AARST

MW-RN 201x

Proposed American National Standard

Protocols for the Collection, Transfer and Measurement of Radon in Water

AARST CONSORTIUM ON NATIONAL RADON STANDARDS

Public Review: MW-RN *04-2020*

Protocol for the Collection, Transfer and Measurement of Radon in Water

COMMENT DEADLINE: June 1st, 2020

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Submittals *(MS Word preferred) may be attached by email to StandardsAssist@gmail.com or submitted in paper form by fax to (913) 780-2090*

1) Do not submit marked-up or highlighted copies of the entire document.

2) If a new provision is proposed, text of the proposed provision must be submitted in writing. If modification of a provision is proposed, the proposed text must be submitted utilizing the strikeout/underline format.

3) For substantiating statements: Be brief. Provide abstract of lengthy substantiation. (If appropriate, full text may be enclosed for project committee reference.)

REQUESTED FORMAT

Title of Public Review Draft: **MW-RN Proposed Standard 04-2020**

• **Name:** Affiliation:

• **Clause or Subclause**:

• **Comment/Recommendation**:

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• [___] Check here if your comment is supportive in nature and does not require substantive changes in the current proposal in order to resolve your comment.

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Contact information:
AARST Consortium on National Radon Standards.
Email: standards@aarst.org
Efax: 913-780-2090
Website: www.radonstandards.us
527 N Justice Street, Hendersonville, NC 28739

Rev. 05-01-2019

Introduction and Scope Summary

This standard of practice contains procedures, minimum requirements and guidance for measuring radon in water that enters a building through groundwater supplies for determining if mitigation is necessary to protect current and future occupants of family dwellings and commercial buildings.

The protocols contained in this standard specify minimum requirements and procedures for the collection and transport of water samples, as well as protocols for the quantitative transfer of the sample to a measurement device to determine radon concentrations in water.

This standard includes the U.S. EPA accepted analytical methodologies, liquid scintillation and alpha-scintillation cells, along with essential information on use of electret ion chambers and acknowledgement of continuous radon monitors.

A structure for defining a national reference for calibration and quality control, in lieu of a federally reference, is provided, as well as recommended action levels and acknowledgement of current state-recommended action levels.

Health Advisory

Radon is the leading cause of lung cancer among nonsmokers and the second leading cause of lung cancer in the general population.[1] Elevated concentrations of radon in water can increase radon concentrations in indoor air. Radon in U.S. homes causes approximately 21,000 lung cancer deaths each year.[2] Be it at home, work or school, an individual's exposure to radon gas combines over time to increase the risk of preventable lung cancer.

In 1999, with publication of BEIR VI[2], the National Academy of Science confirmed that any exposure to radiation, including any concentration of radon, carries risk. In 2009, the World Health Organization's WHO Handbook on Indoor Radon confirmed the association between indoor radon exposure and lung cancer, even at the relatively low radon concentrations found in residential buildings.[1]

Designation of this standard: MW-RN

As used for catalogue identification, "MW-RN" stands for "Measurement of Water for Radon."

Normative References

ANSI/AARST MS-QA, Standard for Radon Measurement Systems Quality Assurance

The Consensus Process and Continuous Maintenance of Standards

The consensus process developed for the AARST Consortium on National Radon Standards and as accredited to meet essential requirements for American National Standards by the American National Standards Institute (ANSI) has been applied throughout the process of approving this document.

This standard is under continuous maintenance by the AARST Consortium on National Radon Standards for which the Executive Stakeholder Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the standard. Updated addenda and change request forms and instructions may be obtained in electronic form from at www.radonstandards.us.

[1] World Health Organization, "WHO Handbook on Indoor Radon: A Public Health Perspective" 2009

[2] National Academy of Sciences, "Biological Effects of Ionizing Radiation" (BEIR VI Report) 1999

AARST Consortium on National Radon Standards
Email: standards@aarst.org Fax: 913-780-2090Website: www.RadonStandards.us
527 N Justice Street, Hendersonville, NC 28739

Notice of right to appeal: (See Bylaws for the AARST Consortium on National Radon Standards available at www.RadonStandards.us .) Section 2.1 of Operating Procedures for Appeals (Appendix B) states, "Persons or representatives who have materially affected interests and who have been or will be adversely affected by any substantive or procedural action or inaction by AARST Consortium on National Radon Standards committee(s), committee participant(s), or AARST have the right to appeal; (3.1) Appeals shall first be directed to the committee responsible for the action or inaction."

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MW-RN
Protocol for the Collection, Transfer and Measurement of Radon in Water

SECTION 1.0 PURPOSE AND SCOPE

1.1 This standard of practice contains minimum requirements and guidance for measuring radon in water that enters a building through groundwater supplies for determining if mitigation is necessary to protect current and future occupants of family dwellings and commercial buildings.

This standard includes procedures for the collection and transport of water samples, as well as protocols for the quantitative transfer of the sample to a measurement device to determine radon concentrations in water. This standard includes the U.S. EPA-accepted analytical methodologies, liquid scintillation and alpha-scintillation cells, along with essential information on use of electret ion chambers and acknowledgement of continuous radon monitors.

A structure for defining a national reference for calibration and quality control, in lieu of a federally reference, is provided, as well as recommended action levels and acknowledgement of current state-recommended action levels.

1.2 Limitations

1.2.1 This document is not intended to address all detailed technical aspects of measurement technology or quality assurance.

1.2.2 Analytical methods that may be in current use shall successfully complete intercomparison or proficiency tests prior to routine use and reporting of results.

1.2.3 While this consensus document provides current best practices, individual States may require alternate sample collection, transport, preparation, and/or analysis procedures. Adherence to this standard does not guarantee or supersede compliance with regulations of any federal, state or local agency with jurisdiction where testing is performed.

1.2.4 Application of the procedures to matrices other than drinking water may produce adverse results.

1.3 Significance of use

This document is intended to aid water-supply owners/managers, residents and staff, professionals, state radiation control programs or anyone involved in the measurement of radon in water supplies to assess the need for mitigation and to provide radon risk information for the benefit of occupants.

This standard addresses the needs of citizens, radon service providers, property owners, residence/facility managers, consultants, manufacturers and regulators concerned with proper radon measurements in groundwater supplies.

1.4 Applicability

1.4.1 The terms “Note–” and “Informative Advisory” indicate provisions considered helpful or good practice, but which do not contain a mandatory requirement.

1.4.2 These standards of practice can be adopted as requirements for contractual relationships or adopted as recommendations or requirements of an authority or jurisdiction such as for private proficiency programs, a state radon program or other governmental body.

SECTION 2.0 DEFINITIONS

Accuracy: Closeness of agreement between an observed value and an accepted reference value.

Alpha Scintillation Cell: Also known as a Lucas cell, a type of gas chamber that is coated with silver-activated zinc sulfide that scintillates when struck by alpha particles emitted during radon decay. A photomultiplier measures the light pulses that are proportional to the radon content.

Blanks: A type of QC check that quantifies detector response due to factors other than the measurement itself. Blanks are devices deployed to measure effects on the measurement result from anything other than the environment tested (e.g., during storage, handling and transport).

Calibration: To adjust or determine or both the response or reading of an instrument or device relative to a series of conventionally true values.

Calibration Factor: That factor or function that represents the relationship between the method's response and the concentration to which it is responding. The calibration factor is based on measurement system response divided by the concentration to which it is responding.

Continuous Radon Monitor (CRM): An electronic device with adaptations that can provide numeric measurements of radon concentration in a water sample.

Cocktail: A vial containing both a water sample and liquid scintillation fluid for the measurement of dissolved radon.

Dark adapt: Placement of a liquid scintillation cocktail, prior to measurement, in a holding area with no light for a period (generally 1 to 3 hr) in order to control chemiluminescence and false counts.

Duplicates: Two identical samples collected at the same time, using the same procedures and tested separately. Duplicate samples are used to evaluate collection and measurement precision.

Electret Ion Chamber (EIC): An ion chamber with a charged electret that discharges due to the decay of radon and its short-lived progeny proportionally to the radon level inside the chamber.

Intercomparison: A mutual comparison of measurement results that may be used to develop a consensus value.

Laboratory: Any person(s) or entity that measures and reports radon levels.

Maximum Contaminant Level (MCL): The highest level of a contaminant that is allowed in drinking water. MCLs take the best available treatment technology and cost into consideration.

Method Detection Limit (MDL): The minimum concentration of a substance that can be measured and reported with an established confidence (95% at minimum) that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix containing the analyte.

Ostwald Solubility Coefficient: A measure of the solubility of radon in water, defined as the ratio of radon concentration in water to radon concentration in air, measured as 0.51 and 0.25 for water temperature of 0°C and 20°C, respectively.

PTFE: Polytetrafluoroethylene, with the known brand name Teflon, is chemically inert and impervious to radon diffusion. It is used as an alternative to aluminum foil in bottle caps to retard the loss of radon.

