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Project Summary

Radon Removal by POE GAC Systems: Design, Performance, and Cost

Jerry D. Lowry, Sylvia B. Lowry, and Julie K. Cline

Data were collected from 121 commercial point-of-entry (POE) granular activated carbon (GAC) units over an 8-yr period. These data have been summarized to indicate the effectiveness of these units to remove radon (Rn) from drinking water supplies. Although the long-term data are limited to but a few of the 121 units, it is clear that GAC is effective for removing radon from drinking water.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

In the report summarized here, field data has been collected from sites that use GAC to remove Rn from groundwater supplies. The data which have been collected from 1981 to 1989 are focused primarily on POE applications and, to a lesser extent, on small water supplies that serve schools or small housing developments. The full report includes information about design, installation, operation, monitoring, performance, gamma exposure rates, shielding, and costs.

There were 121 POE GAC units (manufactured by Lowry Engineering, Inc. [LEI])* located in 12 states that were sold, installed, and monitored to varying degrees over a 7-yr period. Most of the POE GAC units were sold, installed, and monitored as part of a private research effort by Lowry Engineering, Inc., initiated in October 1984. Most of the POE GAC units are in Maine and New Hampshire (Table 1), and the units were used with waters having varying quality characteristics.

Table 1. *Number of POE GAC Units by State*

State	*Number*
Maine	*61*
New Hampshire	*20*
New Jersey	*12*
Kentucky	*1*
Pennsylvania	*6*
Massachusetts	*5*
Colorado	*3*
Rhode Island	*3*
Connecticut	*6*
New York	*1*
North Carolina	*1*
Vermont	*1*

The U.S. Environmental Protection Agency (EPA) under the Safe Drinking Water Act is considering a maximum contaminant level for Rn of between 100 and 2,000 pCi/L. The work and results outlined in this report must be taken into perspective with the current concern about Rn levels in drinking water supplies. All of the decisions associated with the POE GAC units described in this report were based on the respective states safe guideline advisory levels in the range of 10,000 to 20,000 pCi/L. Many of these GAC units will not produce a treated water Rn level below the new proposed levels of 200 to 2,000 pCi/L.

*Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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This does not mean that POE GAC units will not be effective for future installations after the new MCL is embraced; however, different design and application decisions would have to be considered to ensure satisfactory performance.

Design, Installation, and Monitoring of POE GAC Units

The POE GAC units were single vessels housing 1.0 to 3.0 ft^3 granular activated carbon, depending upon the model purchased. The majority of the units contained 1.7 ft^3 of carbon. A typical POE GAC unit is illustrated in Figure 1. These units were normally installed downstream of an existing pressure tank and were operated under the existing household water pressure. The GAC units were designed to operate in the down flow to minimize backwashing. At some locations, shields (made of water, lead, or bricks) were placed around the GAC unit to monitor the reduction in gamma emissions from the units.

Once the GAC unit was properly installed and commissioned, it was essentially maintenance free. The sediment filter, when used, was typically in the 30μ to 50μ range and required replacement or washing approximately two times a year. Occasionally, with a water supply having abundant sediment, the filter would need cleaning or replacement as often as once a month. Backwashing of GAC units was recommended only if the hydraulic capacity of the unit became noticeably diminished, as indicated by a significant drop in water pressure at the tap. Regular once a week backwashing reportedly caused a lower overall removal efficiency and was not needed if a sediment filter was in place. Field experience bears this out for very few cases of loss of hydraulic capacity have been reported.

The monitoring program since October 1984 consisted of:

1. an initial sampling and analysis after 3 wk to confirm the success of the installation,
2. sampling and analysis performance check once every 6 mo for a period of 2 yr.

In addition to these samplings, 11 of the units were selected for a more detailed analysis.

The sampling procedure used most extensively involved the homeowner collecting samples using 40-mL glass septum, capped vials of the type used in Volatile organic carbon (VOC) analysis. Some of the first installed units were sampled by the direct syringe method with the use of prepared scintillation vials. In both cases, the samples were normally mailed directly to the Radon Research Laboratory at the University of Maine where they were analyzed by liquid scintillation.

