"Is my employer required to test for radon in this space and take steps to reduce it if the level is too high?"

The State of New Hampshire has no regulations regarding radon testing or mitigation in the workplace other than those pertaining to buildings owned or rented by the State (NH Code of Administrative Rules He-P 1804.05). However, the U.S. Occupational Safety and Health Administration (OSHA) has a regulation that applies to radon in the workplace, Code of Federal Regulations (CFR) Title 29, Part 1910.1096. Please note that state and local governments, marine terminals, agricultural and construction operations are exempted from this regulation. OSHA regulation 1910.1096 can be found at http://www.osha-slc.gov/OshStd_data/1910_1096.html.

With respect to radon in the workplace it is important to understand that there are three separate yet related issues to consider: the responsibility to test a workplace, the responsibility to post a warning notice if the radon concentration is over a specified amount, and the responsibility to reduce radiation dose to the worker.

In general, the OSHA regulation requires that an employer post an **Airborne Radioactivity Area** sign in any area in which the radon concentration exceeds 7.5 picocuries per liter (pCi/l) "... averaged over the number of hours in any week during which individuals are in the area," (29 CFR 1910.1096(e)(4)(i)(b)). Of course the only way for an employer to determine the radon concentration in the workplace is to conduct a survey. Surveys for this purpose may need to be conducted in two stages, short-term sampling to identify potential problem areas and long-term sampling in areas of concern as indicated by short-term sampling. We suggest that sampling follow the protocols for residential sampling recommended by the National Environmental Health Association and the National Radon Safety Board, and that sampling procedures include short-term sampling during the winter months.

It appears that from a federal perspective an employer's obligation to test for radon in the workplace is dependent on whether the employer knew or, through exercise of due diligence, could reasonable be expected to know of the potential for elevated radon concentrations to exist in the workplace in question.

Under OSHA regulations an employer's obligation to mitigate a radon concentration is based on the **potential** radiation dose (exposure) to a worker, or workers, **not** just the presence of radon in the workplace. Therefore, under this regulation it would be necessary to determine both radon concentration and occupancy time in order to determine whether the resulting dose (exposure) was sufficient to warrant taking some remedial action. Mitigation of radon-related radiation dose might take the form of reducing or preventing radon entry into the workplace, dilution (reduction) of existing radon concentrations through increased ventilation, requiring workers to wear protective masks that filter out radon decay products, installing electrostatic filters on air circulating devices (an effect similar to that of wearing protective masks), and limiting worker time in the space in question.

Questions regarding OSHA's responsibility to enforce radon testing and reduction of exposure to ionizing radiation (dose) in the workplace should be directed to either the OSHA Consultation Program at the NH Department of Health and Human Services (603) 271-2024, or to OSHA's main office in New Hampshire at (603) 225-1629.

RADON IN WATER

"I didn't know radon could be a problem in drinking water."

Radon can get into the air of a home by two principal methods, through cracks and other openings in the foundation of a home and dissolved in the water supply. From a national perspective, airborne radon entering as a soil gas through the foundation is certainly the biggest threat to health. However, when radon enters a home through the water supply, much of the radon leaves the water through normal usage and becomes a component of the indoor air, thus raising the occupants' risk of developing lung cancer. Some radon remains in the water and may be ingested when the occupants drink water taken directly from the faucet. Using water for cooking or the preparation of coffee, tea, or other drinks releases the radon from the water and minimizes the risks associated with ingesting the water.

The National Academy of Sciences (NAS) established a central estimate of the risk to the General Population from radon entering through the water supply. The General Population risk estimate makes no attempt to adjust the central estimate to account for differences in individual histories. The NAS estimate indicated that approximately 89 percent of the risk associated with radon that **enters through the water supply** comes from the inhalation of the radon that leaves the water through normal household use, the remaining 11 percent is from ingestion of radon in drinking water.

The National Academy of Sciences recently published a report on the risks associated with radon in drinking water. That report may be found on the Academy's web site at http://www.nap.edu/catalog/6287.html.

"I have heard that it takes 10,000 pCi/L in the water to change the radon concentration in the air by one pCi/L, is that right?"

That is the correct ratio, but it is important to understand that this ratio is just an approximation and is meant to apply to the average contribution that waterborne radon makes to the radon concentration in the air when dealing with a large number of houses, it is not intended to apply to any one particular house. More importantly, the ratio refers to the average concentration in the water supply and the annual average radon concentration of the house as a whole, not just the airborne radon concentration in any one location for any one brief period of time. Radon released from use of water on the first and second floor of a home is not likely to substantially influence the radon reading in the basement because most of the air movement in the house is in an upward direction.

