



Standard Test Method for Radon in Drinking Water¹

This standard is issued under the fixed designation D 5072; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the measurement of radon in drinking water in concentrations above 0.04 Bq/L.

1.2 This test method may be used for absolute measurements by calibrating with a radium-226 standard or for relative measurements by comparing the measurements made with each other.

1.3 *This standard does not purport to address the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

D 1129 Terminology Relating to Water²

D 1193 Specification for Reagent Water²

D 2777 Practice for Determination of Precision and Bias of Applicable Test Methods of Committee D-19 on Water²

D 3370 Practices for Sampling Water from Closed Conduits²

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, refer to Terminology D 1129 and to other published glossaries.

4. Summary of Test Method

4.1 This test method is based on the scintillation counting of radon-222 and its daughters, a gaseous daughter product of radium-226.

4.2 An aliquot of unaerated water is drawn into a syringe then gently injected beneath 10 mL of liquid scintillation mix that does not contain an emulsifier. The vials are capped, shaken, and allowed to stand 3 h prior to counting. A commercial liquid scintillation counter is used to count the sample.

5. Significance and Use

5.1 The most prevalent of the radon isotopes in ground water is radon-222. This isotope presents the greatest health risk compared to the other naturally occurring radon isotopes if ingested via the water pathway.

6. Interferences

6.1 Other radionuclides soluble in the scintillation mix may interfere. Water that is contaminated with high energy beta/gamma emitters, even though they are not soluble in the scintillation mix, may also interfere. These interferences would be rare in drinking water samples but may be observed in some cases.

7. Apparatus

7.1 *Sampling Funnel.*

7.2 *Tube*, with standard faucet fitting.

7.3 *Disposable Syringe*, 12 mL capacity, with 20 gage, 38 mm (1 in.) hypodermic needle.

7.4 *Glass Liquid Scintillation Vials*, 20 mL capacity with polyethylene inner seal cap liners.

7.5 *Liquid Scintillation Counter.*

8. Reagents and Materials

8.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.³ Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

8.2 *Purity of Water*— Unless otherwise indicated, references to water shall be understood to mean conforming to Specification D 1193, Type III.⁴

8.3 *Radioactive Purity*—Radioactive purity shall be such that the measured radioactivity of blank samples does not exceed the calculated probable error of measurements.

¹ This test method is under the jurisdiction of ASTM Committee D-19 on Water and is the direct responsibility of Subcommittee D19.04 on Methods of Radiochemical Analysis.

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² *Annual Book of ASTM Standards*, Vol 11.01.

³ "Reagent Chemicals, American Chemical Society Specification," Am. Chemical Soc., Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see "Analytical Standards for Laboratory Chemicals," Poole, Dorset, U.K., and the "United States Pharmacopeia."

⁴ If this water is not aerated or degassed prior/subsequent to demineralization, radon background may be substantial. This can happen if the lab uses RO, EDI or only demineralization resins for purification of their water.

8.4 *Radium-226 Solution Standard*, traceable to the National Institute of Standards and Technology (NIST).

8.5 *Scintillation Cocktail Mix*, without emulsifier. Toluene based mix is acceptable.

9. Sampling

NOTE 1—Refer to Practices D 3370 for applicable sampling instructions. Also see U.S. Environmental Protection Agency reports EPA 520⁵ and EPA 600⁶.

9.1 Attach the sampling funnel and tube to a faucet with the standard faucet fitting.

9.2 Slowly turn on the water and allow a steady stream to flow out of the funnel for approximately 2 min. This purges the tube and ensures a fresh sample.

9.3 Reduce the flow of water and invert the funnel. The flow should be adjusted to a level that does not cause turbulence in the pool of water contained in the funnel. Allow excess water to spill over one edge of the funnel.

9.4 Examine the hose connection and tubing for air bubbles or pockets. If these are visible, raise or lower the funnel until they are removed.

10. Calibration and Standardization

10.1 Add a known quantity of traceable NIST radium-226 standard solution to a known volume of water.

10.2 Combine a 10 mL aliquot of the radium-226 standard solution with 10 mL of scintillation mix in a 20 mL glass scintillation vial.

10.3 Allow approximately 30 days for buildup of radon (that is, secular equilibrium with radium-226).

10.4 Shake vial to transfer nearly all the radon to the scintillation mix phase (radon is highly soluble in the scintillation mix). The radium-226 remains in the aqueous phase and, therefore, does not contribute significantly to the count rate.

10.5 Allow for the buildup of short-lived radon progeny and for dark-adapting by waiting 3 h before counting.

10.6 In liquid-scintillation vials, prepare background samples consisting of 10 mL of Type III reagent water and 10 mL of scintillation solution. Cap the vials and shake to mix the contents. Allow approximately 30 days for decay of any residual radon.

10.7 Count the standard and background samples for 50 min or longer.

11. Procedure

11.1 Clean scintillation vials with alcohol and add 10 mL of scintillation mix.

11.2 Collect unaerated sample in accordance with Section 9.

11.3 Place the tip of the hypodermic needle approximately 3 cm under the surface of the water in the funnel and withdraw

a few millilitres of water and eject this water. Using this procedure, rinse the syringe and hypodermic needle two or three more times.

11.4 Again, place the tip of the needle approximately 3 cm below the surface of the water and withdraw approximately 12 mL.

NOTE 2—The water should be pulled into the syringe slowly to avoid extreme turbulence and collection of air bubbles. If large air bubbles are noticed in the syringe, the sample should be rejected and redrawn.

