Summary of The Report on The Investigation of Radon Removal by Different Techniques

Original Report Titled
"Removal of Radon From Ground Water Supplies Using Granular Activated Carbon or Diffused Aeration"

by

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Background

During the last twenty years in the State of Maine many of the drilled wells have indicated the presence of high levels of naturally occurring radioactive Radon 222 (Rn-222) gas. This also has been true in driven points and occasionally, in dug wells. The radioactive Rn-222 is not associated only with wells in the State of Maine. It has been found to also be common to other New England states and other parts of this country. There is concern that this radioactivity may be a health risk. The U.S. Environmental Protection Agency in its drinking water standards is considering establishing a level above which steps should be taken to reduce the Rn-222 level. As yet that limit has not been decided upon. Limits have been suggested in several studies; ranging from 2500 to 10,000 picocuries of Rn-222 per liter. Due to the difficulties in understanding how Rn-222 behaves in the body, to date no definite limit has been suggested by the EPA.

The health risk concern is from the ingestion and inhalation of Rn-222 gas which is absorbed by groundwater in its migration through the bedrock to a well. From the well it is then pumped into a residence and ingested or inhaled during drinking. A growing concern is that some of this radon gas is released within the household from faucets, bathtubs, showerheads, and other water use fixtures. The Rn-222 is inhaled by the occupants of houses, which due to energy conservations over the last few years, have become quite tight and lack the exchange with the outside air. There has been a study made suggesting that water containing Rn-222 be treated or vented to the exterior of the residence before it reaches the occupants of the residences, particularly drilled wells which are vented to the basement of a house. The report suggest that these drilled wells should be vented completely to the exterior of the house. Consequently any radon removal equipment in the house should also be vented to the exterior of the house to reduce the inhalation risk to the occupants.

As a result of these concerns for public welfare a study was made by Dr. Jerry Lowry at the University of Maine in Orono, Maine. The study concerned the use of radon removal equipment from drilled wells using in one case, granular activated carbon and in a second case diffused aeration. A second study performed by the Division of Health Engineering in the Department of Human Services, Augusta, Maine, based on the principle of spray aeration, provides a third way to reduce or remove Rn-222 from water. The study by Dr. Lowry compared the effectiveness of six available commercial brands of granular activitated carbon. It also made estimates on the cost of two processes of Rn-222 removal, one by activated carbon, the other by diffused aeration using three different types of diffusors.

Granular Activated Carbon

Dr. Lowry's study developed a series of graphs and charts to indicate a comparison of the different GAC products that he used. He found a variation in the ability of GAC to absorb the Rn-222 between different manufacturers' products. These charts indicated the degree of removal. Moreover these charts led to the design of a GAC filter that could accomplish the degree of removal that was desired. Some of the advantages of the GAC unit are the simplicity of operation, the lack of mechanical equipment to maintain, the relatively small space occupied by the treatment facility, the probable reactivation of the GAC by back-washing, the ability of the GAC unit to accept overloading and, as the load is reduced, to resume its normal ability or capacity. Slightly oversizing a GAC unit for steady flow conditions will balance out a condition where the reduction of radon gas and the decay rate are the same, greatly extending the life of a GAC unit. Laboratory tests conducted by Dr. Lowry were run on a known concentration of radon gas, 113 picocuries per liter. This concentration was reduced by a GAC unit to a concentration of 31 picocuries per liter.

After the laboratory tests were performed, a field test was conducted on a residential drilled well. The radon concentration varied from 13,000 to 24,400 picocuries per liter, with an approximate average concentration of 17,000 picocuries per liter. The experimental study of a GAC unit in this residence provided a reduction to 3200-3300 picocuries over a period of time, yielding a reduction of about 81.5 percent. This was in a house occupied by two adults and two children, having an average daily usage of about 155 gallons per day. If necessary, and additional GAC unit could be added to further reduce the 3300 picocuries per liter to a smaller figure.

