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ENVIRONMENTAL RESEARCH BRIEF

Low-Cost/Low-Technology Aeration Techniques For Removing Radon From Drinking Water

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ABSTRACT

Simple low-cost/low-technology aeration techniques were investigated to determine their effectiveness in removing radon from drinking water. The techniques consisted of flow-through storage and minimal aeration in various configurations, and were found to be effective in varying degrees for the reduction of radon. These low-cost/low-technology aeration techniques may be easily applied in small communities.

INTRODUCTION

In an effort to assemble information concerning simple treatment techniques for the removal of radon from drinking water, the University of New Hampshire and the New Hampshire Department of Environmental Services (NHDES), through a U.S. EPA Cooperative Agreement, evaluated low-cost/low-technology aeration treatment techniques for radon removal. All the techniques involved storage and/or storage with minimal aeration. These tests included monitoring radon reduction in a distribution system, radon release from an open air storage tank with no mixing (still pool of water), radon reduction in a flow-through reservoir system with various influent control devices, and radon reduction in a flow-through reservoir system with minimal bubble aeration.

DISTRIBUTION SYSTEM

The site selected to evaluate radon loss in a distribution system was the Rolling Acres Trailer Park in Mont Vernon, NH. The trailer park consists of 33 mobile homes served by 2 wells that are currently being treated using granular activated carbon (GAC) to remove radon. The distribution system consists of 3.8 cm (1.5 in.) to 5.1 cm (2 in.) diameter pipe. Distances between sampling locations were measured with a surveyor's tape (Figure 1). Samples were taken in the evening from kitchen taps at 5 homes located at various distances from the pump house. The first two sets of samples were of GAC-treated water. During the next two sampling periods, raw water was pumped directly into the distribution system. The greatest reduction (18.8%) in radon concentration occurred at the sampling point furthest from the pump house (Table 1), but overall the reductions observed were very low (0% to 10%).

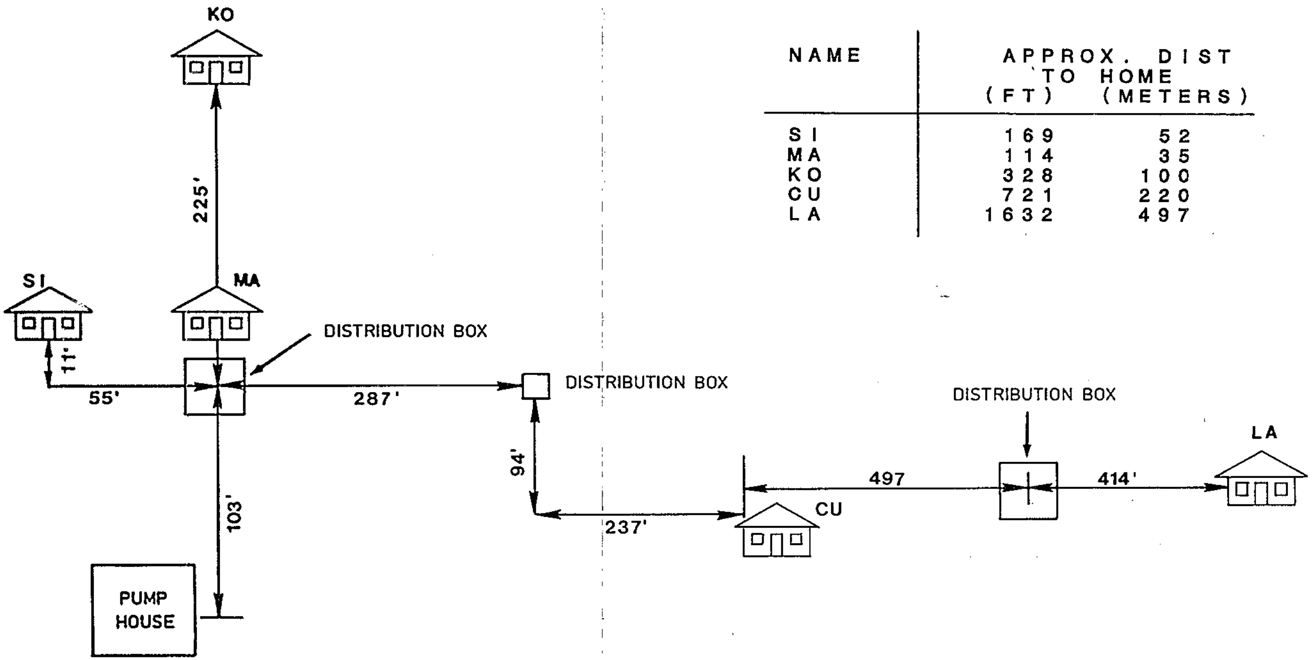
The actual reduction of radon in a distribution system would result from decay alone, so loss during distribution would not be significant unless the distribution system was extraordinarily long or the flow rate extremely slow. Small reductions are anticipated in short systems, but the removal rate would vary with water usage. Data were collected at Mont Vernon during periods of high flow and thus represented a worst case senario.