11.5 Invert the syringe and slowly eject any small air bubbles and extra water. Retain precisely 10 mL of water in the syringe.

11.6 Remove the cap from a vial and carefully place the tip of the needle into the bottom of the liquid scintillation solution. Slowly eject the water from the syringe into the vial.

NOTE 3—The water is injected under the liquid scintillation solution to prevent loss of radon from the sample. If the water is forced out of the syringe with much pressure, it will cause turbulence in the solution and could result in loss of radon.

11.7 Carefully withdraw the hypodermic needle from the vial and replace the cap. The cap should be tightly secured to prevent leakage. Shake the vial to mix the contents.

11.8 Repeat the previous steps to obtain two separate aliquots from each sample.

11.9 Load the samples into the liquid-scintillation counter and, after waiting for 3 h, count for 50 minutes.

11.10 After dark-adapting them, count a background sample, consisting of 10 mL of water and 10 mL of scintillation solution, and a standard radium-226 solution sample for 50 min at the beginning of counting and after every ten drinking water samples.

12. Calculation

12.1 Calculate the becquerels per litre of radon in the sample by using the following equation:

$$A = \frac{(C_S - C_B)(1000 \text{ mL})}{(CF)(D)(10 \text{ mL})(1 \text{ L})}$$

where:

A = becquerels of radon per litre of sample,

C_S = sample counts per second (cps),

C_B = background cps,

CF = conversion factor calculated as, (cps measured for calibration standard in 10.7) / (dps (disintegrations per second) of radium-226 contained in 10-mL aliquot of 10.2).

$$D = \text{decay correction } D = \exp\left(-\frac{0.693(T)}{t_{1/2}}\right),$$

T = time in days from collection time to midpoint of counting time, and

$t_{1/2}$ = radiological half-life of radon, 3.82 days.

13. Precision and Bias ⁷

13.1 The collaborative test conducted on this test method included 15 laboratories each with one operator. Three activity

⁵ EPA 520/5-83-027 Methods and Results of EPA's Study of Radon in Drinking Water. Published December 1983. For availability, contact the Superintendent of Documents, U.S. Government Printing Office, North Capital and "H" Sts., NW, Washington, DC 20401.

⁶ EPA 600/2-87/082 Two Test Procedures for Radon in Drinking Water. Published March 1989. For availability, contact the Superintendent of Documents, U.S. Government Printing Office, North Capital and "H" Sts., NW, Washington, DC 20401.

⁷ Supporting data on the precision and bias of this test method have been filed at ASTM Headquarters Request RR: D19-1142.

levels between 60 Bq/L and 2454 Bq/L were tested with three replicates per level. The determination of the precision and bias statements were made in accordance with Practice D 2777.

13.2 These collaborative test data were obtained using reagent grade water. For other matrices, these data may not apply.

13.3 The overall and single operator precision have been found to vary with level in a manner according to Table 1.

13.4 The bias of this test method, based upon the collaborative test data, was found to vary with level according to Table 2.

14. Quality Control

14.1 Whenever possible, the project leader, as part of the external quality control program, should submit quality control samples to the analyst along with routine samples in such a way that the analyst does not know which of the samples are the quality control samples. These quality control samples, which usually include duplicate and blank samples, should test sample collection and preparation, as well as sample analysis whenever this is possible. In addition, analysts are expected to run internal quality control samples that will indicate to them whether the analytical procedures are in control. Both the external and internal quality control samples should be prepared in such a way as to duplicate the chemical matrix of the routine samples insofar as this is practical. The quality control samples that are used routinely consist of five basic types: blank samples, replicate samples, reference materials, control samples, and “spiked” samples.

15. Total Propagated Uncertainty

15.1 The total propagated uncertainty associated with the

TABLE 1 Radon Precision Data

Bq/L	s(o)	s(t)
60	3	5
604	20	61
2454	67	288

TABLE 2 Radon Bias Data

Amount Added Bq/L	Amount found Bq/L	% Bias
60	58	-2.6
604	576	-4.7
2454	2308	-6.0

radon activity concentration can be estimated as follows:

$$\sigma_A = \frac{\left[\frac{C_s}{t} + \frac{C_B}{t} + (C_s - C_B)^2 \left[\left(\frac{\sigma_{CF}}{CF} \right)^2 + \left(\frac{\sigma_{mL}}{10 \text{ mL}} \right)^2 + \left(\frac{\sigma_D}{D} \right)^2 \right] \right]^{1/2} (1000 \text{ mL})}{(CF)(d)(10 \text{ mL})(1 \text{ L})} \quad (1)$$

where:

- σ_A = total propagated uncertainty associated with the radon activity concentration (Bq/L),
- σ_{CF} = uncertainty associated with the conversion factor CF ,
- σ_{mL} = uncertainty of the volume of the 10-mL sample analyzed,
- σ_D = uncertainty associated with the decay correction D , and
- t = counting time of the sample and background (s).

15.2 The *a priori* minimum detectable radon activity concentration can be estimated by the following equation:

$$MDC = \frac{\frac{2.71}{t} + 4.65 \sqrt{\frac{C_B}{t}}}{(CF)(D)(0.01 \text{ L})} \quad (2)$$

where:

- MDC = minimum detectable radon activity concentration (Bq/L).

16. Keywords

16.1 radon; radon-222; Rn-222; radium; radium-226; Ra-226; water-drinking

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