"If the radon concentration in my water only increases the airborne radon concentration by a couple of picocuries per liter, that's less than 4.0 pCi/L so I don't need to fix my water, right?"

No. This is a common misunderstanding that revolves around a misinterpretation of the 4.0 pCi/L threshold for mitigating radon in air. The level at which we recommend taking steps to lower the radon concentration in the home is not based so much on a risk threshold, but rather a technological threshold; a realization that it may simply be unreasonable to expect appreciable reductions from efforts to reduce radon entry through the foundation when the initial readings are less than 4.0 pCi/L. However, radon entering through the water supply and escaping into the air can be virtually eliminated by installing technology to remove radon from the water supply. Even reducing airborne radon concentrations by 1 pCi/L can reduce the lifetime cancer risk by about 5 cancers per 1000 persons in the general population.

"Is the radon level in my water safe?"

Understandably, many people think of "safe" as a yes/no condition, either something is safe or it is not. However, "safe" is a concept that means different things to different people; what one person considers "safe" might be a condition thought to be quite dangerous by some other person. With respect to radon, one's water supply is generally thought to be "safe" when it contains less radon than the recommended or regulated amount, in New Hampshire that value is 2,000 pCi/L … but there is still risk at that concentration. Using the National Academy of Sciences' central estimate of the risk from radon in water, the general population lifetime risk at 2,000 pCi/L is an expectation of between one and two additional cancers per 1000 persons ... some would consider that "safe," others would not. Whether one's water is "safe" is an individual decision.

So, if the recommended or regulated amount of radon in the water supply doesn't represent a "safe" amount, what does it represent? The answer is that it represents the value EPA or some other regulatory authority determines to be the most reasonable balance between accepting risk and the cost of avoiding risk; an analysis that recognizes the desirability of removing all risk while simultaneously recognizing that achieving zero risk may be technologically unrealistic or cost prohibitive.

"Are there some parts of New Hampshire where I won't have any radon in my well water?"

Certainly there are portions of the State where the chemistry of the bedrock is less likely to result in high levels of radon in the water, but there is little prospect of having no radon at all. In the broad sense, the types of bedrock that are more frequently associated with the ability to emanate significant amounts of radon are found in the eastern half of the State, a couple of notable exceptions are areas in the vicinity of Jaffery and New London.

"What is EPA's regulation for radon in water?"

At present EPA has no regulatory standard for radon in water. The 1996 radon amendment to the Safe Drinking Water Act instructed EPA to propose a regulatory standard for radon in community water systems by August of 1999 and after receipt and review of public comment on that proposal, to promulgate a rule by August of 2000.

The Administrator of EPA signed the proposed radon rule on October 19, 1999, it appeared in the Federal Register on November 2. A copy is available as a PDF file at http://www.epa.gov/safewater/radon/proposal.html. The proposal sets two regulatory standards for community groundwater systems, 300 pCi/l and 4000 pCi/l. The latter option is only available in conjunction with the simultaneous operation of a program by a state or public water system to reduce radon in indoor air such that the risk reduction achieved by the program to reduce radon in indoor air equals or exceeds the additional risk the public is exposed to through higher levels of radon in their drinking water supply.

EPA missed the August, 2000 deadline for promulgation of the rule. EPA submitted their final version of the rule to the Office of Management and Budget (OMB) for review early in 2001. OMB's evaluation was suspended while the new Presidential Administration, including a new director of EPA, examined the rule. At the present time the anticipated date for publication of the Final Rule is sometime during 2005.

EPA has no authority to set regulatory standards for radon in individual, private source, drinking water supplies. However, from a practical viewpoint it might be expected that whatever EPA sets as the final standard for radon in community drinking water supplies will, in time, become the *de facto* standard for private supplies.

"What is the recommended level for radon in water in New Hampshire?"

As early as 1991, the Department of Environmental Services and Department of Health and Human Services recognized the need for establishing a common guideline that could be used to answer questions from the public regarding acceptable levels of radon in private drinking water supplies until such time as a federal regulatory standard was set for radon in community supplies. It was determined that until that time arrived, the position of these two State agencies would be to recommend that homeowners investigate treatment if the average annual radon concentration exceeded 2000 pCi/L. This position was not meant as a "line in the sand," but rather a recognition that there may be some risks associated with radon in drinking water, that individuals are at different levels of risk depending on their age and smoking history, and that at 2000 pCi/L it is prudent to investigate and evaluate those risks when making a determination as to whether or not to reduce radon in a private supply.