Design of GAC Unit

The design of a GAC unit for radon reduction is dependent upon four factors:

1. The radon concentration of the untreated water.
2. The average daily water usage.
3. The concentration of radon desired in the GAC effluent.
4. The effective adsorptive capabliity of GAC material.

The equipment necessary for radon reduction with a GAC unit is primarily a means of regulating the device to control the flow to the GAC unit and the properly sized GAC unit. From the test results Dr. Lowry developed a graph, (Figure 1) which would indicate the approximate removal of radon gas, depending upon the gallons per day used and the quantity of GAC material used within the tank. From this graph and knowing the approximate water usage per day for the residence and the percent removal desired, you can determine the quantity of GAC material that should be contained in a canister. Generally, for the average house using less than 200 gallons per day, one and one half cubic feet of granular activated carbon should suffice. An additional chart (Figure 2) indicates

FIGURE 2

Influent Radon p/Ci/L	Effluent Radon p/Ci/L
10,000	1,600
30,000	4,800
60,000	9,600
100,000	16,000
200,000	32,000

a known concentration of raw water the approximate concentration of the effluent from a GAC unit. This may be used as a guide. If a greater reduction is desired, then an additional GAC unit may be added in series with the first unit. A reduction of 85% may be expected using the following quanitities of GAC for the flow rates indicated

0 to 200 gallons/day - 1.5 cubic G.A.C.
200 to 400 gallons/day - 2.5 cubic G.A.C.
400 or more, increase in direct proportions.

In testing the removal efficiency of the GAC unit wait 15 days for the unit to stabilize.

Diffused Aeration

A second method of treatment investigated by Dr. Lowry is diffused aeration. This method introduces air into the water through a device such as a porous plate. Dr. Lowry tried three different devices and found the porous plate to be most effective. Using this air injection method there are two techniques which may be used.

One is a batching method where a volume of water is treated by aeration, the other is a flow-through method which is a continual process. Using the batching method it is necessary to have an aeration tank, an air compressor, an automated control system for the operation of the compressor, tanks, pump and a series of storage tanks in which to store the treated water. Through the batch method tests that Dr. Lowry conducted, he found that he could accomplish nearly 96 percent removal of radon gas. After treatment the water was pumped to a finished water tank. This was repeated for a series of other water tanks until the daily use of water was held by each one of the tanks. Therefore, when there was a water demand in the house for the water, there would be an ample quantity of tested water available.

The second method of diffused aeration, was on a continuous flow-through design. This is simpler than the batch method and requires an aeration tank and an air compressor, in addition to the normal hydropneumatic tank. The aeration process is controlled by the aeration pump, coming on when the water pump begins to operate and continuing to operate after the water pump is stopped. The contents of the aeration tank are recycled three to four times which provides a reduction of about 96 percent. Normally, this would require less than one hour of aeration and it will provide approximately 30 to 40 gallons. If water was used for a longer period of time in the house the radon content would probably increase slightly, but not sufficiently to be of concern. This flow-through method also provides a simplification of equipment occupying less space.

Upon the completion of his testing Dr. Lowry found that he was securing very close to the 96 percent reduction of radon gas through the flow-through method which was similar to the reduction he was getting in the batch method.

Spray Aeration

The third type of aeration treatment was investigated by the Divison of Health Engineering, Department of Human Services, Augusta, Maine. This method depended upon spray aeration where water was pumped from a receiving tank into a series of atomizing sprays to release the radon from the water. The radon was then vented to the exterior of the building. This method was operated on both the principle of batch and flow-through, in that a quantity of water that was received in the treatment tank was spray aerated by a timing and solenoid valve system. The removal efficiency for this type of operation was approximately 93%. The equipment necessary was one receiving tank of about 45 to 50 gallons, two atomizing spray heads, a time clock and controls, and solenoid valves to control recirculation of the tank contents.

The greatest obvious advantage of any of these precesses of aeration and GAC is the reduction of radon gas by 93 to 96 percent.