Qualified Measurement Laboratory: A measurement service that has demonstrated a minimum degree of quality for analysis of measurement samples as demonstrated by:

a) successful intercomparisons with other qualified laboratories to indicate a minimum degree of quality for analysis of measured samples. The results of intercomparisons shall be recorded in quality assurance records and made available to the public upon request;

b) certification by a private certification program where available that evaluates laboratories conducting analytical services for measurements of in water in areas of the country no state licensure or lab certification program exists; and

c) state licensure or certification program, where applicable, for licensure or certification programs that evaluate laboratories conducting analytical services for measurements of in water.

Qualified Sample Collector: An individual who has obtained a minimum degree of appropriate technical knowledge and skills specific to properly collect a water sample as demonstrated by:

a) completion of educational courses and ongoing continued education (CE) associated with radon in water that is documented in quality assurance plans and available to consumers of services;

b) certification by a private certification program where available that evaluates individuals for specific technical knowledge and skills related to radon in water in areas of the country no state licensure or certification program exists; and

c) state licensure or certification program, where applicable, for licensure or certification programs that evaluate individuals for specific technical knowledge and skills related to radon in water.

Quality Assurance Plan (QAP): A formal document describing in comprehensive detail the quality system, including responsibility for data validity, quality assurance policies, quality control procedures, and other technical activities that need to be implemented to ensure that the results of the work performed will satisfy the stated performance criteria.

Quality Control: The technical activities that measure the attributes and performance of a process, item, or service against defined standards to verify that they meet established specifications.

Relative Percent Difference (RPD): A statistic used to evaluate the difference between two measurements when there is no evidence to support one being more accurate than the other.

RPD = [(A – B) / mean] * 100, where A is the larger result, B is the smaller result, and mean is the average of the two results.

Spike: Spikes assess sources of error in the measurement system. A measurement system includes losses during sample transfer and preparation, as well as errors due to devices used to measure the known radon concentration. Spike results may be used to track calibration factor stability and in-control operation of the measurement system. Results of spikes are assessed using the statistic of Relative Percent Error.

Traceability: Property of the result of a measurement whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties.

Warning and Control Limits: Warning Limits are set at a deviation from stable, in-control performance that would be expected to occur by chance only 5% of the time (95% confidence level; CL), and Control Limits are set at that deviation from stable, in-control performance that would be expected to occur by chance only 1% of the time (99% CL). This standard provides default warning limits based on industry practice.

SECTION 3.0 FIELD OPERATIONS - PREPARE FOR COLLECTING WATER SAMPLES

3.1 Prepare To Document Testing

Informative Advisory—Proper documentation is critical and is part of any defensible Quality Assurance Plan (see AARST MS-QA *Standard for Radon Measurement Systems Quality Assurance)*.

3.2 Required Documentation When Collecting Samples

Information to be recorded for the testing of radon in water shall include all of the following:

3.2.1 *Test purpose*

The reason or purpose for the sample collection and measurement shall be documented, with the intent to identify the purpose as initial, confirmatory, seasonal, or post-mitigation.

3.2.2 *Collector and sampling method*

The name of the sample collector, the supplier of the collection device, and the method of collection shall be documented when a professional service is used.

3.2.3 *Location and sampling information*

For every sample, an address and a description of exact location of the spigot used for sample collection, and the volume of water expelled prior to collection, shall be recorded. A description of water treatment and/or storage tanks prior to the sampling spigot shall be documented.

3.2.4 *Collection date and times*

Due to the short half life of radon, a sample collector shall record the exact water collection date and time for use in calculating the decay factor and radon concentration.

3.2.5 *Water temperature*

- If water temperature is used to indicate a fresh water supply, identification of the device used to determine the temperature and the water temperatures immediately before and after the sample collection shall be recorded.
- If the water temperature is not used to indicate a fresh water supply, the method used (such as measured or calculated volume) to assure fresh water shall be described.
- When flushing holding tanks or water lines to obtain samples because there is no suitable faucet or spigot prior to the holding tank, the volume of water discarded shall be recorded.

3.2.6 *Extenuating factors*

Discrepancies or peculiarities regarding sample collection (such as aerator could not be removed or bubbles formed in the sample vial) shall be recorded.

3.3 Preparation For Sample Collection, Handling and Shipping

Persons collecting water samples are to:

a) prepare to take samples immediately after flushing water lines and holding tanks;
b) prepare to collect two water samples (duplicates) at a spigot in accordance with Section 4;
c) prepared to handle water samples with care for temperatures where stored and transported as described in Sections 6.2 and 6.3; and
d) prepare to forward water samples to the laboratory immediately or within 24 hours as described in Sections 6.1.

3.4 Vacant Building Testing

Sampling protocols for occupied and vacant buildings are to be identical.

Note—Water measurements done at vacant buildings should be remeasured within 30 days of occupancy if the water supply has not supplied by a municipal treatment facility.

SECTION 4.0 FIELD OPERATIONS – LOCATIONS FOR COLLECTING WATER SAMPLES

4.1 Controlled Flow and Controlled Prevention of Aeration Required

Because radon will readily emanate from water that is exposed to air and thereby will diminish the reliability of the result, the location for sampling waterborne radon from water piping shall include:

a) A faucet or spigot that can slow the flow rate until water flows out without turbulence. Water flow when collecting the sample shall be non-turbulent and shall be at a low flow rate; and

b) Removal of all aeration devices at the spigot or faucet from which the water will be obtained.

4.2 Holding Tanks and Prior To Water Treatment Equipment

The sample shall be taken at a collection location that is prior to water treatment equipment. This includes collecting the sample prior to auxiliary water storage units, such as a spigot or faucet located prior to a holding tank, or directly associated with the initial (upstream) pressurized holding tank assuming the tank is flushed in accordance with Section 4.3.

Exception: An indoor faucet is a suitable collection location provided it is after only basic sediment filters (no treatment or holding) and the supply water line is flushed in accordance with Section 4.4. If the sample is collected after any water treatment equipment or water storage unit, a full description of the treatment or holding tank configuration shall be documented.

Note—Often an outside faucet or drainage spigot from the initial pressurized holding tank has no aerator and is untreated. Therefore, these locations may be ideal for collection of the raw water sample. Water collected after any storage unit or treatment device is expected to incur some degree of radon loss from the water and should be avoided.

4.3 Flush Holding Tanks and Water Lines

Prior to sample collection, a complete flushing of water from holding tanks and water piping is required to obtain a water sample that is representative of the water in the ground.

The criteria for determining when a sufficient volume of water has been discarded is based on either:

a) A noticeable decrease in water temperature that generally agrees with estimates of time it would take to discard a sufficient volume of water; or

b) Calculations for the volume of water to be discarded and then measuring the volume of water that has been discarded while flushing.

4.3.1 *Water volume calculations*

When estimating or calculating a sufficient volume of water to be discarded, the process shall include:

a) Twice the volume capacity of the holding tank(s).

b) Piping from the well or other source of water to the holding tank(s); and

c) Water pipes that deliver water to the spigot, faucet or other sample collection location.

Note—For flushing water pipes, Equation 1 can be used to determine the minimum volume of water (V; gallons) that should be flushed (discarded) prior to sample collection.

$$V = 7.5\ \pi\ r^2\ L \qquad (1)$$

where r = the radius of the piping (ft),
L = total length of the piping (ft) from bottom of well to collection point, and 7.5 is the conversion from ft^3 to gallons.

Informative Calculation Results on Flushing Volumes and Duration

Water Lines Flushing Duration

Pipe ID	1/2" pipe	3/4" pipe	1" pipe	1.25" pipe	1.5" pipe
Length	**100 feet**	**100 feet**	**100 feet**	**100 feet**	**100 feet**
Gallons within pipe	2 gallons	3 gallons	4 gallons	5 gallons	6 gallons
Faucet @ 1 gal/min	*2 minutes*	*3 minutes*	*4 minutes*	*5 minutes*	*6 minutes*
Faucet @ 1.5 gal/min	*1.5 minutes*	*2 minutes*	*3 minutes*	*3.5 minutes*	*4 minutes*
Pump @ 4 gal/min		*0.8 minutes*	*1 minute*	*1.3 minutes*	*1.5 minutes*

Holding Tank Flushing Duration

Tank Size	**10 gallons**	**20 gallons**	**40 gallons**	**60 gallons**
Flush twice	20 gallons	40 gallons	80 gallons	120 gallons
Faucet @ 1 gal/min	*20 minutes*	*40 minutes*	*80 minutes*	*120 minutes*
Faucet @ 1.5 gal/min	*14 minutes*	*27 minutes*	*53 minutes*	*80 minutes*
Pump @ 4 gal/min	*5 minutes*	*10 minutes*	*20 minutes*	*30 minutes*

Informative Examples of Flushing Volumes and Duration

Note—1 and 2 are examples where opening two facets will cut the time in half.