OPEN-AIR STORAGE

A laboratory study at the University of New Hampshire monitored radon reduction from a still pool of water. A 115-L (30-gal) plastic storage tank (Figure 2) was filled to a depth of 68 cm (27 in.) with water containing radon.During four individual runs, the radon concentration was monitored for 5 to 6 days (Figure 3). Samples were taken at various depths in the tank to determine if the radon concentration varied with depth. No significant difference in radon concentration was found within the tank.

High levels of radon removal (80% to 90%) were observed, but 5 to 6 days of storage were necessary to achieve these reductions. Theoretical reduction by radon decay alone would be 67% over 6 days, thus open air storage contributed to a greater reduction in radon removal than by decay alone. A 24- and 48-hr average reduction rate of

Figure 1. **Mont Vernon Distribution System.**



NAME	APPROX. DIST TO HOME (FT)	(METERS)
SI	169	52
MA	114	35
KO	328	100
CU	721	220
LA	1632	497

TABLE 1. Percent Radon Reduction in a Distribution System

	Approximate Distance from Pump House, m (ft)				
	35 (1114)	52 (169)	100 (328)	220 (721)	497 (1632)
Influent Radon (26,644 pCi/L GAC, Treated)					
Run 1	0	*	10.8	4.1	15.6
Run 2	0	*	7.3	9.2	*
Influent Radon (234,000 pCi/L, Untreated)					
Run 3	#	*	#	#	18.8
Run 4	2.1	†	#	11.8	7.5

* Radon concentration at sample point exceeded influent radon concentration.
\# Sample data not available.
† Homeowner not available during sampling.

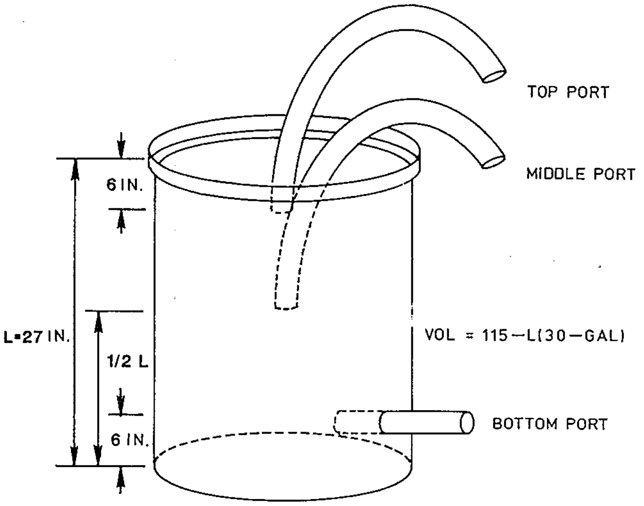
30% and 50%, respectively, was observed. A small community that could store the water at atmospheric pressure for several days could use this technique, although extended storage may be impractical in most cases.

FLOW-THROUGH RESERVOIR

A flow-through reservoir system (Figure 4) was constructed in Derry, NH, to treat water supplied by the Southern New Hampshire Water Supply Company. The storage tank was designed to contain water to a depth of 0.6 m (2 ft) [total volume of 1.64 m^3 (433 gal)], with variable influent entry. The modes of influent entry studied were: 1) entry at the bottom of the reservoir, 2) discharge 0.6 m (2 ft) above the reservoir level, 3) discharge 0.6 m (2 ft) above the reservoir level with a spray attachment, and 4) discharge 0.6 m (2 ft) above the reservoir level through a venturi apparatus to add air to the stream. In addition to the four tests with varied influent entry type, minimal bubble aeration was added to entry types 1 and 2.

