INTERCOMPARISON OF THE SENSITIVITY AND ACCURACY OF RADON MEASURING INSTRUMENTS AND METHODS

Andreas C. George

Radon Testing Corporation of America
2 Hayes Street, Elmsford, NY 10523

ABSTRACT

Radon testing in the US has reached a plateau with about two dozen different types of instruments and methods being used to make about one million measurements per year. Knowledge of the sensitivity and accuracy of radon testing instruments can make it easier for testing firms and home inspectors to select the most appropriate device for their radon testing program. This paper compares the sensitivity and as a consequence the accuracy of every type of device that information was given by the manufacturer or cited from published literature. Some instrument manufacturers, did not make this information available. The sensitivity expressed in counts/minute per 4 pCi/L, was selected because most of the measurements for radon in the US are <4 pCi/L. The instruments listed in this paper represent passive and continuous radon monitors such as scintillation cell, pulse and current ionization chamber, solid-state alpha monitors and several diffusion barrier charcoal integrating collectors. For comparison, the sensitivity of one open face charcoal canister is also included. The sensitivity of alpha track detectors and electret ion chambers are also included in terms of number of tracks/cm^2 /4 pCi/L^{-1} D^{-1} and Volts/4 pCi/L^{-1} D^{-1}
The sensitivities of continuous radon monitors ranges from 0.17 to 24 cpm/4 pCi L^{-1} ranging from 0.17 - 5.7 cpm/4 pCi/L, in the instruments most frequently used. By comparison the sensitivities of diffusion barrier charcoal vials or canisters range from 48-145 cpm/4pCi L^{-1}
At radon levels of <4 pCi/L, most of the continuous radon monitors will provide poor results if counts are acquired at minute intervals. For this reason, EPA, requires continuous radon instruments to accumulate hourly counts to improve accuracy.

Introduction

In the 1980's a great deal of awareness was generated about the health risk from exposure to radon and radon decay products. The United States Environmental Protection Agency (EPA), undertook the responsibility and the task to address the increased concern from radon exposure by establishing a radon program that incorporated research and development of instruments and methods to measure and evaluate the risk from breathing radon and radon decay products in the indoor and occupational environment. EPA revised the number of annual lung cancer deaths in the US from 14,000 to 21,000 accounting about 13% of all lung cancers. EPA also, assigned a 3.5 times increase in the risk to non-smokers and 2.1 times to smokers.

In the US, unlike other countries most of the measurements of radon are performed with instruments and methods using short-term exposures ranging from 2-7 days. There are about four million real estate transactions per year in the US, and a large number of radon measurements today are driven by real estate transactions.

According to EPA, in the last eighteen years more than 20 million measurements for radon were made in the US, showing that 6% - 8% of the homes have radon equal or >4 pCi/L. AARST, suggests that as many as 10% of the houses have radon equal or greater than 4 pCi/L. About 15% of the housing stock has been tested initially, averaging about one million radon measurements per year. EPA, also states that about 10% of the homes above the action level have been mitigated averaging about 50,000 mitigations per year. If all these numbers are accurate, radon measurement providers, home inspectors and mitigation firms will be very busy for a long time.

According to the National Association of Home Builders Research center, about 200,000 new homes are built with radon resistant features. Usually a passive mitigation system is installed. When a small number of these homes were tested for radon, it was found that as much as 50% had radon levels >4 pCi/L. EPA should make it mandatory that these so-called radon resistant homes be routinely tested for radon before the buyer moves in. If the radon is found to be >4 pCi/L, the passive system should be activated by installing a suction fan.

In the early days of radon testing, most of the short-term measurements were made with passive open face and diffusion barrier activated carbon collectors which were analyzed using either the gamma or alpha-beta counting technique [1-2]

The diffusion barrier activated carbon collector technique first used in the late 1980's, constitutes a very precise method for measuring radon for periods ranging from 2-7 days even if the radon varies by as much as a factor of 10 and the humidity ranges from 20% - 80%, during the measurement [1, 3]. In calibrating activated carbon collectors, it is necessary to derive a family of calibration factors for various times of exposure and different amounts of adsorbed moisture. This is done by exposing groups of activated carbon canisters or L/S vials in a chamber with a known concentration of radon and relative humidity covering the time periods that are typically used in the field. The calibration factor is thus obtained from an equation of best fit constructed from the radon chamber calibration data [1, 3, 4]

For different types of charcoal, it is necessary to do a complete evaluation and calibration. Charcoal from different manufacturers and from different batches should be investigated, before adapting them with the analytical system. George [1] and Gray [3], conducted radon intercomparison measurements between diffusion barrier activated carbon collectors and continuous radon monitors and found their average radon values to be in very good agreement even if the radon concentration varied by several factors during the 2-7 day field tests.

Intercomparisons with diffusion barrier charcoal canisters by the Department of Energy, Radon Testing Corporation of America (RTCA) and the Pennsylvania DER, also showed average radon values to be in very good agreement with the average value obtained with continuous radon monitors.

Open face activated carbon collectors are very reliable for exposure periods of 2-3 days even when the relative humidity is 70%. In very humid environments and for exposures beyond 4 days, the carbon bed can be saturated to a large extend and the charcoal canister will under-respond.