Example 1 *(longer pipe runs)*

	Pipe ID	Length	Water Volume	At Faucet	Flush duration
From water source to the home	1 inch	250 feet	10 gallons	1.5 gal/min	6 minutes
Interior distribution pipe(s)	1 inch	50 feet	2 gallons	1.5 gal/min	2 minutes
10 Gallon Holding Tank			20 *flushed twice*	1.5 gal/min	14 minutes
		Total Gallons to Flush	**32**	***Total Flush duration***	**22 minutes**

Example 2 *(shorter pipe but slower flow)*

From water source to the home	1 inch	25 feet	1 gallons	1 gal/min	1 minutes
Interior distribution pipe(s)	1 inch	50 feet	2 gallons	1 gal/min	2 minutes
10 Gallon Holding Tank			20 *flushed twice*	1 gal/min	20 minutes
		Total Gallons	23	***Total Flush duration***	23 minutes

Example 3 *(higher flow rate direct from pump)*

From water source to the home	1 inch	300 feet	12 gallons	4 gal/min	3 minutes
		Total Gallons to Flush	12	***Total Flush duration***	3 minutes

Example 4 *(larger holding tank)*

From water source to the home	1 inch	300 feet	12 gallons	4 gal/min	3 minutes
40 Gallon Holding Tank			80 *flushed twice*	4 gal/min	20 minutes
		Total Gallons to Flush	12	***Total Flush duration***	23 minutes

4.3.2 ***Water temperature method***

All of following steps are required when using water temperature to determine if a sufficient amount of water has been discarded:

(1) Prior to flushing, evaluate the water system to estimate the volume of water and time it will take to flush holding tanks and water lines;

(2) Prior to flushing, measure and record the water temperature;

(3) Proceed with flushing by discarding water until a noticeable decrease in water temperature remains consistent;

(4) Measure and record the resulting water temperature.

(5) Collect the water samples when the decrease in water temperature nominally agrees with expectations of the water volume that needed to be discarded.

4.3.3 ***Water volume method***

All of following steps are required when calculating and measuring the water volume discarded:

(1) Prior to flushing, calculate and record the volume of water in holding tanks and water lines to be discarded;

(2) Proceed with flushing while measuring the water discarded;

(3) Once exceeding the calculated volume of water, record the volume of water discarded and collect the water samples.

SECTION 5.0 FIELD OPERATIONS - SAMPLE COLLECTION

Informative advisory—It is critical to avoid any water that is collected in the sample container from coming in contact with air. As the solubility of radon is greater in air, exposure of the water sample to air can result in a loss of radon and a falsely low result. There are two EPA-recommended methods[4] for collection of a representative water sample that involve no contact of the water with air and likely provide a more accurate result, as opposed to collection methods that allow a slight contact of the water sample with air. While gloves are not required for collecting water samples to measure radon, clean hands are recommended.

5.1 Collection Methods

5.1.1 All water samples shall be collected using only the methods described herein, or as approved by a state or nationally-recognized certification program.

5.1.2 Use of a hose of a size greater than ½" (1.25 cm) max. diameter, and no longer than 24" (60 cm) shall not be used.

5.1.3 Sample bottles shall not be filled directly from or in contact with the faucet spigot.

5.2 Take the Sample(s) Immediately After Flushing Water Lines or Holding Tanks

The sample(s) shall be collected immediately following the purging of water from piping and tanks in accordance with Section 4.

5.3 Duplicate Samples Required

All water samples for radon determination shall be collected in duplicate.

Note—Collection (and analysis) of duplicate samples serves to 1) confirm results for decisions regarding mitigation, and 2) allows a check of the reproducibility of the collection, transfer, and analysis methods.

5.3.1 *If a single sample was collected*

In the event only a single sample was collected or for unforeseen circumstances one is found suitable for analysis and the concentration is below 20,000 pCi/L (740 Bq/L), a sequential sample shall be collected within 2 weeks of the initial sampling. Flushing of the water line shall be identical each time. Sequential sampling shall be documented with the date and time of collection for both water samples. Both individual results and an average shall be reported unless State guidance differs.

Note—While decisions to mitigate are not prohibited at any time, comprehensive testing provides confidence that decisions are not being made based on inconclusive or inconsistent collections or measurements.

5.4 Visible Bubbles In the Sample

After closing sample collection bottles, the bottle shall be inspected to ensure there are no bubbles larger than 1-mm (1/16") diameter. If a bubble larger than 1-mm (1/16") diameter exists in the bottle, the water from the sample bottle shall be discarded and the collection procedure repeated.

[4] Whittaker, E.L., Akridge, J.D., Giovano, J. (1989) Two Test Procedures for Radon in Drinking Water: Interlaboratory Collaborative Study. U.S. EPA Environmental Monitoring Systems Laboratory, Las Vegas, NV. EPA 600/2-87/082.

5.5 Collection Method 1 – Bottle

Use of appropriate supplies is required to collect and retain a representative sample. Water samples shall be collected in glass bottles. Teflon™ (PTFE) or aluminum-lined septum shall be required for the caps to eliminate loss of radon from the sample.

An inverted septum will allow radon to emanate from the water sample and result in a low concentration of radon. The collector shall document the orientation of the lined septum on the bottle. Observance of an improper septum shall be recorded and the sample voided.

Note 1—Ring caps for the bottle with Teflon lined septa are recommended. When the bottle is completely filled, the septum will create a bulge in the cap interior.

Note 2—Bottles made with low potassium glass will often produce a lower sample background.

5.5.1 *Bottle method—Filled bowl or small bucket*

For this method, the container is to be placed directly under the spigot (without aerator) and filled. Alternatively, the tubing and faucet adapter described in Section 5.6.2 is permitted to be used to fill a container (large bowl or small bucket) on condition that the tubing outlet is submerged under the water as soon as possible to minimize radon emanation from the water.

The required collection procedures include discarding a sufficient volume of water to ensure that a representative sample is collected, and Steps 1-9:

(1) Slow the water flow to be non-turbulent and **place the spigot (or tubing) under the surface of the water in the container** as soon as possible to minimize radon emanation from the water (Fig. 5.5.1-a).

Figure 5.5.1-a Filling the bowl or small bucket

Submerged Spigot/Faucet

(2) Allow the water to flow at a slow, non-turbulent rate from the spigot (or tubing) into the container, eventually overflowing the edge of the container (Fig. 5.5.1-b).

Figure 5.5.1-b Overflow the bowl or small bucket

Overflowing the container edge

(3) Allow the water to gently overflow the container for 2 minutes or more prior to sample collection while the spigot (or tubing) continues to be submerged near the bottom of the container.

(4) The sample can be collected from the filled container while the water is still flowing (and spigot or tubing is submerged) or the water can be stopped, and the container moved to a solid surface. If the latter, work quickly and with little agitation of the water.

(5) Insert both hands, with one containing a capped, empty glass bottle, gently below the surface of the water in the container (Fig. Fig. 5.5.1-c).

Figure 5.5.1-c Filled Bowl or Small Bucket

Filling bottle from a container filled with water

(6) Near the bottom of the container, open the bottle and allow it to fill with water. Close the bottle underwater, using a PTFE-septum or foil-lined cap, and remove the bottle.

(7) Inspect the bottle; it shall be filled and contain no bubble larger than 1-mm (< 1/16") diameter. If a bubble larger than 1-mm exists in the bottle, discard the water from the sample bottle, and repeat the procedure beginning with the overflowing of the container with fresh water for 2 minutes.

(8) After collecting the first sample, collect a second (duplicate) sample in the same fashion and record pertinent sampling information in accordance with Section 3.2.

(9) If possible, keep the filled bottles cool to minimize the formation of bubbles from dissolved gasses. Send the filled bottles to the laboratory for analysis.

5.5.2 ***Upright funnel—Bottle method***

A short length of clear tubing (2-3 inches) is attached to the stem of a funnel. The tubing shall be of sufficient internal diameter so as not to constrict the water flow.

The required collection procedure includes Steps **1-9**:

(1) Allow water to flow at a slow, non-turbulent rate from the spigot (without aerator) into the top opening of the funnel.

(2) **Submerge the spigot below the water level in the funnel as soon as possible**; the water will exit the stem of the funnel.

(3) Allow the water to also gently overflow the brim of the funnel (Fig. 5.5.2).

Figure 5.5.2 Upright funnel

Filling bottle using submerged upright funnel

(4) Allow the water to gently overflow the funnel for more than one minute prior to sample collection. With the water overflowing the funnel, place the stem of the funnel into the bottom of the glass bottle. Water overflowing the edge of the funnel shall not enter the bottle.

Informative note—Use of clear tubing is recommended so the collector can visually observe that there are no air pockets or bubbles in the tube (if air is observed, pinch the tubing near the air pocket to release the trapped air).

(5) Fill the bottle only with water coming out of the funnel stem (Fig. 5.5.2).

(6) Overflow the bottle for approximately one minute.

(7) Slowly remove the bottle, and cap immediately using a PTFE-septum or foil-lined cap.

(8) Inspect the bottle; it shall be filled and contain no bubble larger than 1-mm (< 1/16") diameter. If a bubble exists, discard the water from the bottle and repeat the procedure.

(9) After collecting the first sample, collect a second (duplicate) sample in the same fashion and record pertinent information about the samples in accordance with Section 3.2. If possible, keep the filled bottles cool to minimize the formation of bubbles from dissolved gasses. Send the filled bottles to the laboratory for analysis.

5.5.3 ***Upright funnel—Immersed Bottle Method***

A short length of clear tubing (4-6 inches) is attached to the stem of a funnel. The tubing shall be of sufficient internal diameter so as not to constrict the water flow. The required collection procedure includes Steps 1-9:

(1) **Allow water to flow at a slow, non-turbulent rate from the submerged spigot** (without aerator) into the top opening of the funnel. Water flows out the tubing placed into the bottom of the container (large bowl or small bucket) and slowly fills the container.

