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# GRANULATED ACTIVATED CARBON WATER TREATMENT and POTENTIAL RADIATION HAZARDS

By

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## INTRODUCTION

Almost thirty years ago Smith et al. <sup>(1)</sup> reported high levels of radon in the ground waters of northern New England. Twenty years later, concerns about the health effects of radon and the presence of high radon concentrations in some ground waters of Maine led to studies by a number of researchers, many associated with the University of Maine at Orono <sup>(2-5)</sup>. Early in these investigations it became clear that 1) radon is readily released from water through normal household water use and 2) the principal health risk from radon is from inhalation rather than ingestion. Consequently, indoor use of untreated water with a high radon concentration leads to an unnecessary risk of lung cancer. Reduction of this risk is the goal of the proposed regulation of radon in public water supplies by the Environmental Protection Agency. It is becoming increasingly common in New England real estate transactions to transfer to private or domestic water supplies the regulations protecting public health as stated in the Safe Drinking Water Act.

Although the results of investigations reported here are specific to radon (Rn-222) removal from domestic water supplies, the principles and problems apply to all systems where treatment is by

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granular activated carbon (GAC), regardless of the contaminant being removed. The subjects of this paper are the secondary problems of gamma radiation and disposal of radionuclides resulting from the accumulation of radioactive radon progeny on GAC filters.

## GAC Adsorption

Early in the investigation of radon treatment technology it became apparent that two basic methods, 1) aeration by various techniques and 2) granular activated carbon filtration were both better than 95% effective for reducing radon in water <sup>(6)</sup>.

The technical aspects of the adsorption of radon on GAC have been extensively described by Lowry et al., and the practical field application to domestic and small public water supplies reported <sup>(8,9,10)</sup>.

An important point for the present discussion is that a radon adsorption/radioactive decay steady state relationship is attained in a GAC bed after about thirty days. As a result of this steady state condition and the very small mass of matter retained by the GAC, a GAC bed is theoretically capable of constant and essentially perpetual radon removal. Uranium and, to a lesser extent, radium are also removed from water by GAC filters; but this will not be discussed here.

The appeal of GAC over aeration for very small systems has been its relatively low initial cost coupled with low operation and maintenance costs. This

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apparent advantage of the GAC treatment system is a result of its simple design, the lack of moving parts and no need to repressurize for distribution. Depending on the initial radon content and the percent radon removal required to meet a given finished water quality, the cost advantage shifts to aeration systems at water usages between 10,000 and 20,000 gpd.

From the beginning, it was recognized that decay of radon within the GAC bed would result in the growth of radon progeny. Figure 1 shows the uranium decay series, which includes radon and its daughter products or progeny. If these daughter products are retained in the GAC bed, the system will proceed toward radioactive equilibrium between radon and the progeny. In the case of beta and gamma emitting daughters Bi-214 and Pb-214, equilibrium with Rn-222 is attained within hours. Beta emitting Pb-210, because of its longer half-life, would take 22 years to reach fifty percent of equilibrium.

The health benefit that results from the removal of radon has overshadowed other radiological health considerations. It was recognized from the beginning that gamma radiation from a GAC filter could be a health hazard but perhaps this possibility was not fully appreciated.

### Empirical Methods

Lacking evidence to the contrary, it was assumed in the early studies that radon progeny were totally retained on the GAC. This is an appropriately conservative worst case scenario when considering the health effects of gamma radiation from GAC beds. Later research has confirmed essentially total retention of radon daughters by GAC <sup>(6)</sup>.

A typical domestic style water supply consists of a fiberglass or plastic tank 54 inches tall with an inside diameter of 10 inches and containing 2.5 cubic feet of GAC. The tank is operated in the down-flow mode and backwashing is done only when necessary to alleviate physical blockage of filter flow. Gamma profiles of a GAC tank in operation show that most of the radiation is emitted from the top several inches of the bed, as shown in

Figure 2 <sup>(7)</sup>. Survey meter readings of the maximum gamma ray dose at several tank surfaces produced the following correlations between dose and influent radon concentration:

$$\text{Max mR/hr} = \text{Rn}_{\text{inr}} (\text{pCi/l}) / 17800 \quad (7)$$

$$\text{Max mR/hr} = \text{Rn}_{\text{inr}} (\text{pCi/l}) / 10360 \quad (8)$$

$$\text{Max mR/hr} = \text{Rn}_{\text{inr}} (\text{pCi/l}) / 8595 \quad (8)$$

While it is obvious that these relationships may differ greatly, a detailed discussion of the possible reasons for these differences is beyond the scope of this paper. However, it is important to note that this may be due largely to geometrical relationships between the radiation source and the survey meter detector. Large errors can result when the detector is in close proximity to the source.

There is a better way to measure the radiation environment around a GAC tank. A series of measurements made at various, often substantial, distances from the source provide the raw data for defining the radiation environment <sup>(8)</sup>. The gamma radiation dose at the source or at any distance is then proportional to the reciprocal of the distance squared.

To measure the gamma radiation field around GAC tanks, ten units were selected that had been in service between seven months and six years. Nine of these units are considered in this paper. The tenth unit, with an influent radon of 2620 pCi/l, produced so little radiation as to be virtually impossible to measure at a distance with acceptable accuracy. The tanks were disconnected and placed outside the installation building, and the gamma exposure field was measured by taking up to 400 readings within a two dimensional grid. The measurements of the distribution of gamma exposure rates surrounding the GAC vessel established isogamma lines from a maximum at the side of the vessel to the prevailing background of the installation area. This is illustrated in Figure 3.