In the tests where minimal bubble aeration was used, a laboratory-made bubbler was used. This bubbler was constructed using 0.6-cm (1/4-in.) I.D. plastic tubing with holes made at 10 cm (4 in.) intervals by puncturing the tubing with a thumbtack. Four radial arms of 81 cm (32 in.) length were placed in the bottom of the reservoir and air was provided by a laboratory air pump [maximum capacity 0.3 m^3/min (1.1 ft^3/min)]. The bubbles from the tubing appeared to be approximately 1.5 cm (3/16 in.) in diameter and were produced at an average rate of 2 to 3 per second from each hole.

Figure 2. Laboratory Setup for Atmospheric Loss During Storage (No Flow).



Flow controllers were installed in the influent stream to control the flow to 1.1 L/min (0.3 gpm), 2.2 L/min (0.6 gpm), and 3.2 L/min (0.9 gpm). This controlled flow resulted in theoretical detention times of 24, 12, and 8 hr. The nozzle attachment used a garden hose spray nozzle adjusted to give a spray of approximately 15 cm (6 in.) diameter at the water surface [0.6 m (2 ft) from the nozzle end]. At the low flow of 1.1 L/min (0.3 gpm), a fine spray could not be achieved, and thus data are not available for those conditions.

Good removals of radon were achieved in all test combinations (Figures 5, 6, and 7) except for the bottom entry tests. The bottom entry tests provided the minimum water disturbance of any of the tests and thus the lowest removal rate. In fact, the radon removals observed in the bottom entry tests were only slightly better than would be expected by radon decay alone.

In all cases where the water was allowed to fall (or was sprayed) to the reservoir surface, or where minimal bubble aeration was added, high radon removal rates were observed. A minimum removal of nearly 50% was seen with the shortest detention time and simple influent free fall. Higher removals (80% to 95%) resulted with longer detention times and supplemental aeration (Figures 5, 6, and 7). The data collected in this phase of the study showed that simple aeration can be very effective for radon reduction and might be easily applied in small communities.

A laboratory venturi was attached to the influent line of the storage reservoir (Figure 4). The venturi pulled ambient air into the water stream, and measurements were made to determine if the additional air would help to remove radon. The water was then allowed to free fall 0.6 m (2 ft) to the surface of the tank at the 3 flow rates of 0.9 L/min (0.24 gpm), 2.2 L/min (0.6 gpm), and 3.0 L/min (0.8 gpm). The venturi addition increased the radon removal over free fall alone by a range of 5% to 12%, except at the longest detention time [0.9 L/min (0.24 gpm)]. In this case, the radon removal with the venturi was 10% less than by free fall alone. The flow rates may have been too low to generate good venturi action (aeration), thus better removals were not observed in all the venturi runs.

SUMMARY

Simple low-technology/low-cost aeration treatment techniques are capable of lowering the radon concentration in drinking water. Removal percentages of 60% to 87% can be achieved with only 9 hr of retention time and simple aeration. Better than 95% removal was observed with aeration applied during 30 hr of storage. Storage for 30 hr and the addition of minimal aeration should be within the operational capability of a small community. Larger scale testing of the simple aeration technique may be completed under the existing cooperative agreement with the NHDES. The data presented here are a qualitative description of some simple laboratory and field tests to remove radon. Further investigations are necessary to better understand the simple technologies and the options available to small communities.

THE AUTHORS

This low-cost/low-technology aeration study was conducted by Dr. Nancy Kinner, Ms. Carol Lessard, and Ms. Gretchen Schell of the University of New Hampshire, funded under Cooperative Agreement CR812602 with the New Hampshire Department of Environmental Services. The data shown here and the information presented here were compiled by Kinner, Lessard, and Schell (Department of Civil Engineering, University of New Hampshire, Durham, NH 03824) and will be finalized as a project report under U.S. EPA Cooperative Agreement CR812602. K.R. Fox, the EPA Project Officer, is with the Water Engineering Research Laboratory, Cincinnati, Ohio.

Figure 3. Radon Loss During Open-Air Storage.

