Field Test Experience with Charcoal Canisters for Measuring ^{222}Radon in Air

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ABSTRACT

Activated charcoal canisters have been used successfully for the past 20 years in government and private industry radon measurement programs. Both the open face and diffusion barrier charcoal canisters were evaluated and were listed by EPA after they passed the EPA radon proficiency testing. Today, charcoal canisters are used by many professional testers listed by both NEHA and NRSB. The purpose of this paper is to set aside the myth and the misleading information that charcoal canisters are not as accurate as other radon measuring devices. Part of the blame falls within EPA which initially evaluated its open face canisters in limited and selective tests under extreme conditions. That myth was perpetuated for many years, even while EPA developed and evaluated a diffusion barrier charcoal adsorber that showed excellent results in both laboratory and field environments where the radon concentration was varied by more than 10 to 1 and at humidity ranging from 20% to 85%. Although, EPA published the standard operating procedures for radon measurement using diffusion barrier charcoal canisters (EPA 520/5-90-032, November 1990), EPA failed to present and publish the approved report on the evaluation of its diffusion barrier charcoal collector. At the same time, DOE developed a diffusion barrier charcoal collector with excellent results under conditions of extreme humidity where the radon concentration varied by more than a factor of ten. Similarly, the Pennsylvania DEP/Bureau of Radiation Protection/ Radon Division and the Radon Testing Corporation of America (RTCA) developed and used diffusion barrier charcoal collectors with excellent results.

The sensitivity of the charcoal canister is the best of all other radon methods and devices in terms of net counts per minute per 4 pCi/L of radon. For example the counting rate for the 4 inch RTCA canister exposed to radon at 4 pCi/L for 2 days and counted 3 days later will be about 145 counts per minute. In a similar situation, the EPA canister will produce about 48 counts per minute. However, in a three day exposure and counted three days later, the corresponding net counting rates will be 175 and 65 counts per minute respectively. The difference in sensitivity is due to a more sensitive charcoal and a more efficient gamma detector used by RTCA. By comparison, if an RTCA canister was exposed as an open face collector for 2 days and analyzed 3 days later will yield 250 net counts per minute per 4 pCi/L. A continuous scintillation cell monitor with a cell volume of 0.1 liters will yield about 2 net counts per minute per 4 pCi/L of radon. The most sensitive commercial continuous scintillation cell radon monitor is the Eberline RGM-3 with a scintillation cell volume of 3 liters and at 4 pCi/L radon concentration will yield about 24 net counts per minute. The sensitivity of all other types of continuous radon monitors usually ranges from 2 to 7 net counts per minute per 4 pCi/L.

INTRODUCTION

Over the past 20 years activated charcoal collectors have been used to measure radon in the indoor environment during surveys of large areas in large buildings or in private homes. Open face charcoal canisters were first used successfully in the early 1970Õs to measure the radon flux from the surface of soils in Central Florida a region with high phosphate deposits (Countess, 1976). The deployment of properly calibrated open face charcoal canisters identified and confirmed hot radon sites throughout the US. All these happened before there was an EPA program to deal with the radon problem, Most of the initial radon surveys were done with open face canisters that performed very well under typical indoor environmental conditions (George, 1984). Calibrated open face canisters exposed up to 3 days in a private home where the radon varied by a factor of 2, the average of the canisters was <2% low from the average of the continuous radon monitor. Similarly, the average of the open face canisters exposed in a radon chamber where the concentration of radon varied by a factor of 10, was <1% different from the average measured with the continuous radon monitor. The use of open face canisters for exposures lasting 2-3 days are appropriate in environments with humidity up to 70%. Open face canisters can be used with confidence for radon measurements lasting 2-3 days as is commonly used in real estate transactions. Open face charcoal canisters are very sensitive yielding the highest response in terms of net cpm / 4 pCi/L. For integrated measurements of radon over longer periods (up to 7 days), the open face canisters could be saturated with water vapor in a humid environment (RH >70%).

To make certain the charcoal canister technique was viable under extreme conditions of humidity, radon concentrations and for longer periods of exposure, the open face canister can was modified by providing a diffusion barrier cover to improve its response under unusual conditions of exposure.

Diffusion barrier charcoal collectors were developed tested and evaluated for radon measurements with excellent results (Cohen and Nason, 1986, George and Weber, 1990). EPA, developed and tested a diffusion barrier collector with excellent results from both radon chamber tests and from field environments, but did not publish the report that was approved for presentation and publication. This oversight by EPA deprived the radon service providers of the benefits of accurate, very simple and practical measuring radon technology. However, EPA published the standard operating procedures for Radon-222 measurement using diffusion barrier charcoal canisters (EPA 520/5-90-032, 1990) that was useful to those that were already using the technique. In the unpublished report, EPA is stating that the integrating capability of the diffusion barrier charcoal canister improved for exposures ranging from 2 to 10 days without elaborating any further about the excellent results obtained in the laboratory and field situations where the radon concentration varied by more than 10 to 1, at humidity ranges from 20% to 85%.