(2) The tubing remains submerged as water fills the container and overflows for several minutes.

(3) The glass sampling bottle is opened and immersed into the container in an upright position.

(4) The filled bottle is placed on the bottom of the container and the tubing end (with water still coming out) is placed into the bottle to flush the bottle with fresh water.

Figure 5.5.3

Filling an underwater sample bottle in a container using a funnel

Note –Alternative to steps 1-4, the bottle is placed on the container bottom and the tubing placed directly into bottle. Water fills the bottle, overflows, and fills the container.

(5) After the bottle has been flushed, the tubing is removed while the bottle is resting on the bottom of the container.

(6) The PTFE-septum or foil-lined cap is placed back on the bottle while the bottle is submerged, and the bottle is tightly sealed.

(7) Once the sealed sample bottle is removed from the bucket, it is inverted and checked for bubbles.

(8) If a bubble exists, discard the water from the sample bottle and repeat the procedure.

(9) After collecting the first sample, collect a second (duplicate) sample in the same fashion and record pertinent information about the samples in accordance with Section 3.2. If possible, keep the filled bottles cool to minimize the formation of bubbles from dissolved gasses.

5.6 Collection Method 2 – Syringe Method

This collection method applies for laboratory methods that require creating what is known as a "cocktail" by mixing a specific volume of sampled water with a scintillation fluid. The following procedure pertains to extracting 10 mL of water. If a laboratory uses a different volume, the procedure shall be adjusted accordingly. Clear tubing shall be used so the collector can visually confirm that there are no air pockets or bubbles in the tubing.

Informative advisory—When air is observed in the tubing, one can typically pinch the tubing near the air pocket to release the trapped air prior to sample collection.

Note—Proper methods to collect water for a radon measurement have been published. A procedure for sampling potable water from a faucet[5] is frequently used to produce liquid scintillation cocktails, and not for filling of bottles for a laboratory.

5.6.1 *Spigot or faucet—Syringe method*

Immediately after a thorough flushing of the water system in accordance with Section 4, the following Steps 1-10 are required:

(1) Remove all aeration and filter devices from the faucet where the sample will be taken.

(2) Attach a sampling funnel (9" or 23 cm max. diam.) and clear tubing (½" or 1.25 cm max. diam. and 24" or 60 cm max. length) to the faucet.

(3) Turn on the water and allow a steady flow for several minutes. Remove all bubbles in the tubing.

Figure 5.6.1 Spigot or Faucet

U.S. EPA recommended collection method that utilizes an inverted funnel and a syringe to extract the sample for injection into a liquid scintillation cocktail.

(4) Slow the water flow and hold the funnel open end up. Adjust the flow such that the water entering the bottom of the funnel is not turbulent but overflows the funnel.

[5] U.S. Environmental Protection Agency (1978). Radon in Water Sampling Program, Eastern Environmental Radiation Facility, EPA/EERF-Manual-78-1.

(5) Insert the tip of a 15-20 mL syringe well below the water surface and withdraw ~5 mL of water slowly to minimize air bubbles. Invert syringe (tip up) and slowly withdraw plunger only until water in the syringe tubing (or needle) is emptied into the syringe.

Informative advisory—At this point all bubbles in the syringe should have risen to the surface. Gently tap the syringe to release large bubbles from side walls of syringe.

(6) Keeping the syringe upright, push the plunger to eject all water except that in the tubing (or needle). If necessary, repeat steps 5 and 6 to remove visible air bubbles.

(7) With water still flowing slowly, re-insert syringe tubing (or needle) far below the water surface and withdraw water into the syringe, past the 10-mL graduation (Fig. 5.5.2), remove tubing (or needle) from the water, and discard excess water to the 10-mL mark of the calibrated syringe.

(8) Place the syringe tubing (or needle) well below the surface of an appropriate volume of liquid scintillation fluid in a scintillation vial and slowly eject the water from the syringe below the scintillation fluid in the vial.

(9) Slowly withdraw the syringe and tightly cap the vial. Shake vial for 30 seconds.

(10) After collecting the first sample, collect a second (duplicate) sample in the same fashion and record pertinent information about samples in accordance with Section 3.2.

Note—A calibrated glass pipet may be used to extract the water sample. See Section 12.2.

5.6.2 ***Filled bowl or small bucket—Syringe method***

Informative note—The tubing and faucet adapter, described in Section 5.6.1, may be used to fill a container (large bowl or small bucket) on condition that the tubing outlet is submerged under the water as soon as possible to minimize radon emanation from the water. Alternatively, the container can be filled directly from a submerged faucet using the instruction below.

For this method, the container is placed directly under the spigot (with aerator removed) and filled. The required procedure follows:

(1) Slow the water flow to be non-turbulent and place the spigot (or tubing) outlet under the surface of the water in the container as soon as possible to minimize radon emanation from the water.

(2) Allow the water to flow at a non-turbulent rate from the spigot (or tubing) into the container, eventually overflowing the edge of the container.

(3) Allow the water to gently overflow the container for 2 minutes or more prior to sample collection, while the spigot (or tubing) continues to be submerged near the bottom of the container.

(4) The sample can be extracted from the water while the water is still flowing (and spigot or tubing is submerged), or the water can be stopped, and the container moved to a solid surface. If the latter, work quickly and with little agitation of the water (Fig. 5.6.2).

(5) Follow steps 5 through 10 above in Section 5.6.1 using the appropriate volume of water and scintillation fluid.

Figure 5.6.2 Filled Bowl or Small Bucket

Filling syringe from container of water, for injection under liquid scintillation fluid

SECTION 6.0 FIELD OPERATIONS - HANDLING WATER SAMPLES

6.1 Forward Samples Immediately to the Laboratory

Informative advisory—Collectors should coordinate collection, transport, and measurement of the sample with the laboratory. When samples are shipped to a laboratory to be analyzed, the sample should be packaged and shipped within 24 hours of collection or at the first available opportunity.

Note—Due to the relatively short half-life of radon, analytical measurement of a water sample commonly commences within 4 days (96 hr) from the time of collection in order to be considered a valid test result.

6.2 Sample Transport

Informative advisory—For both local handling and shipping, be aware that:

a) Breakage of glass sample containers may occur (due to freezing) during winter months.

b) Bubbles can form in the sample-collection bottles when exposed to heat during summer months. These bubbles can impact test reliability. See Section 5.3.

c) Packaging of water samples for mailing should include containment (e.g., sealable bag) and sufficient absorbent to prevent wetting of adjacent mail in case of breakage.

d) Mailing of cocktails containing liquid scintillation fluid should be avoided.

6.3 Temperature During Sample Storage and Transport

Informative advisory—The person responsible for handling the samples in the field (and in the laboratory) should take measures to avoid compromising the integrity of the sample that can result due to the temperature in the environment where the sample is stored or transported. The solubility of dissolved gases in the water is directly related to its temperature. Groundwater taken directly from a well will be below 60˚ F (15˚ C). While the water sample does not need to be kept cooler than the initial (extracted) temperature, whenever possible the sample should be stored, transported, and shipped in a cool environment to minimize the formation of bubbles, since dissolved gases may come out of solution if the sample is warmed. Some U.S. states may require the use of coolers. Alternatively, when water samples are susceptible to freezing, expeditious handling and transference to the laboratory is advised.

6.4 Bubbles following Collection or Storage

Occurrence of bubbles in the water collection bottle shall be documented.

Informative advisory—If properly collected with no visible air bubbles in the collection bottle, water can often be stored at room temperature for several hours without adverse effects. If the sample warms such that bubbles form in the collection bottle, cooling of the sample will not "redissolve" the gas back into solution.

6.5 Onsite cocktails

Note—Cocktails for liquid scintillation measurement may be prepared onsite by transporting scintillation vials containing pre-measured fluid. Preparation onsite eliminates the need for a sample transfer in the laboratory. This method is primarily used for research or laboratory purposes.

SECTION 7.0 ACTIONS BASED ON TEST RESULTS

7.1 Action Level Guidance

While there is currently no federally mandated or published action level for radon in water, several states have current or proposed maximum concentration limits for radon in potable water. It is advised to check with the state and local health departments on additional guidance for maximum concentration limits for radon in potable water.

Recommended Action Level

- **4,000 pCi/L or greater** (≥ 150 Bq/L) or per local health department requirements
  - Take remedial action to reduce radon concentrations in the water supply for potable water to below the action level.
- **Below 4,000 pCi/L** (< 150 Bq/L) or per local health department requirements
  - *If greater than half the action level:* As with radon contained in soil gas, there is no absolutely safe level for radon in a building's water supply. Consider remedial action to reduce radon in the water supply for potable water if test results indicate radon concentrations greater than half the action level.
  - *Seasonal verification:* Because radon concentrations in groundwater vary by season, it is recommended that the water supply for potable water be measured at multiple times (seasons) during the year to determine the range of seasonal variability in radon concentrations. If seasonal variability is known to be acceptable, as a result of seasonal or semi-annual testing, water retesting should be repeated every 5 years to ensure against unexpected changes to radon concentrations in the water supply.