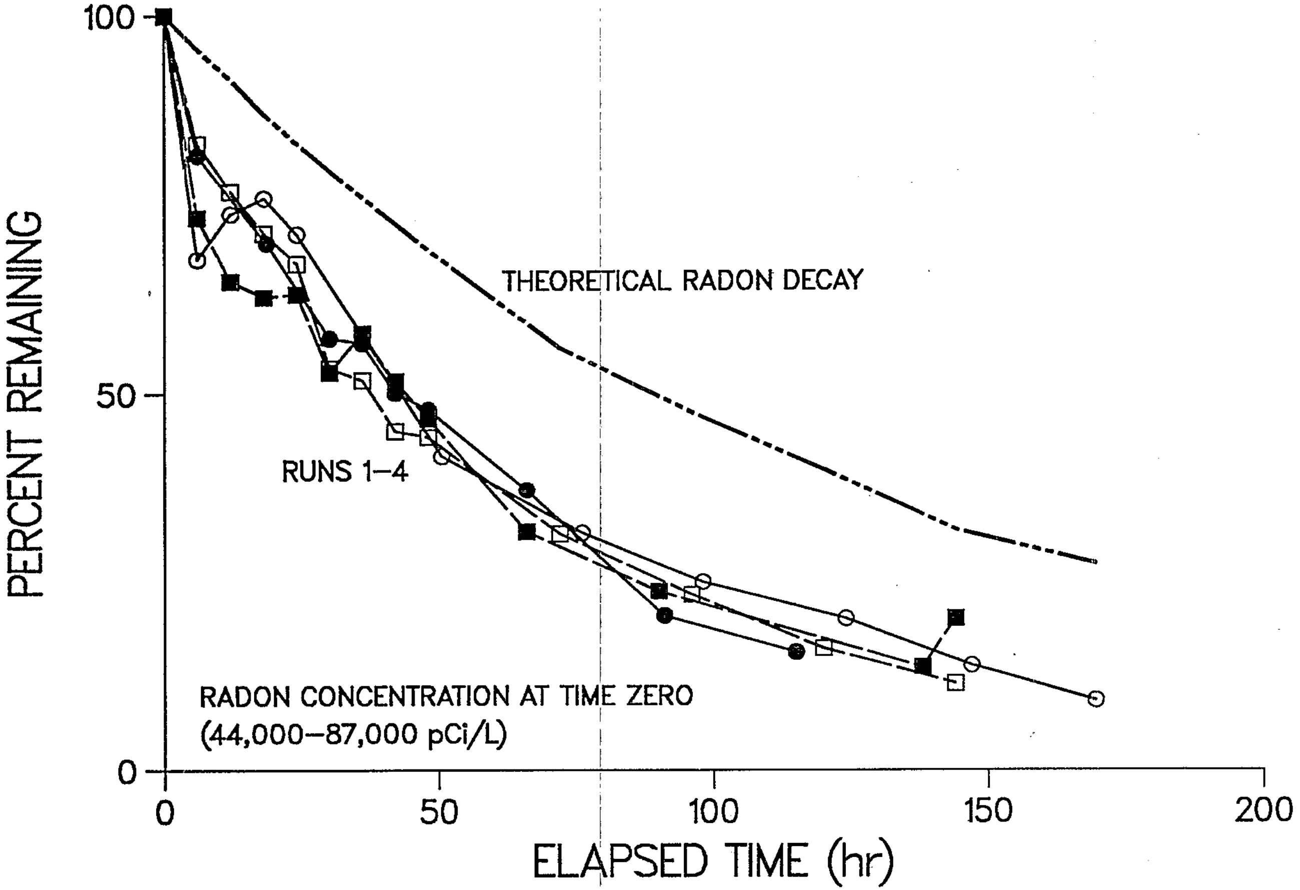


Figure 4. Pilot Scale Atmospheric Tank, Derry, NH.