Diffusion barrier charcoal canisters provide quality measurements at no additional cost in their construction, deployment and analysis. The type that is recycled and can be used for multiple exposures offers the greatest cost advantage.

The purpose of this paper is to present data obtained by several analytical laboratories using diffusion barrier charcoal collectors to measure indoor radon concentration levels in different field applications and to demonstrate that diffusion barrier charcoal canisters are the most sensitive integrating devices for measuring environmental concentrations of radon.

LABORATORY AND FIELD MEASUREMENTS OF RADON USING DIFFUSION BARRIER CHARCOAL CANISTERS

The data presented in this report were obtained with different types of diffusion barrier collectors that are currently used by radon service providers with analytical facilities and active radon measurement programs. EPA, being one of the facilities, used its diffusion barrier collector for several years in a National Radon Survey. Currently, the EPA diffusion barrier charcoal canister is being used by the EPA laboratory in Las Vegas. The EPA laboratory in Montgomery Alabama, the developer of the EPA version of the diffusion barrier canister, ceased its radon program entirely. The design characteristics and sensitivities of different size and configuration diffusion barrier charcoal canisters, LS vials and Open Face collectors exposed to radon at 4 pCi/L for 2 days and analyzed 3 days after exposure are listed in Table 1.

Table 1

Size Characteristics and Sensitivities of Diffusion Barrier Charcoal Collectors for Radon

Facility	Carbon Mass (g)	Analyzer Efficiency cpm/pCi	Sensitivity Net cpm/ 4 pCi/L
EML, DOE	50	0.30	30
US EPA	70	0.28	48
PA, DER	75	0.36	62
RTCA, 3 Inch	50	0.48	90

RTCA, 4 inch 90 0.48 145

RTCA, LS Vial 2 2.54 53

RTCA, 4 Inch Open face 90 0.48 250

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The adsorption characteristics of the EPA canister (EPA David Gray, James Burkhart and A. Jacobson, 1990), and that used by EML until 1995 (A. C. George, 1990) exposed at different conditions of exposure in two different laboratories are shown in Fig 1 and 2 indicating that the diffusion barrier canisters are collecting and retaining radon very efficiently for up to seven days even at humidities of 80-90%. It appears that the break point of the carbon in the collectors is not reached at the extreme conditions of the tests. Both figures show that radon adsorption is linear for all test conditions of humidity up to 5 days of exposure. At very high humidity (>75%), adsorption is curtailed slightly after the fifth day, but the sensitivity is still quite high. The desorption rate of radon by diffusion barrier charcoal canisters exposed from 2 to 7 days is reduced significantly and the effective half-life of the canister increases allowing the canister to integrate over longer periods up to 10 days. The RTCA and the Pennsylvania DER and other diffusion barrier charcoal canisters were not evaluated with the same detail but they should behave similarly as it will be shown from radon intercomparison measurements with continuous radon monitors.

The integrated radon measurement results obtained in radon test chambers and in residential buildings by the different diffusion barrier charcoal collectors are compared with the average values obtained with calibrated continuous radon monitors. Figure 3, shows the integrated average value of radon concentration measured with EPA diffusion barrier canisters exposed in the EPA radon test chamber in Montgomery Alabama for seven days. The radon concentration varied from 0.5 pCi/L to more than 11 pCi/L. The average diffusion barrier canister result was < 1.3 % lower than the average of the continuous radon monitor even when the radon concentration varied by more than a factor of 20 during the test period. Figure 4, compares the results of four day radon measurements obtained in the two EML radon test chambers kept at the same environmental conditions of temperature and humidity but with radon concentration levels of 4 pCi/l and 38 pCi/L. The diffusion barrier canisters were moved back and forth between the two chambers several times. The results indicate that the diffusion barrier canister either underestimated or overestimated the continuous radon monitor average by < 3.3% (George and Weber, 1990).

Figure 5, intercompares the radon measurements obtained with RTCA diffusion barrier canisters exposed alternately in the EML radon test chamber and in a 0.2 pCi/L low radon environment for four days. Even with a radon variation of over a factor of 150 in the two test environments the canister average was only 6.6% lower than the average of the continuous radon monitors. In another intercomparisons test, RTCA diffusion barrier canisters were exposed alternately in the EML test chamber and in 0.2 pCi/L low radon environment for three days. The average of the RTCA canisters was 52.7 pCi /L as compared to the continuous radon monitor average of 53.8 pCi/L showing only a 2% difference while the radon concentration varied by more than a factor of 260.