To accompany the gamma data, accurate water use measurements were made by water meter. Radon measurements of raw and treated water were made 15 and 5 times respectively during the three week period preceding the gamma measurements. The existence of accurately established radon concentra-

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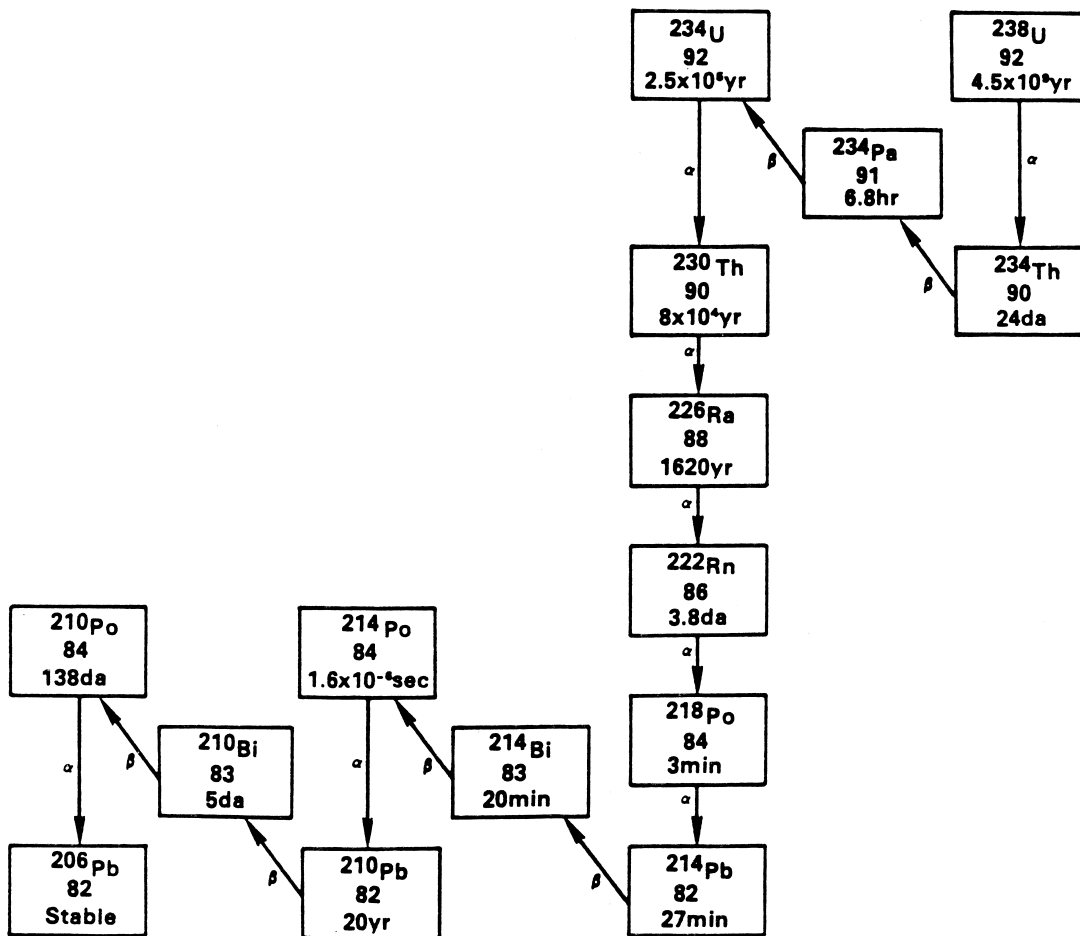
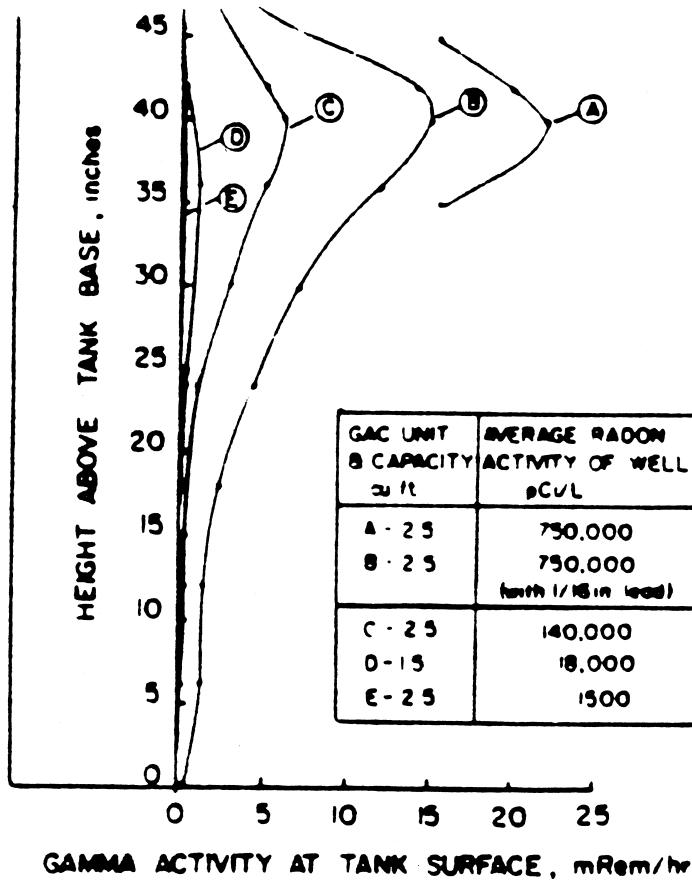


Figure 1  
Principal Decay Mode & Half-Life



## Gamma Activity Profiles for Several GAC Beds

FIGURE 2  
(Taken From Ref. 7)