Performance of POE GAC Units

The performance of a GAC unit can be accurately predicted if the following information is known:

1. average water usage,
2. average influent radon concentration,
3. GAC adsorption/decay constant (Kss), and
4. volume of carbon used, with the use of the equation:
   Radon (out)/Radon (in) = exp(-Kss*t)
   where t is the empty bed contact time.

The theoretical and actual removal performance for the POE GAC units are given in Table 2. An average flow of 157 gal/d (21 ft^3) and a Kss of 3.0/hr (Barneby Cheney 299 GAC) were used to estimate the expected performance. In actual field operation, some units exceeded this predicted performance; however, when all field units are considered overall, removal was something less than the theoretical performance.

The actual removal percentages in Table 2 are the average removal percentages taken without regard to specific knowledge of problem units. Possibilities for errors in sampling point, possible partial by-pass due to equipment problems or possible improper plumbing, etc., were not investigated in every case where removal was less than expected. Higher-than-estimated water use could also have affected the averages. We believe, however that the effect of these elements on the performance numbers is very small. Unknown water quality factors at specific sites are believed to be responsible for the lower performance at some sites.

Analysis of Selected GAC Units

Eleven individual sites were selected for a more detailed analysis and discussion. These sites have POE GAC units with one or more of the following characteristics: in service for a relatively long period, significant number of performance checks, a particular water quality problem other than Rn, or a progressive premature failure. Two of the eleven GAC units are discussed in this summary.

Site No. 64

The POE GAC unit at site 64 was routinely monitored during its 42-mo life, which was intentionally terminated. (It was replaced by an aeration system). During its life, 10 samples were taken to check performance. The average removal was 96.3%, and the raw and treated water Rn levels averaged 154,000 pCi/L and 5,750 pCi/L, respectively. The last two data sets for this unit indicated a possible error in sampling or analysis. For the treated water Rn, one set was significantly higher and one significantly lower. No investigation was made to further define the possible problem.

Site No. 43

This site has had a GAC unit operational for a period of 31 mo and has been monitored 8 times. The site is unique in that the amount of iron in the raw water is significant and the iron precipitates in the bed. On a site inspection, the top of the GAC was found to be beneath a 2.0-in. layer of bright orange iron precipitate. Although a large amount of precipitate was present and the unit had never been backwashed, the performance was documented to be greater than 99.4%. In fact, this unit consistently performed at a high level and had not been hampered by the iron level in the raw water. The Rn levels in the raw and treated waters were 112,900 pCi/L and 638 pCi/L, respectively.

At the present time there are not enough data to predict the long term life of the Rn adsorption/decay steady state. The report data indicate that each GAC unit must be considered on a case-by-case basis; few systems fail prematurely, whereas others continue to show theoretical removal efficiencies for extended periods without any signs of deterioration of the adsorption/decay steady state. Other factors, such as Pb-210 and its progeny buildup in the bed, may dictate the service life of a GAC bed in a state that regulates Pb-210.

Conclusions and Recommendations

A large body of performance data for over 100 GAC POE and small water supply GAC systems was summarized to document the effectiveness of these systems to remove Rn in the field. Based on the analyses of raw and treated water, the following conclusions and recommendations can be made:

Approximately 84% of the 121 POE GAC systems in the field are still achieving Rn removals of greater than