The disadvantages appear to be with the aeration system, due to the complexity of controls that are necessary, the maintenance required for these controls, additional pumps and the space required for storage of treated water. However, in the case of high concentrations of radon gas in the vicinity of 100,000 picocuries per liter, the space required for this type of treatment (aeration) may not exceed the space required by GAC units.

One of the distinct advantages of reduction through aeration is its flexibility. With a high concentration of 100,000 picocuries per liter or greater, the detention tank sizes or the time of aeration may be increased to still provide approximately 96% removal of radon gas.

Conclusions

From his observations and the results of his investigation, Dr. Lowry has draw certain fundamentals. Using these fundamentals and cost figures he has developed three examples of situations which may be found in some gravel wells or drilled wells having radon gas concentratons of 15,000, 30,000 and 150,000 picocuries per liter. Using these examples, he has estimated some capital outlay and operating costs. The chart which will provide approximate estimates for a residential installation is as follows. These figures are estimates as of 1981.

Summary of Performance and Economics
200 gpd Demand

Influent Rn pCi/L	Effluent Rn pCi/L		Cost (estimated) 1981			
			Capital		Operating	
	GAC	Aeration	GAC	Aeration	GAC	Aeration
15,000	1350-3300	750	$431-$757	$890	$19	$60
30,000	2700-6600	1500	$431-$757	$890	$19	$60
150,000	1200 (2)	7500	$1500	$1000	$40	$80

It appears that for radon gas concentrations below 50,000 picocuries per liter the GAC unit may be less expensive to install and operate. Above this figure, the aeration process may be less to capitalize and operate. The reason is that above the 50,000 figure two GAC units may be needed to achieve the same degree of reduction as one unit (GAC) at the lower figure; however, if there is a need to reduce the radon levels down to very low figures, (accomplishing 96 percent reduction) it may be to the home owner's advantage to install an aeration type treatment process.

In general, installation and operation of a GAC unit will be easier and have fewer mechanical parts for maintenance. Either type of treatment will need some means of removal of the radon to the exterior of the residence. In the aeration process it will be necessary to vent the concentrated radon gas from the aeration chamber to the exterior of the house. In the installation of a GAC unit it will be necessary to provide a discharge for the backwash to the house drain or to some other point outside of the residence.

Based upon the results of the research described in the preceding sections, the following conclusions are made:

1. The effective adsorption of radon gas from water on to granular activated carbon (GAC) varies with the manufacturer.

2. The combined processes of adsorption and decay with the GAC bed results in a steady state operation which extends the adsorptive removal of radon far beyond the point of GAC saturation, as defined by an adsorption isotherm. The ultimate life of GAC for continuous adsorptive removal of radon is not known, but appears to be in terms of years.

3. A GAC unit operating in a typical household water supply has the ability to effectively dampen any short-term high water use events, without experiencing any significant effluent deterioration.

4. The decay daughters of radon were retained in the GAC; however, the capacity for the adsorption of radon daughters was not determined.

5. The maximum accumulation of radon and radon daughters within the GAC was calculated and found to be significant compared to the influent radon concentration. There is a need for further examination of radioactive daughter products that may be retained by the filter.

6. Limited data on biological growth within a column that had operated for longer than four months indicates a minimal amount of activity. It is expected that water supplies that require radon removal will tend to be ones that will support minimal biological growth, unless iron or manganese is present.

7. A 1.0 to 2.5 ft^3 GAC unit depending upon water usage, is capable of removing up to 96% of the radon in a single family water supply application.

8. A diffused aeration unit of 35-40 gal. capacity is capable of removing more than 95% of the radon in a single family water supply application.

9. An overall performance and economic comparison of GAC vs. diffused aeration indicates that the removal units are essentially equal. The GAC unit is slightly cheaper in most applications, However, the diffused aeration unit has a greater potential for higher removal efficiency. The diffused aeration unit will have higher operation and maintenance costs.

FIGURE 1

DARCO 4000 DESIGN CHART FOR WATER USAGE
RANGING FROM 100 TO 600 GPD