Figure 7, shows radon results obtained in a residential building in New Jersey during a four day exposure. The home was known to have unusual variation in radon concentration in wich the performance of the EML diffusion barrier canister could be tested.. Although, the radon concentration varied from 7 Ð130 pCi/L, the average radon measured with the diffusion barrier canisters overestimated the true value by only 2.7%. Figure 8, shows radon measurements with EPA diffusion barrier canisters obtained in the field for six days indicating very good agreement with the continuous radon monitor results (CRM average = 9.5 pCi/L versus 8.8 pCi/L with the average of the diffusion barrier canisters). The radon varied from 4 pCi/L to 17 pCi/L. Figures 9, 10 and 11, show the results of radon measurement intercomparisons obtained with the EPA diffusion barrier canisters in the field for seven days, indicating very good agreement between the average of the continuous radon monitor and the average of the canisters. The radon varied from (1.3 Ð 7.8 pCi/L), (3 Ð 12 pCi/L) and (1.2 - 9.5 pCi/L), respectively. Figures 12 and 13, show another set of radon intercomparisons obtained with the EPA diffusion barrier canisters exposed in the field for six days. The results in both situations show very good agreement between the continuous radon monitor and the average value of the EPA canisters. The radon varied from (2 Ð 10.2 pCi/L) and (3 Ð9.5 pCi/L), respectively. The summary presentation of the EPA field radon test results depicted in Figures 8-13 are shown in graphical form in Figure 14. A close agreement between the average radon value of the EPA canisters and the average value measured with a continuous radon monitor is observed in all tests conducted for 6 to 7 days in various locations.

Figures 15 through 17, show field radon measurements made in residential buildings in Pennsylvania by the Pennsylvania Bureau of Radiation Protection. They exposed diffusion barrier canisters that were similar to EPAÕs simultaneously with a continuous radon monitor and electret ion chambers. Figure 15, shows the difference between the diffusion barrier canisters and the continuous radon monitor or the electret ion chambers to be <5.3pCi/L.The concentration of radon during the measurement varied from 2-6 pCi/L. In Figure 16, in another 7 day exposure the radon varied from 7 Ð 23 pCi/L and the difference between the diffusion barrier canisters and the continuous radon monitor and the average of electret ion chambers was 10%. In Figure 17, in a third field intercomparison during a period of seven days, the concentration of radon ranged from 5 Ð 60 pCi/L and the difference between the diffusion barrier and the continuous radon monitor was < 2.5%. The difference between the average of three electret ion chambers and the continuous radon monitor was <2.2%, indicating good agreement between the passive integrating devices and the continuous radon monitor.

Table 2, lists the sensitivity of other methods reported by the developers and manufacturers of the different instruments. Representative instruments with different methods of detection such as scintillation cells, ionization chambers and solid state detectors are compared. The sensitive volume of these instruments is given except in one device. The sensitivity is roughly proportional to the sensitive volume of the instrument.

Comparing the sensitivities of diffusion barrier canisters listed in Table 1 with those of the other methods listed in Table 2 it is readily seen that at low radon levels < 4pCi/L the charcoal canisters exhibit the highest sensitivity.

Table2

Sensitivity of Different Radon Measurement Methods

Radon Measurement Method	**Sensitive volume Liters**	**Sensitivity Net cpm/ 4 pCi/L**
Scintill. Cell (Lucas, Radonics ÐCertifier)	**0.10**	**2.0**
Scintill. Cell Pylon AB-5	**0.27**	**5.6**
Scintill. Cell (EML)	**0.46**	**8.4**

Scintill. Cell (Eberline RGM-3) 3.00 24.0

Pulse Ion. Chamber (femto-TECH) 0.20 1.2

Pulse Ion. Chamber (ATMOS- 12D) 0.60 2.8

Pulse Ion. Chamber (AlphaGuard MC50) 0.55 7.6

Solid State Detector (Sun Nuclear Đactive) ---- 1.20

Solid State Detector (RAD 7 0.60 2.80

Solid State Detector (EML Radometer) 6.00 20.0

RTCA, 3 inch canister (50.0 g) 90.0

RTCA, 4 inch canister (90.0 g) 145.0

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Electret Ion Chamber 0.20 8.0 Volts/ 4pCi/L-Days

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CONCLUSIONS

The radon measurement results from four radon test facilities that use passive diffusion barrier charcoal canisters indicate that they integrate accurately at high humidities and under extreme variations of radon concentrations. When their sensitivity is compared to other methods and techniques for measuring radon, they are the most sensitive devices yielding the highest net counting rate for a radon level of 4 pCi/L or less. Properly calibrated open face canisters used for 2-3 day exposures yield accurate results.l

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