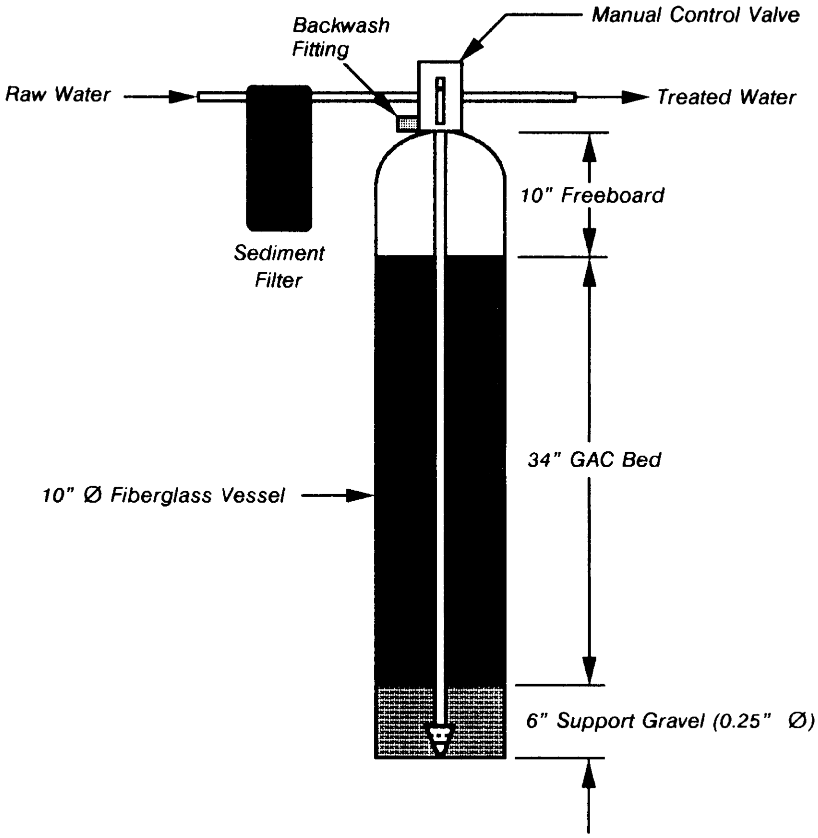

***Figure 1**. POE GAC unit.*

***Table 2**. Expected Versus Actual Removal Performance for POE GAC Units*

GAC Model	Number of Actual Units	Flow gpd	Empty Bed Contact Time, hr	Performance %	
				Expected	Actual
GAC 10	12	157	1.14	96.7	90.7
GAC 17	59	157	1.94	99.7	92.5
GAC 30	12	157	3.43	99.99+	98.6

95% (Oct. 1989). Approximately 113 units (94% of all 121 units) achieved greater than 90% Rn reduction. Seven POE GAC systems experienced a premature failure believed to be related to water quality. The problem of premature failure is clearly associated with particular regions within specific states.

Some systems achieved removals close to the theoretical steady state level calculated with the use of a first-order relation for the ratio of treated Rn to raw water Rn. In general, however, the Kss value in the field were slightly less than that measured in the laboratory with a different batch of GAC.

The ultimate bed life for a POE GAC unit cannot be predicted based upon the limited, long-term data collected to date. For the 11 systems that were monitored for 2 to 6 yr, there are no clear indications of loss of efficiency over time. The long-term data are limited to a few units; however, it is clear that one unit

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has performed at a high efficiency for over 6 yr without signs of needing replacement. Based on the 11 units, a typical POE GAC unit may last a decade giving removals of greater than 90%.

The levels of Pb-210 and its progeny in the treated water produced by POE GAC units should be documented for units that have been operated for extended periods.

The gamma exposure rate associated with POE GAC units should be documented more extensively. Actual dosimetry measurements should be made on occupants in households that have these units.

The full report was submitted in fulfillment of Contract No. 8C6155TTST by Lowry Engineering, Inc., under sponsorship of the U.S. Environmental Protection Agency.

Jerry D. Lowry, Sylvia B. Lowry, and Julie K. Cline are with Lowry Engineering, Inc., Unity, ME 04988.
***Kim R. Fox** is the EPA Project Officer (see below).*
The complete report, entitled "Radon Removal by POE GAC Systems: Design, Performance, and Cost," (Order No. PB91-125 633/AS; Cost:$17.00, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
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