One thing to keep in mind is that radon concentrations in well water may vary considerably over the course of the year, fluctuations in the range of 30 percent around some average value are common, but in extreme circumstances the variation may be as great as a factor of 5. Decisions about risk and about treatment should be made accordingly.

"Why is New Hampshire's recommendation so much lower than those of other states?"

Recommendations concerning acceptable levels of radon in water made by health and environmental agencies in New England states vary considerably, as do the types of action encouraged by states at those respective levels. Recommendations by other New England states appear less restrictive than New Hampshire's. Currently, recommendations regarding treatment for the removal of radon from private drinking water supplies take effect at: New Hampshire (2,000 pCi/L), VT (4,000 pCi/L), CT (5,000 pCi/L), RI (10,000 pCi/L), MA (10,000 pCi/L) and ME (20,000 pCi/L).

In some states the recommendations for treatment to remove radon actually indicate the concentration at which radon removal is warranted, while in other states the recommendation may refer to the concentration at which one should start gathering information in order to make an informed decision. New Hampshire's recommendation of 2,000 pCi/L refers to the point at which interested parties should investigate treatment.

When EPA first proposed a Maximum Contaminant Level (MCL) for radon in community water systems, Federal Register (July 18, 1991), they provided a combined (ingestion plus inhalation) lifetime risk estimate of approximately 1×10^{-4} associated with a radon concentration of 150 pCi/L in a residential water supply, an expectation of approximately 1 cancer per 10,000 persons in the general population. Mindful of the uncertainties in EPA's risk estimate and the large number of private supply wells in New Hampshire with elevated radon concentrations, the NH Departments of Health and Human Services and Environmental Services determined that an average waterborne radon concentration of 2000 pCi/L would be a reasonable point at which to advise individuals to consider treatment to remove radon from private water supplies. Based on the unit risk estimates EPA provided in the Federal Register, 2000 pCi/L represents a lifetime risk of approximately 1×10^{-3}, an expectation of 1 cancer per 1000 persons; considerably more risk than EPA normally allows in community water systems, but, considering the potential fiscal impact, a recommendation thought justified in light of the uncertainties in EPA's risk estimate.

In all cases, state agencies in New England are providing guidance that reflects their interpretation of the risks based on available evidence with its inherent uncertainty. Many of these guidelines have been in place for several years and were developed without the benefit of data generated by subsequent investigations of the risks. **It is likely that many states will revisit their recommendations concerning radon in private water supplies once EPA has set a regulatory standard for radon in community water supplies.**

"How will EPA's decision about radon in public water supply affect New Hampshire's recommendation for private supply?"

At this time there has been no decision concerning this issue.

The recent amendment to the national Safe Drinking Water Act actually allows for the creation of two separate regulatory standards for radon in public water supplies and that is causing an enormous amount of confusion. However, it is difficult to imagine a situation in which this State's health agency would want to find itself in the position of suggesting that persons receiving water from private water supplies should accept a level of risk markedly different from those supplied by community water systems.

"Does the depth of the well matter?"

No, not necessarily. The depth of a drilled well is not directly related to the radon concentration of the water produced by that well. What matters is whether one is talking about a well drilled into bedrock versus a well drilled into a stratified sand and gravel aquifer or, for that matter, a dug well or some other surface supply. Also, the radon emanation characteristics of the material the well is drilled into. In New Hampshire, water from wells drilled into bedrock usually has a substantially greater radon concentration than water from other sources. Wells that draw water from stratified sand and gravel aquifers may also have high radon concentrations.

Dug wells do not normally present radon problems.

Radon concentrations in surface waters are never a problem.

"The house I am considering buying has been unoccupied for a few months, are the radon tests still valid?"

This is a common question with a two-part answer. The part of the answer that pertains to airborne radon can be found elsewhere in this document, see the question, "Are radon levels higher in a house that has been closed up for some extended period?"