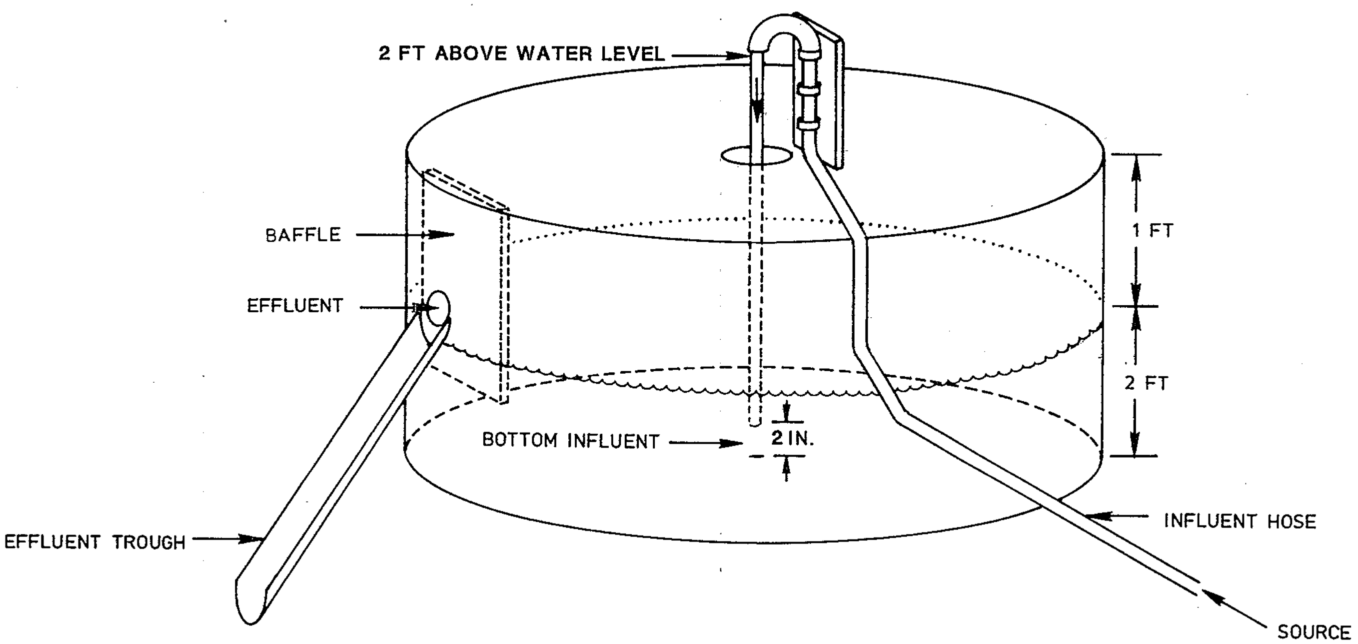


Figure 5. Radon Removal at Derry, NH (3.3 L/min (0.9 gpm) 8 hr Detention Time).