7.2 Consideration for Retesting When Two Test Results Disagree

7.2.1 *Acceptable*

When two water samples were collected the same time and location, the average of the two test results is to be used for determining needs for mitigation if:

a) both test results are above the action level, or

b) both test results are below the action level.

Note—Some variation between duplicate sample results is typical. However, if the variation between duplicate results is unusually large, it might indicate problems in the collection process.

7.2.2 *Where test results disagree on exceeding the action level*

When one test result is above the action level and the other test result is below the action level:

a) *Acceptable*—If the higher result is less than twice the lower result, the average of the test results is to be used to determine if this location needs mitigation.

b) *Not acceptable*—If the higher result is twice or more than the lower result:

1. For two co-sampled (duplicate) tests conducted at the same time, a repeated collocated sample collection for this location is required to obtain a valid measurement.
2. For two tests conducted in the same location but at different times, obtaining confirmation on whether mitigation is warranted requires additional testing.

Note—While decisions to mitigate at any time are not prohibited, comprehensive testing provides confidence that decisions are not being made based on inconclusive or inconsistent collections or measurements.

7.3 Mitigation Methods

Best available technologies shall be used for mitigation of radon in water. A radon mitigation system shall be properly labeled and dated.

Informative Advisory—The best currently available technologies for mitigation of radon in water are:

- **Aeration**
  Note—Aeration systems are often considered the best method for removing radon from water. An aeration system commonly consists of a reservoir of water that has air injected into it. Radon will readily come out of the aerated water and the air is exhausted from the tank through piping routed outside above the roof line. Radon removal rates near 99% are achievable.

- **Filtration with Granular Activated Charcoal (GAC)**
  Note—A mitigation system containing GAC for filtering radon from water should only be utilized when the radon level in the water is below 4,000 pCi/L (150 Bq/L). A single charcoal system can remove about 75% of the radon in water while a double charcoal system can remove about 90%.

Note—New evolving technologies that are performance based and demonstrated as an acceptable mitigation method may be developed over time. Home water softeners and other water treatments are not radon mitigation systems and may become an additional source of radon. A water softener should not be backwashed into a septic tank without consent from state or local officials.

7.4 Post-Mitigation Testing

7.4.1 *Initial testing to confirm effectiveness of mitigation efforts*

Evaluation for the effectiveness of applied remediation of radon in a water supply is best achieved through measurement of both untreated and treated samples. When a water supply is to be mitigated to reduce the radon level:

a) duplicate untreated samples shall be collected in conjunction with, or within 96 hours prior to, installation of any mitigation procedure where initial testing indicated less than 40,000 pCi/L (1500 Bq/L) of radon in a water test that was conducted within the previous year; and

b) duplicate post-mitigated water samples shall be collected no earlier than having flushed holding tanks and water lines in accordance with Section 4 and no later than 30 days after the full operation of the system commences.

7.4.2 *Post-mitigation test locations*

The post-mitigation test locations and procedures shall meet all the requirements of Sections 4 with the post-mitigated water samples collected at a location that is prior to other water treatment equipment. The exact location of the spigot(s), date and time, collection method, and other pertinent information shall be recorded.

7.5 Mitigation Maintenance and Monitoring

7.5.1 *Maintenance*

Informative Advisory—It is critical that mitigation systems be properly maintained to protect occupants from hazards that can include radon, biological contaminants and other radiological concerns. Contaminants, such as bacterial contaminants, can also adversely influence effectiveness and life expectancy of the mitigation system.

7.5.2 *Ongoing water testing to verify continued effectiveness*

Informative Advisory—The radon-in-water concentration should be tested no less than yearly and periodic testing twice a year is recommended.

7.5.3 *Aeration technologies*

Informative Advisory—It is recommended that aeration systems be serviced no less than annually or as recommended by the manufacturer to maintain efficiency and to remove contaminants.

7.5.4 *Filtration technologies (GAC)*

Informative Advisory—All parts of a charcoal system require maintenance, including replacement of the charcoal, depending on the quality of the water and the quantity used. When a GAC system is used to treat water, the GAC will collect the radioactivity and emanate a significant (and possibly harmful) amount of gamma-ray activity. Failure to maintain a GAC system will diminish its efficiency to reduce radon and other contaminants in the drinking water.

7.5.4.1 Occupant and Worker Safety Requirements— Filtration Technologies (GAC)

A barrier and notification, such as florescent tape and sign, shall be posted on the perimeter of the GAC system to warn occupants to potential gamma radiation emitted from radionuclides collected on the GAC.

Informative Advisory—To minimize exposure, building occupants and water treatment personnel should limit the length of time in close proximity (within 4 feet) to the GAC system. Changing of GAC tanks should be done by professionals trained to safely handle the emanation of radon and the gamma radiation from radon decay products trapped by the system.

SECTION 8.0 REPORTING RESULTS – ALL PROFESSIONAL SERVICES

8.1 All reports—Essential information

Essential information that shall be included in reports:

a) The complete address of the building measured;

b) Name of the professional field service company, contact information, and identification of the measurement professional(s) who are responsible for adherence to protocols and their current certification ID numbers or equivalent state certification ID numbers, as applicable;

c) Name of the laboratory or service provider responsible for sample analysis with contact information and their current certification ID numbers or equivalent state certification ID numbers, as applicable; and

d) Radon Information Sources. Include contact information of the State Radon Office or other local authority for where the test is conducted and information for obtaining federal or state guidance documents.

8.2 All reports—Measurement results

Test reports shall be provided that comply with all of the following requirements:

a) The test report shall contain the measurement result from each sample processed and the associated error of the measurement result.

b) The test report shall contain the final result expressed as the average of duplicate measurement samples for each measurement location and the associated measurement error.

b) The test report shall contain the dates and times of the sampling and sample identification numbers,

c) The test report shall provide notice where evaluation of a sample indicates concerns that may have adversely affected test results such as during sample collection, storage, shipping or during laboratory processes.

8.3 Professional field service reports—Measurement results

In addition to requirements of Section 8.2, test reports provided by individuals or companies conducting professional field services shall comply with all of the following requirements.

a) The test report shall contain the reason or purpose for the measurement, with the intent to identify the purpose as initial, confirmatory, seasonal or post-mitigation;

b) The test report shall contain a description of each sampling location that can be supplemented with diagrams or photographic records; and

c) Where the average of duplicate or confirmatory measurement disagree on exceeding the action level and the higher result is twice or more than the lower result, the test report shall contain guidance in accordance Section 7.2.2 b.

8.4 Professional field service reports—Deviations from protocol

A description of any observed deviation from this measurement protocol shall be included in the test report. Examples include:

a) Discrepancies or peculiarities regarding sample collection (such as aerator could not be removed or pressure tanks were present);

b) Spigot locations required for meeting this protocol were unavailable or inaccessible; and

c) Problems were identified with storage, handling or shipping of samples.

8.6 All reports—Required Guidance Based Upon Concentrations Measured

The test report shall include equivalent statements for each of the guidance messages shown in the Tables 8.6.1 and 8.6.2.

If action level guidance or requirements established by the local health department are lower than 4,000 pCi/L (150 Bq/L) in water, the local action level shall be substituted or provided along with the name of the local state health department or authority that published such guidance or requirement.

Table 8.6.1 For Concentrations of Radon In Water That Exceed 4,000 pCi/L (150 Bq/L) (or a lower action level recommended by local jurisdiction or state health department).

EQUIVALENT STATEMENTS FOR THESE ADVISORIES SHALL BE INCLUDED IN THE REPORT

- Take remedial action to reduce radon concentrations in potable water. Test results from two samples indicate concentrations that exceed an action level of 4,000 picoCuries per Liter (pCi/L) in water.
  - If only a single sample is available, decisions to mitigate at any time are not prohibited. However, a second test aids confidence that decisions are not being made based on a faulty test result.
  - If one test result is above the action level with the other test result below the action level and the higher test result is twice or more than the lower test result, obtaining confirmation on whether mitigation is warranted requires additional testing.
- Post-mitigation testing: The mitigation system is not complete until system effectiveness has been verified by testing.
- It is critical to properly maintain the water mitigation system to protect occupants from hazards that can include radon, biological contaminants and other radiological concerns. The radon-in-water concentration should be tested no less than yearly and periodic testing twice a year is recommended to confirm that the system remains effective.

Table 8.6.2 For Concentrations of Radon In Water That are Less Than 4,000 pCi/L (150 Bq/L) (or a lower action level recommended by local jurisdiction or state health department).

EQUIVALENT STATEMENTS FOR THESE ADVISORIES SHALL TO BE INCLUDED IN THE REPORT

- Consider mitigation if radon in water test results indicate radon concentrations greater than half the action level.
- Confirm low test results if samples were collected under unusual temporary conditions such as:
  - If the building was vacant when initial sample collection is conducted, repeat the collection with 30 days after occupancy if the water supply has not passed through a municipal treatment facility.
  - If initial sample collection is conducted during unusual flood or drought conditions, repeat the measurement under more typical water table conditions.
- Confirm low test results by repeating tests during different seasons and weather conditions. If no seasonal variation is measured, retest radon in water at least every 5 years.
- In addition, be certain to test again when any of the following circumstances occur:
  - modifications are made to the well, pump or water treatment systems.
  - modifications are made to a radon-in-water mitigation system.