As the question applies to radon in the water, it really comes down to asking whether the water being sampled is representative of what the occupant will be getting when the water system is in regular use. Radon has a half-life of about four days, this means that one-half of however much radon is present in the water when the system is used regularly will be lost through normal decay processes in a period of four days ... and half of the remaining amount will be lost over the next four days, etc. etc. etc. Therefore it is imperative that the water be "run" for an extended period prior to sampling in any situation where the home has been unoccupied for any lengthy period of time. The question of how long the water should be run has no specific answer that fits every circumstance; clearly, the object is to sample water whose radon content has not undergone appreciable decay. In general, for a home that has been unoccupied for an extended period it would be prudent to run at least 100 gallons through the system. This can be accomplished for most residential systems by turning on a sufficient number of faucets to cause the well pump to run continuously for 15 - 20 minutes.

"Is the radon concentration in my water common in this state?"

Radon concentrations in private wells in New Hampshire range from a few hundred picocuries per liter to more than a million picocuries per liter. Although no rigorous study has been done of radon concentrations in private wells in New Hampshire, data collected by the NH Department of Environmental Service (DES) laboratory indicate that approximately 50 - 60% of all private drilled wells in New Hampshire produce water with radon concentrations between 300 - 4,000 pCi/L. The situation in community supply wells is similar. Consideration of data provided by the DES indicate that between a quarter and a third of the community groundwater supplies in New Hampshire deliver water with radon concentrations in excess of 4000 pCi/L. In private and community groundwater supply wells, concentrations less than 300 pCi/l occur in less than 5 percent of the wells.

As with private supplies, radon in community water supply systems is not a problem when the water supply is a surface body of water.

"How can I get the radon out of my water?"

Aeration

Aeration is the method suggested by the state departments of Health and Human Services and Environmental Services for the removal of radon from water. There are several aeration devices (air-strippers) on the market. They all rely on the principal that radon is a gas and will escape from the water if given an opportunity. Some technologies utilize a spray technique, some use bubbles, and others employ a trickling “thin film” approach. These are all effective in removing radon from water. Efficiencies of commonly available devices range from 80 percent - 99 percent, costs are in the $2,500 - $5,000 range.

Although the laws of physics ensure that all aeration designed to remove radon from water work to some extent, all devices are not created equal. Apart variation in the percentage of radon the devices are designed to remove there are various physical design features the perspective buyer may wish to consider. Some of these are as follows:

- Gas tight lid seal: Some aeration devices operate under positive pressure during the period when the blower motor is forcing air through the water. It is desirable for the lids of these devices to be fit tightly so as to greatly limit or prevent leakage of radon into the basement space.

- Lid latches: In conjunction with efforts to prevent leakage of radon from the reservoir into the basement through the junction of the lid and the reservoir it may be desirable to have some form of latch arrangement to secure the lid to the reservoir. This feature is particularly important if there is a danger of the vent pipe filling with frost/ice during the winter months, the result of which would be an increase in pressure in the reservoir during blower operation and the possibility of expelling radon directly into the basement through the junction of the lid and the reservoir. Regardless of the integrity of the lid seal, the issue and consequences of vent icing should be discussed with the vendor.

- Routing of the vent stack: Once released from the water, radon must be transported from the aeration device to the outdoors. In selecting an aeration device one should pay particular attention to the design of the vent pipe to ensure that radon is exhausted well away from doors and windows and also away from areas where people (children) may come in close contact with the exhaust vent. The importance of this design feature increases as the concentration of radon in the water and the amount of water use increases; at water radon concentrations of just a few thousand piccuries per liter it may be appropriate to vent radon at only a few feet above the ground, provided there are no openings into the house within 10 feet of the vent and that the immediate vicinity is not frequently inhabited.

- Screening of vent pipes: Vent pipes designed to carry away radon removed from the water supply present a direct access to the water stored in the aeration device’s reservoir. It is important that the open end of these vents are positoned in a manner that does not allow easy access by foreign matter, and, that they are secured from entry of insects and various small animals.

- Source of air intake: All aeration devices require the intake of air. It is desirable that these intakes have a source of clean air; when possible it may be desirable to obtain intake air from the outdoors so as to avoid depressurization of the basement space and to provide protection against introducing various airborne particles (fumes) originating from household projects into the water supply. When siting an exterior vent intake, be sure to avoid areas where the intake air may contain substantial amounts of airborne pollutants, notably, automobile exhaust.

- Switches and solenoids: While more of an engineering feature than a health issue, it is advisable for an aeration device to be fitted with a back-up feature to guard against failure of the primary switch that controls water volume in the reservoir and consequent overflow.