TEST RESULTS AND INTERCOMPARISONS

The sensitivities of different instruments are listed in Table 1. The type and principle of detection of each instrument or method along with the cost are shown for comparison. The cost of individual instruments with accessories ranges from about $925 - $8,000, with the most popular, between $2,000 - $4,000. The cost of radon detectors or collectors analyzed by private laboratories, is about $25.00.

Instruments with greater efficiency or sensitivity can achieve results with smaller uncertainty than instruments with poor sensitivity. EPA, recommended that continuous monitors should be capable to measure 16 counts per hour per pCi/L [5]. Using the recommended 16 counts per hour per pCi/L sensitivity, at least three continuous radon monitors in Table 1, do not meet this sensitivity criterion. The reliability of electronic instruments must be established and be maintained through a rigorous quality assurance program. Unless routine instrument performance checks prior to and after each measurement and frequent cross-checks in the field are conducted, one does not know with certainty if the continuous radon measuring instrument obtained accurate results. Most of the users of electronic instruments in the field know how to start and stop a radon test but they may or may not be able to perform field performance checks.

Table 1. **RADIOSENSITIVITY AND ACCURACY OF RADON MEASURING INSTRUMENTS AND METHODS**

Instruments	Principle of Detection	Sensitivity cpm/4 pCi/L	Cost with Accessories
Passive-Sun Nuclear	Solid-State	0.17	$ 925
Passive RS500	Solid state	0.30	$2,145
Passive-Radon Scout	Solid-State	0.31	$1,000
Passive-E-Smart	Current Ioniz.	1.2	$2,000
Passive Femto CRM-510	Pulse Ioniz.	1.2	$3,000
Passive Alpha Guard	Pulse ioniz.	2.8	$6,000
Active Radonics	Scintill. Cell	2.0	$8,000
Active Durridge	Solid-State	2.8	$4,500
Active Pylon AB-5	Scintill. Cell	5.7	$3,500
Active DOE	Scintill. Cell	8.4	$3,000
Active Eberline	Scintill.Cell	24.0	$6,000
Pass.DB-50g-RTCA can.	Gamma Detect	90.0	$25*
Pass.DB-90g-RTCA can.	Gamma Detect	145.0	$25*
Pass.DB-70g-EPA can.	Gamma Detect	48.0	$25*
Pass. DB-75g PA/DER	Gamma Detect	60.0	$25*
Pass. OF-90g canister	Gamma Detect	250.0	$25*

(* Cost per test)

The sensitivities of different types of alpha track detectors [6] and electret ion chambers are listed in Table 2. Although, the sensitivities of these devices cannot be compared directly with those listed in Table 1, in terms of net cpm/4 pCi/L, the information is useful for the selection of the proper device for short-term or long-term measurements. Alpha track detectors having low sensitivities must be exposed for at least three months in an environment with radon at 4 pCi/L to obtain an adequate number of tracks.

RADIOSENSITIVITY OF ALPHA TRACK DETECTORS AND ELECTRET ION CHAMBERS

Test Device	Number of Tracks/cm^2 / 4 pCi L^{-1} D^{-1}	Volts/ 4 pCi L^{-1} D^{-1}
Landauer CR-39	1.6	
REM CR-39	8.0	
NYU CR-39	11.4	
Swedish Makrofol	3.6	
Italian LR-115	22.0	
Italian LR-115 (Open Type)	4.8	
Rad Elec Short-term		8.0
Rad Elec Long-term		0.7
RTCA Electret, Long-term		0.6

CONCLUSIONS:

Evaluation of diffusion barrier and activated carbon collectors in radon chambers and in field testing measured the average radon concentration very accurately at high humidity and under extreme variation of radon concentration [1, 3] When results are needed in a hurry for (2-7 day exposure), activated carbon collectors are the most sensitive, most accurate and most cost-effective devices yielding very high counting rates per cpm/4 pCi/L. Those who use electronic continuous radon monitors should make sure the instrument meets the criteria recommended by EPA. Most of the measurements in the US are less than 4 pCi/L and sensitivity becomes very important. Because of the low counting rate of most electronic continuous monitors, the counting rate should be based on hourly basis to improve counting statistics. Alpha track detectors due to their low sensitivity are suitable for long-term exposures and can measure the annual average accurately. The two types of elecret ion chambers have similar sensitivities and can be used for short-term or long-term exposures depending on the thickness of the electret.

REFERENCES

[1] A. C. George and T. Weber. An improved passive activated carbon collector for measuring environmental ^{222}Rn in indoor air. Health Physics Vol. 58 (1990) 583-589.

[2] A. C. George. State of-the-art instruments for measuring radon/thoron and their progeny in dwellings. A review: Health Physics Vol. 70 (1996) 451-463

[3] US Environmental Protection Agency NAREL. Standard operating procedures for ^{222}Rn measurement using diffusion barrier charcoal canisters. EPA 520/5-90-032, November 1990. or in The 1992 International Symposium on Radon and Radon Reduction Technology Volume 2, Session 5. Minneapolis, MN September 22-25, 1992.

[4] P.H. Jenkins. A critiqueof the EPA method for analyzing and calibrating charcoal canisters for radon measurements. Proceedings of the 2002 International Radon Symposium. Reno Nevada. October 27-30, 2002

[5] US Environmental Protection Agency. Protocols for Radon and Radon Decay Product Measurements in Homes. EPA-402-R-92-003, June 1993.

[6] M. Urban and E. Piesch. Low level environmental radon dosimetry with a passive etch device. Radiation Dosimetry Vol. 1, (1981), 97-110.