8.7 All reports—Other Health Guidance Advisories

The test report shall also include equivalent statements for each of the following statements shown in the Tables 8.7.

Table 8.7 Other Health Guidance Advisories

EQUIVALENT STATEMENTS FOR THESE ADVISORIES SHALL TO BE INCLUDED IN THE REPORT

- The EPA recommends that all homes and buildings be tested for radon in indoor air. The quantity of radon in air that often comes from soil is not identified by a measurement of radon in water.
- Treatment of potable water for bacteria should always be an important consideration (e.g., ultraviolet light, chlorination).
- Measurement of gross alpha (GA) activity is another consideration to reveal if there are other dissolved radioisotopes in the water, such as radium and uranium.
- Radium-bearing scaling can sometimes occur inside the pipes of a water system. Such an occurrence can be revealed by comparing radon levels in water samples collected prior to flushing the water system with those collected after flushing the system.
- Other contaminants in the water may impact the function of a radon in water mitigation system. To make sure the radon water mitigation system functions as intended, it may be necessary to test the water for other contaminants and also treat the water for those other contaminants.

8.8 Professional field service reports—Radon mitigation system status (if applicable)

Where a mitigation system or efforts to mitigate radon are observed, the test report shall include:

a) a statement that a mitigation system was observed and whether it appeared to be operating.
b) a statement regarding the condition of any temporary radon mitigation strategies that are not permanent installations, and
c) a statement on the limits of the inspection. It is permissible to provide a statement in the report that the test company offers no findings as to the proper installation and operation of the mitigation system.

8.9 All reports—Opinions and interpretations

When opinions and interpretations are included, the basis upon which the opinions and interpretations have been made shall be included in test reports. Opinions and interpretations shall be clearly marked as such in a test report.

8.10 All reports—Statement of Test Limitations

Informative advisory—The report should describe the general limitations of the test. An example is the following: "There is an uncertainty with any measurement result due to statistical variations and other factors such as daily and seasonal variations in radon concentrations. Variations can occur due to changes in groundwater concentrations, operation of the dwelling, or dynamics associated with the size of the well and soil permeability."

SECTION 9.0 PROFESSIONAL SERVICES - QUALIFIED SAMPLE COLLECTORS

9.1 Defined

For professional services, only a Qualified Sample Collector accredited by statute, state licensure or nationally-recognized certification program shall collect a water sample for radon. For the purposes of this document, a "Qualified Sample Collector" is defined as a person who:

a) has satisfactorily completed a water measurement training course accredited by a national certification program such as the National Radon Proficiency Program (NRPP) or the National Radon Safety Board (NRSB); or as recognized by state licensure or certification program;

b) collects water samples in accordance with this standard with measurement results derived from sample analysis services provided by a Qualified Laboratory; and

c) establishes and maintains a quality assurance management system for the tasks they perform that monitors and controls the quality of test devices and testing procedures.

If available or where applicable, this definition includes "An individual that has demonstrated a minimum degree of appropriate technical knowledge and skills specific to the collection of radon in water samples:

a) as established by a national certification program such as the National Radon Proficiency Program (NRPP) or the National Radon Safety Board (NRSB); or

b) as required by statute, state licensure or certification program"

9.2 Quality Assurance Required For Field Operations

Each qualified sample collector shall be responsible for developing, documenting and implementing their own procedures for defensible quality control processes and assessments within the context of their own operation's quality management system.

9.2.1 *Condition of water collection vials or containers*

Standard operating procedures for field operations are to include checks for the integrity of the vial or container of the collected sample at time the sample is collected, and during handling and transport. Any concerns encountered are to be documented and relayed to the qualified sample collector responsible for data validation of test results.

SECTION 10.0 PROFESSIONAL SERVICES - QUALIFIED LABORATORIES

By definition, a laboratory analyzes a water sample for radon and provides the result to a radon professional or directly to the public.

10.1 Criteria Requirements for Qualified Laboratory Status or Designation

To be considered qualified for conducting analytical services for determining the radon concentrations in water samples, the person(s) or team, regardless of business organizational structure, shall operate under a quality assurance plan (QAP) that includes the following requirements for quality of personnel and practices.

10.1.1 *Responsibilities*

Ensuring adequate quality control (QC) within the laboratory is to be the responsibility of laboratory management, with duties often assigned to quality managers. Adequate QA includes verification and documentation of:

a) sufficient training of individuals responsible for laboratory operations;
b) continued applicability of the calibration factors and functions (curves);
c) QC operations conducted at required frequencies, with results within warning and control limits or appropriate investigative and corrective actions taken, as needed;
d) maintenance and repair records of equipment and systems, and
e) quality policies as specified in a QAP, revised as operations change, and records of all QC checks, which are available to auditors or credentialing authorities, subject to confidentiality agreements.

10.1.2 *Sufficient training*

Laboratory management personnel are to be responsible to ensure sufficient training is obtained for all individuals associated with measurement activities, to include:

a) operations shall be conducted under the responsible charge of a qualified measurement professional;
b) individuals who collect samples or analyze data obtained by radon measurement instruments in the field shall be qualified measurement professionals; and
c) all parties associated with testing and analysis should be qualified for their apportioned tasks.

10.1.3 *Approved methods*

Methods approved for analysis of radon in water shall be those verified to comply with requirements in Section 10.4. Laboratories shall be allowed to utilize any such approved method to analyze a water sample for radon, after successfully meeting all requirements herein for Qualified Laboratory Approval.

10.1.4 *User Instructions*

The laboratory shall provide user instructions for how to collect samples consistent with collection procedures in Section 4 and consistent with at least one collection method consistent with a collection method. In addition, the laboratory shall provide instructions for any requirements on handling and shipping that the laboratory deems appropriate for their region, clientele or relative to time of year, such as:

a) thermal insulation envelopes or wrapping, or
b) procedures for keeping samples cool in summer; or
c) procedures to prevent samples from freezing in winter.

10.1.5 *External testing programs—Intercomparisons and performance testing*

To be considered qualified, a laboratory shall participate in at least one external proficiency testing program or large-scale intercomparison exercise annually and report a result within 10% of the known for a concentration above 300 pCi/L (11 Bq/L) for each method utilized in analyzing a water sample for radon.

Laboratories shall continue to maintain satisfactory participation in annual intercomparison studies and/or proficiency testing. A failure shall result in the provision of

a) a corrective action report,
b) analytical proof of an effective remedy, and
c) the successful participation in a follow-up intercomparison study and/or proficiency testing study.

Where a laboratory or method has failed acceptable criteria for intercomparisons or performance testing, the Qualified Laboratory status or designation for use of the method shall be terminated after 90 days:

a) unless identifying corrections and successfully completing another intercomparison or performance test; or
b) if failing two consecutive intercomparison or performance tests, successfully complete three intercomparisons or performance tests with Qualified Laboratories.

10.2 General Quality Assurance and Quality Control (QA/QC)

The frequency of conducting samples for quality assurance is dependent on the measurement instrument being used and the sample measurement load. Qualified Laboratories, Qualified Measurement Professionals, and all users of this document must comply with ANSI/AARST MS-QA *"Radon Measurement Systems Quality Assurance"* for details that relate to proper quality assurance during collection and measurement of the radon content of water. In general, a laboratory shall have demonstrated minimum detectable limit (MDL) and precision studies.

10.3 Quality Control (QC)

Analytical laboratories that measure and report concentrations of radon in water shall maintain a demonstrated and documented QA/QC program. The quality assurance plan shall, at a minimum, contain the following requirements.

10.3.1 *Routine validation*

Performance of the measurement instrument shall be confirmed each day before use, and if a large sample load, at least one for every 10 samples on average. Blank samples, consisting of laboratory grade pure water, shall be constitute at least 5% of measured samples. Duplicate samples from the same bottle, of a concentration greater than 300 pCi/L (11 Bq/L), shall constitute at least 10% of the measured samples.

10.3.2 *Reference standards and the quality assurance plan*

A QA Plan shall be written, followed, and verifiable (documented). Quality assurance is typically performed using reference standards, either purchased or created in-house. The reference standards do not necessarily have to be traceable to an accrediting organization, but are instead used to determine that the instrument-measurement parameters have not changed since the previous check(s) and the last external standardization, proficiency test, or intercomparison. The value of the reference standard is determined following each instrument standardization, and then shall be tabulated (or charted) with each use to aid in the identification of a trend (e.g., loss of efficiency). Warning and Control limits shall be established. Documentation regarding the quality assurance that is conducted shall be kept current.

10.3.4 *Staff and procedures*

Each laboratory shall appoint a technical manager, who shall be a full-time staff member, and who shall exercise actual day-to-day operation of the laboratory, including reporting of results. The technical manager shall be documented (named), shall have a minimum of two years of experience in radionuclide analysis, and shall review quality assurance data for the laboratory.