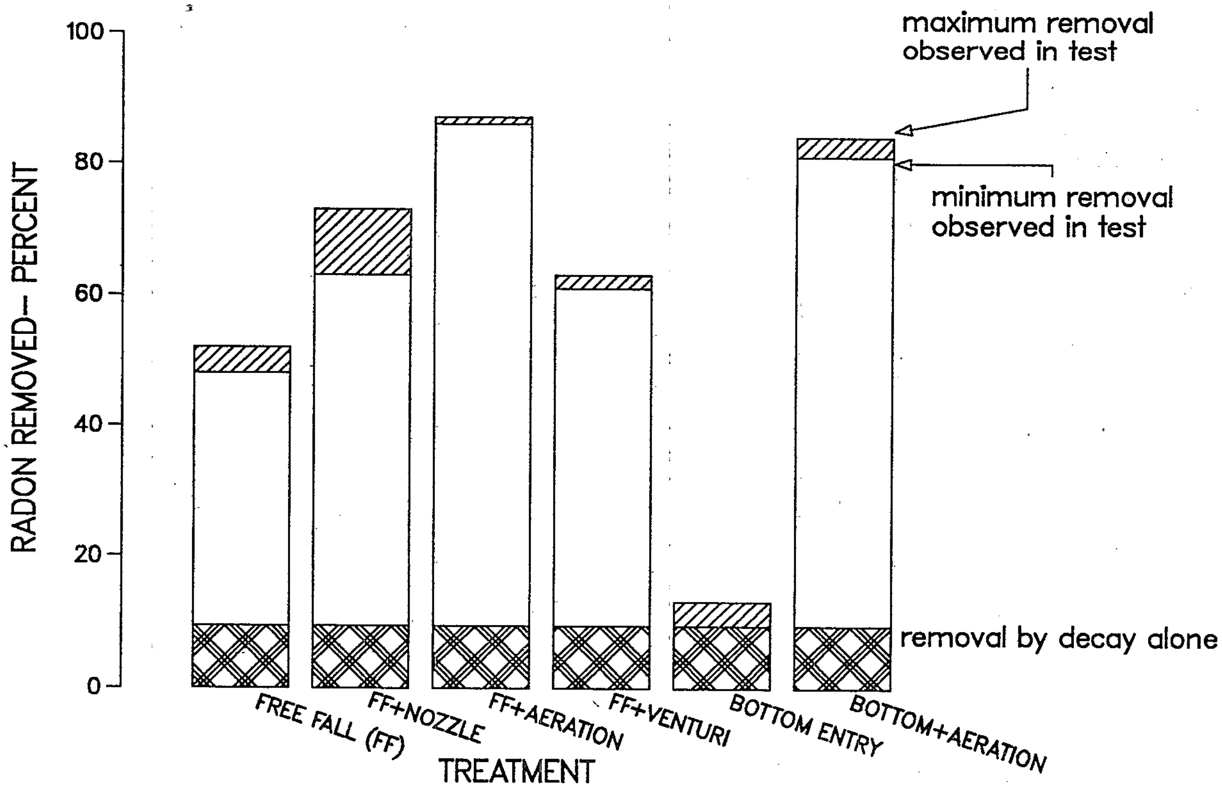


Figure 6. Radon Removal at Derry, NH (2.2 L/min (0.6 gpm) 12 hr Detention Time).