- Homeowners should also recognize that introduction of air into the water system may violate local “health” or “building” codes. It is prudent to discuss this possibility with the manufacturer or installer of aeration devices as well as local code officials and to adopt and implement a schedule for periodic cleaning of the device. Exposing treated (aerated) water to ultra violet light (UV) as part of the treatment process can be an effective treatment for bacterial contamination that may be introduced through the aeration process.

- Some aeration devices have a vent fan installed in the vent pipe after the water reservoir. The object of this fan is two-fold:
    - to keep the entire system under negative pressure and avoid migration of radon from the stripping reservoir to the basement if a seal or gasket should develop a leak, and
    - to prevent contaminants from entering the vent pipe from outside the home and making their way down the vent and into the water storage reservoir.

Sometimes these secondary fans run constantly and sometimes they only operate in conjunction with the operation of the primary fan that introduces radon into the water reservoir.

A partial list of vendors of devices that remove radon from water through aeration can be found by consulting fact sheet WSEB-3-12 in the Public Outreach section of the DES Water Supply Engineering Bureau website http://www.des.state.nh.us/wseb.

Persons considering aeration technologies as a means of removing radon from water should be aware that the process may be complicated by the presence of high levels of iron and manganese in that water. When these elements are present in high concentrations and in conjunction with certain water chemistry it is possible that aeration may result in "rusty" colored water or in discoloration of laundry. When this occurs it may be necessary to remove the iron and manganese from the water supply prior to aeration for the removal of radon. Water treatment technologies installed for this purpose generally cost in the range of $1200 - $1500. More information concerning removal of iron and manganese from drinking water supply, as well as several other water quality and water supply issues, may be obtained from Fact sheets posted on the DES website, http://www.des.state.nh.us/wseb, or by contacting the DES Water Supply Engineering Bureau directly at 271-2952 and requesting a fact sheet for the subject material of interest.

Other issues, such as noise, energy requirements and possible sweating of the water reservoir may be of concern.

Filtration

Radon is also easily removed from water by filtration through granular activated carbon (GAC). However, not all carbon is created equal with respect to its ability to remove radon, some types are better than others. Further, high levels of iron or manganese in the water can coat the carbon particles in the filter material and reduce the efficiency of radon adsorption.

Although they are considerably less expensive to install than aeration devices, the NH Department of Health and Human Services **does not** recommend the use of GAC filters for removal of radon for two reasons:

- First, there is the issue of the gamma radiation field that builds up around the filter, a consequence of the build up of radon decay products, lead-214 (^{214}Pb) and bismuth-214 (^{214}Bi) on the filter material. If the radon concentration in the water supply is relatively constant and if there is no radium or uranium in the water supply to become trapped on the filter material, this radiation field will reach approximate steady state equilibrium in about 30 days. If the filter does trap uranium or radium, their subsequent sequential decay will slowly introduce more radon to the system and lead to a slowly increasing level of radiation being emitted from the decay of ^{214}Pb and ^{214}Bi.
- The second question concerns the eventual replacement of the GAC material in the tank ... once the carbon has concentrated the radon decay products **and perhaps other radionuclides (uranium and radium)**, what does one do with the carbon?

Anyone wishing to examine the theoretical rate of retention of radon by GAC filters, the subsequent radiation emitted from radon daughter products and the long term build up of the alpha emitting radon decay product lead-210 (^{210}Pb) should access the EPA website at http://www.epa.gov/region01/eco/wrsdp.html and download a copy of the software model CARBDOSE. Those persons registering at the site will be notified electronically of any future updates to CARBDOSE or any of the other software available at the site.

It is probably also worth noting that according to one company that services these devices, a reasonable "rule of thumb" for maintenance costs for GAC systems would be approximately $500 - $600 every 2-3 years, based on a 2-3 year replacement cycle, a two cubic foot carbon bed, and the random chance that other work may need to be done to the system at the time the carbon is replaced.

The reader may find information pertaining to the measurement and removal of other radionuclides in water by consulting the DES website at http://www.des.state.nh.us/wseb, under the option Public Outreach, select fact sheets, specifically, WSEB 3-11. The DES website contains an extensive list of fact sheets dealing with a large number of water supply and water quality concerns including: ion exchange treatment (2-12), hardness (3-6), radon (3-12), iron and manganese (3-17) and installation practices for water treatment aerators (2-23).