The name of each analyst that prepares or measures each water sample and the analytical methodology used shall be documented for each sample. The analyst and the analytical method utilized for

intercomparison or proficiency testing shall be the same as that used for routine analysis of water samples. Only the named, properly-trained analyst(s) and approved method(s) shall be utilized to obtain reportable results for radon in water samples.

10.4 Approved Laboratory Method

Validation of a proposed analytical method is the process by which a laboratory verifies the performance of the test method. Proposed test methods shall demonstrate that they have acceptable performance characteristics such as accuracy, precision, and detection capability for the measurement of radon. This is generally achieved by comparing the performance of the proposed method to that of existing approved methods and shall include results of recent performance testing and/or intercomparison studies. The applicant shall obtain (and provide if requested) sufficient data to allow determination that the performance of the proposed method is comparable to test methods already approved for radon measurements in water. The validation study shall include results for the reagent blank, detection limit, and method performance.

10.5 Intercalibration

In lieu of a nationally recognized or federal primary reference that can be used for comparison across multiple methods to validate radon activity concentrations in water, the following generalized structure for developing a national reference for calibration and quality control is provided.

10.5.1 *Reference for radon activity concentrations in water*

A radon reference can be developed using sources of both naturally-occurring (for precision) and man-made (for accuracy) water samples containing ^{226}Ra and/or ^{222}Rn (radon) for intercomparison, calibration, and standardization purposes. Examples include:

a) ^{222}Rn: Several states have identified groundwater sources containing ^{222}Rn at concentrations exceeding 100,000 pCi/L (3700 Bq/L). Sampling bottles, filled using techniques provided in Section 5 above, would need to be distributed quickly to participants. The advantages are ease and cost of sampling, no handling of radium standard, and a real sample scenario (decay);

b) ^{222}Rn: The production of radon in sealed containers of water has been accomplished using both ^{226}Ra-impregnated resin and sealed filter sources. The dissolved radon remains in radioactive equilibrium until opened, and upon refill and closure of the container, equilibrium is re-established after 30 days, meaning the source is reusable. Easy to produce but includes handling of radium;

c) ^{226}Ra: Some states have identified groundwater sources containing ^{226}Ra at concentrations exceeding 300 pCi/L (11 Bq/L). No special filling technique is needed, but a 30 day minimum is needed to obtain radioactive equilibrium of radon and its short-lived decay products in the water. Easy to produce but concentrations are often low; and

d) ^{226}Ra: Water containing a known activity ^{226}Ra in equilibrium with radon can be produced using NIST-traceable standards. Although these are the best sources for a national reference, handling and distribution of ^{226}Ra poses potential contamination. Mineral-oil-based cocktails are usable up to one year.

10.5.2 *Intercomparisons*

Prior to a laboratory offering commercial services involving the analysis of water samples for radon, a qualified laboratory shall have demonstrated proficiency by successfully participating in an intercomparison study with at least three approved laboratories. The new laboratory shall prove the capability to achieve, report (to certifying bodies and/or the public), and maintain test results that are within 25% of the established mean (unless noted) for radon at three distinct concentrations:

a) one to evaluate levels below 1000 pCi/L (37 Bq/L) (within 50% of the established mean),
b) one about five times a), and
c) one at significantly greater levels.

The National Primary Drinking Water Regulations (NPDWR) defines the minimum detection limit (MDL) as a concentration that can be measured with a precision of ± 100% at the 95% confidence level (2σ). Detection limits are dependent on the following:

a) Background or blank count rate,
b) Instrument sensitivity (i.e., efficiency),
c) Volume of sample that is analyzed,
d) Sample decay time, and
e) Counting time.

As the 1991 proposed a maximum contaminant level for waterborne radon was 300 pCi/L (11 Bq/L), the MDL for an approved method shall be less than 200 pCi/L (7.4 Bq/L).

10.5.3 *Performance testing programs or facilities*

In lieu of a nationally recognized or federal program to qualify laboratory reference facilities, external laboratories that successfully meet requirements for State programs or intercomparisons in accordance with Section 10.5.2 shall be acceptable for use as a reference facility when conducting performance tests.

SECTION 11.0 LIQUID SCINTILLATION - LABORATORY PROCESSING

Note—A variety of analytical methods are permitted following successful participation in interlaboratory intercomparison or proficiency testing studies and approval of the methodology. The text below provides details pertaining to the U.S. EPA-accepted methods which are most prevalent. The sample transfer protocols may be applicable to other methods.

11.1 Analytical Measurement of the Water Sample

11.1.1 *Sample preservation*

The person responsible for handling the samples in the field and in the laboratory should take measures, as appropriate, to avoid compromising the integrity of the sample due to temperature in the environment where the sample is stored or transported.

Water samples shall not be preserved with acid as this is unnecessary, potentially dangerous for the collector, and would introduce air contact with the water sample (and potential loss of radon).

11.1.2 *Time limits*

The cocktail vial shall dark-adapt a minimum of 1 hour after sample preparation before beginning measurement.

Note—As radon decays with a half-life of 3.82 days, measurement of the radon activity commonly commences within 4 days of sample collection and the measurement is often completed within 8 days of collection.

11.1.3 *Sample measurement period*

Samples shall be measured for a sufficient period to attain a maximum total reporting error (at 2 sigma; 95% confidence level) of 25% or less for radon-in-water concentrations above 300 pCi/L (11 Bq/L). The 2-sigma (95% confidence level) total uncertainty associated with the reported concentration shall be provided for all samples.

11.1.4 *Laboratory vials*

Polyethylene (or similar) material as a collection bottle or cap septum will allow radon diffusion and result in low concentration values, so these materials shall not be used for sample collection and storage.

An inverted septum will allow radon to emanate from the water sample and result in a low concentration of radon. The collector shall document the orientation of the lined septum on the bottle. Observance of an improper septum shall be recorded.

While not recommended, it is permissible to use polyethylene vials for holding prepared cocktails for measurement by liquid-scintillation counting.

Informative advisory—Caps for liquid scintillation vials (either glass or polyethylene) that are prepared for measurement should be aluminum- or PTFE-lined.

11.1.5 *Air bubbles*

For cases in which bubbles have formed in the collection bottle and the sample needs to be analyzed because it cannot be re-collected, the occurrence and estimated size of the air bubbles in the bottle shall be documented on the report by the laboratory analyst. Correction to the measured activity is not required unless the bubble exceeds ¼" (0.6 cm) in diameter.

A simple calculation to correct the measured concentration when the sample bottle has an air bubble, of radius r, is to determine the displaced volume of water using:

$$V\ (mL) = 4 * (4/3\ \pi\ r^3) \qquad (2)$$

where a multiplier of 4 is included since the equilibrium radon concentration in air is about quadruple that for an equal volume of water (see Ostwald solubility coefficient for radon). For example, a ¼" (0.6-cm) air bubble in a 22-mL bottle contains the equivalent of 0.134 mL of water, thus the measurement result would be 2.4% low.

Table 1 provides information regarding radon loss from a water sample due to a bubble in the collection bottle, with analytical results expected to be low by the value in the right column.

Table 1

Estimated impact of an air bubble on radon loss in a 22-mL water bottle. For 40-mL bottles, reduce "% Rn lost" by about half.

U.S. name bubble size	diameter inches	radius inches	radius cm	cm3	4/3*pi	mL water missing	%water missing	@4/1 ratio % Rn lost
"1/8 inch"	0.125	0.063	0.159	0.00400	4.189	0.017	0.08	0.30
"1/4 inch"	0.250	0.125	0.318	0.03201	4.189	0.134	0.61	2.44
"3/8 inch"	0.375	0.188	0.476	0.10802	4.189	0.452	2.06	8.23
"1/2 inch"	0.500	0.250	0.635	0.25605	4.189	1.072	4.87	19.50

11.2 Transfer Methods

11.2.1 *Sample extraction*

Extraction of a water sample from the collection bottle shall be conducted using either an airtight graduated syringe or transfer pipet. The identity of the transfer device shall be documented. The following pertains to extracting 5-10 mL of water; if a laboratory uses a different volume the procedure shall be adjusted accordingly.

Informative advisory—Water samples are often collected in glass VOC-type bottles and transported back to the laboratory before an aliquot of the water is extracted from the collection bottle for analysis. This approach eliminates the need to carry glass vials containing an organic-based scintillation fluid into the field, and is recommended when conducting sample transport by mail (the postal service and package-shipping companies discourage the mailing of organic liquids in glass containers).

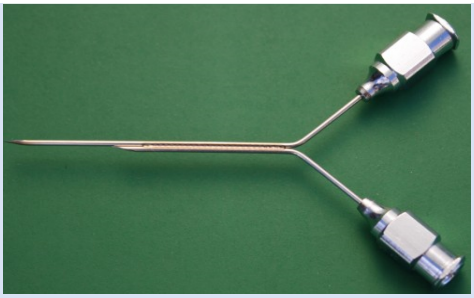
11.2.2 *Syringe options*

Two types of syringes can be used to transfer a water sample from a collection bottle to a liquid scintillation vial. Both types shall be graduated and air tight.