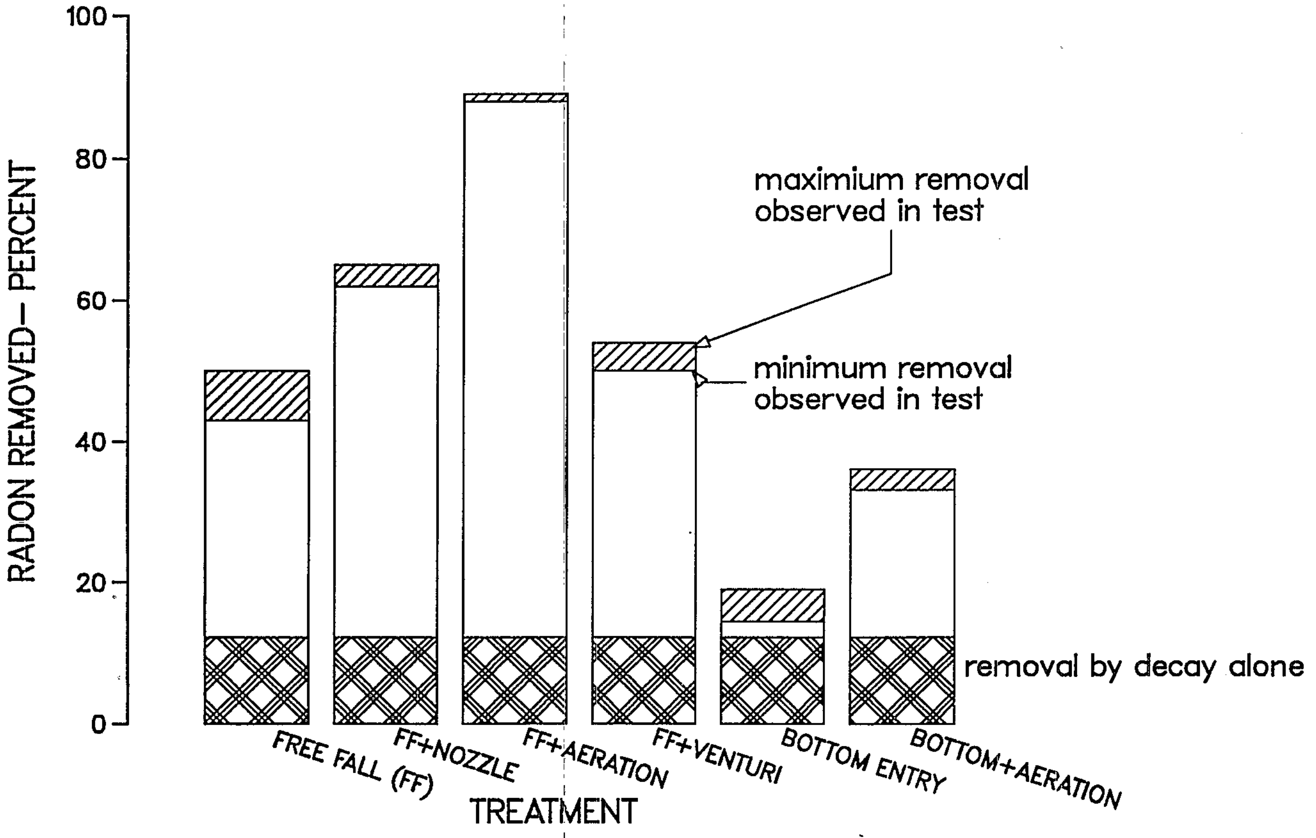
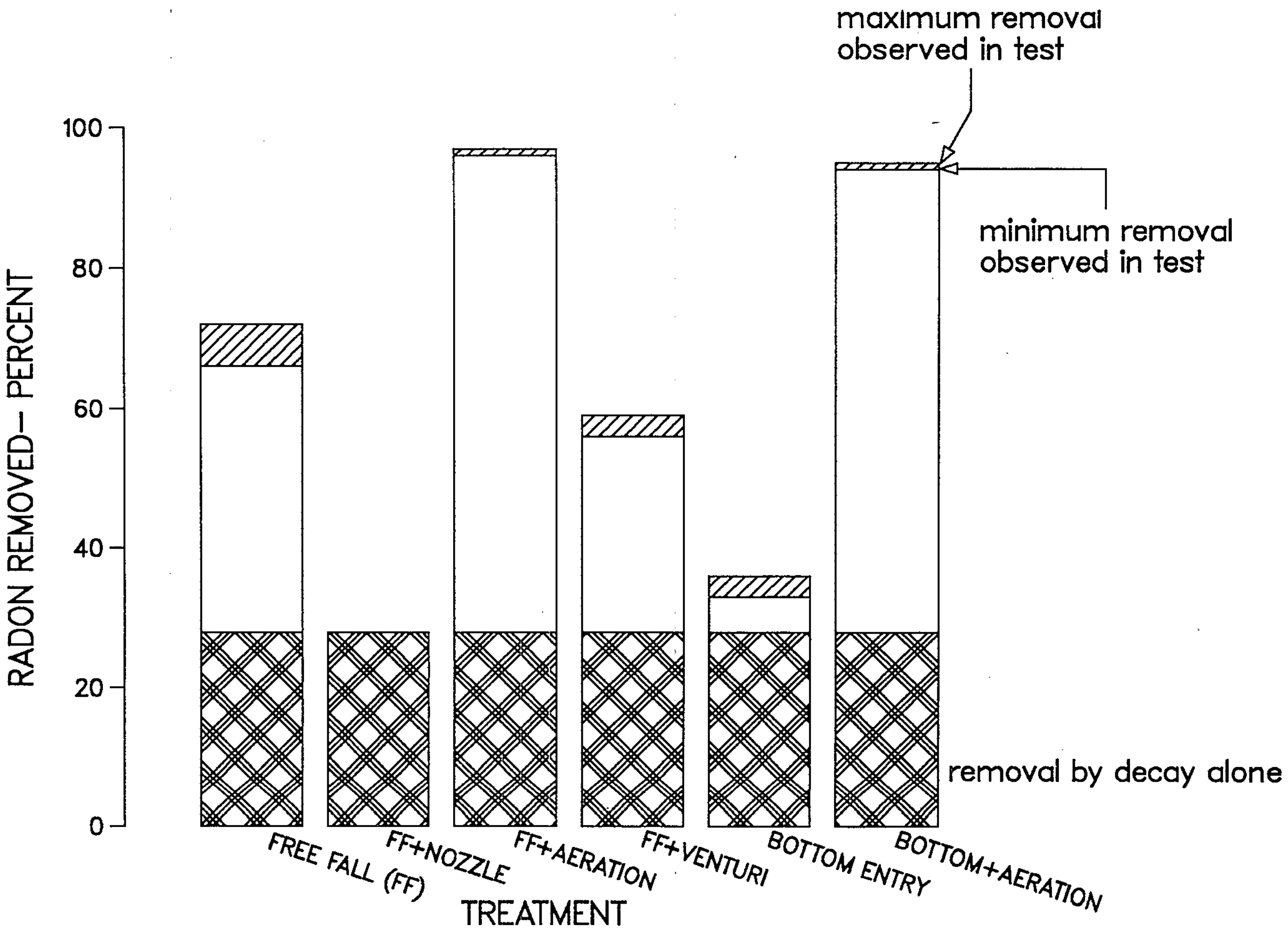


Figure 7. Radon Removal at Derry, NH (0.9 L/min (0.24 gpm) 30 hr Detention Time).



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