Informative advisory—A syringe with a large diameter tubing is recommended over the use of a hypodermic-needle syringe (6-10 gauge diameter), since the latter forces the extracted water through a constriction that produces sufficient pressure to enable dissolved gases to come out of solution from the water. If a needle syringe is used to pierce the septum of a ring-capped bottle, insert another needle or use a purge transfer needle (Fig. 11.2.2) to allow air back into the capped bottle while the water is being extracted.

Figure 11.2.2

Example of purge transfer needle use to extract water from a capped collection bottle



11.2.2.1 Single-port hypodermic needle

If a needle syringe is used, the needle diameter shall be 10 gauge or larger. Both the use of a single-port hypodermic-needle syringe and the diameter (gauge) of the needle shall be documented. The cap shall be removed, or another needle shall be inserted through the septum to allow air into a capped bottle.

Informative advisory—A single-port hypodermic-needle syringe should be avoided but is permitted for use in the laboratory to transfer a water sample.

Figure 11.2.2.1

Example of a single-port hypodermic needle syringe

11.2.2.2 Extracting a water sample using a syringe

Regardless of the syringe used, the following procedure to extract a water sample from a collection bottle (Steps 1-5) shall be adhered to:

(1) Insert the tip of the tubing or needle, attached to a 15-20 mL syringe, below the water surface and withdraw 5-10 mL of water slowly to minimize air bubbles. Withdraw the tip from the water, invert the syringe (tip up) and withdraw the plunger slowly until water in tubing (or needle) is emptied into the syringe.

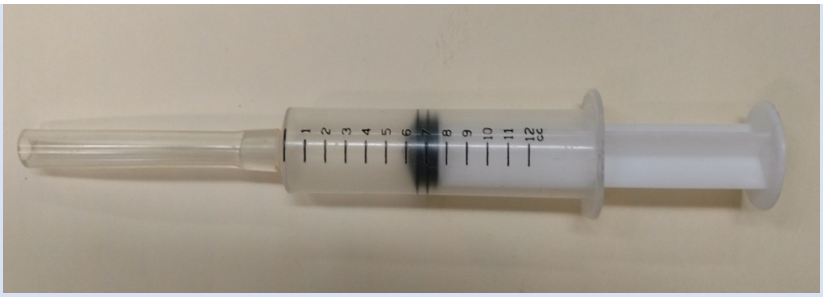
Informative advisory—All bubbles in the syringe should have risen to the surface. If necessary, gently tap the syringe to release large bubbles from inside wall of the syringe.

(2) Keeping the syringe upright, push the plunger to eject all water except that remaining in the tubing (or needle).

(3) Re-insert tubing (or needle) far below the water surface and withdraw water into the syringe, past the 10 mL graduation, remove tubing (or needle) from the water, and discard excess water to the 10-mL mark of the calibrated syringe.

Figure 11.2.2.2

Calibrated syringe to extract water from a collection bottle for transfer to a liquid scintillation vial



(4) Place the syringe tubing (or needle) well below the surface of the appropriate volume of liquid scintillation fluid contained in a scintillation vial and slowly eject the water from the syringe at the bottom below the scintillation fluid.

(5) Slowly withdraw the syringe and tightly cap the vial. Shake the vial for 15-30 seconds. Dark-adapt the cocktail vial a minimum of 1 hour after preparation before beginning measurement.

11.2.1.3 Extracting a water sample using a glass pipet

A graduated glass pipet may be used to extract a water sample. In a single draw, extract over 15 mL of water into the glass pipet. The volume reading on the graduated pipet is noted prior to insertion of the pipet outlet below the surface of the scintillation fluid in a scintillation vial and slowly discharge exactly 10 mL of the water. Follow step (5) above.

There shall be at least 5 mL of water remaining in the pipet after the transfer as a buffer or barrier between the air and the water to be analyzed. The syringe and tubing (or needle) shall be rinsed with radon-free water after sample collection from each water supply.

11.3 Calculations

11.3.1 *Decay correction*

Radon decays with a half-life ($t_{1/2}$) of 3.82 days. Therefore, a correction for decay shall be incorporated into the calculation of concentration using the following:

$$A_0 = A_t e^{\lambda t} \quad (3)$$

where A_0 = decay corrected activity (activity at time of collection),
A_t = measured activity,
λ = decay constant for radon (0.6931 / $t_{1/2}$), and
t = time from sample collection to the midpoint of the measurement period (same units of time as used for $t_{1/2}$.

Reported radon activities above 300 pCi/L (11 Bq/L) shall include an uncertainty calculated at the two sigma (95% confidence) level.

11.3.2 *Relative percent difference (RPD)*

RPD is used to evaluate the difference between two measurements when neither one can be assumed to be more accurate than the other. The RPD compares the difference between two measurements divided by their mean, which in this case is the best estimate of the true concentration. RPD is always positive and is used as an estimate of imprecision. The RPD is determined by dividing the difference in the duplicate values (A-B) by the average (mean) of the two duplicate values. RPD values for duplicate samples shall be less than 10%.

$$RPD = [(A - B) / mean] * 100 \quad (4)$$

where A = the larger result,
B = the smaller result, and
mean = the average of the two results.

The user shall calculate and report the relative percent difference for duplicate samples.

11.3.3 *Liquid scintillation activity*

The radon concentration (A_0, in Bq/L) is determined using the measured count rate for the region of interest (ROI) from the spectrometer. While other formulae are possible, the following formula can be used to calculate the radon activity (A_0) in the water sample at the time and date of collection:

$$A_0 = (cpm - bcpm) / (60 * V * \varepsilon * DK) \quad (5)$$

where cpm = measured count rate (counts/minute),
bcpm = background count rate (counts/minute),
60 = conversion factor between dpm and Bq,
V = water volume (L),
ε = detector efficiency (cpm/dpm), and
DK = decay factor from sample collection to the midpoint of the measurement, determined using $e^{-\lambda t}$.

11.4 Safety warnings and waste management

Organic-based scintillation fluids are commonly used for radon measurement and some of these pose a significant harm to humans. Since radon is soluble in solvents such as toluene and xylene, cocktails containing those solvents may be used for radon analysis. Lipophilic xylene-based scintillation fluids (e.g., Insta-Fluor) are applicable for measurement of radon in water, while environmentally-friendly fluids (e.g., Opti-Fluor O) are an alternative. Other organic-based fluids, such as mineral oil, are much less hazardous to handle, but shall also be disposed of properly. Typically, after the sample has been measured by liquid scintillation counting, the cocktail is poured from each vial into a larger container. Since each cocktail is typically 20 mL of volume, a 2-L container can hold the contents of approximately

100 scintillation vials. Due to the immiscibility of the water and organic fluid, two distinct layers will form in the waste container. Unless the water layer is known to contain high concentrations of ^{226}Ra, the water portion of the cocktail may be decanted and discarded safely down a drain. Any radioactivity from radon and its decay products that remain in the water will not present a hazard. The organic-based fluid shall be discarded through an accredited waste hauler or burned in a high-temperature incinerator.

SECTION 12.0 ALPHA SCINTILLATION CELL - LABORATORY PROCESSING

As described above, water is collected in glass VOC-type bottles at the sampling location and transported to the laboratory. A glass bubbler will be used to transfer the dissolved radon from the water sample to a fully evacuated alpha-scintillation cell. Due to their fragility and possible agitation (turbulence) of the encapsulated water, bubblers are not transported to a sampling location. The syringe shall have an attached tubing or needle of at least 6 inches in length in order to reach the bottom of the bubbler.

12.1 Prior to transferring the sample

To avoid the loss of radon from the water sample while being placed into the bubbler, the glass bubbler shall first contain an aliquot (typically 10 mL) of distilled, or radon- and ^{226}Ra-free, water prior to the sample transfer. (The exact volume and method of adding this water to the bubbler are irrelevant.) Follow Section 11.1 above.

12.2 Transfer procedure

Syringe—Use a graduated syringe with attached tubing (or needle) of sufficient length to reach the bottom of the bubbler. Similar to that described above (Section 11.2.1), extract ~5 mL of water from the collection bottle into the syringe, invert the syringe (tip up), withdraw the plunger slowly until the water in the syringe tubing (or needle) is emptied into the syringe, and then (with tip remaining up) push the plunger to expel the water from the syringe (although the tubing or needle will now be filled with water). Re-insert the intake of the syringe tubing (or needle) near the bottom of the bottle and draw at least 15 mL of water. Remove and invert the syringe and expel any excess water (retain 10 mL). Insert the syringe tubing (or needle) outlet far below the level of the distilled water in the bubbler, slowly expel the water sample into the bottom of the glass bubbler. Cap the bubbler immediately.

Pipet—Draw over 15 mL of water into the pipet. The volume reading on the graduated pipet is noted prior to insertion of the pipet outlet below the surface of the water in the glass bubbler and slowly discharge 10 mL of the water. There shall be at least 5 mL of water remaining in the pipet after the transfer as a buffer/barrier between the air and the water being transferred.

During transfer of radon from the water in the bubbler, the alpha-scintillation cell provides the force (vacuum) that bubbles the water, so it is important to evacuate the alpha-scintillation cell as much as possible. Inadequate vacuum will result in incomplete transfer of the radon from the water, and thus a low result. The initial vacuum of the scintillation cell shall be greater than 90% (e.g., 80 Torr or 10 kPa) and documented.

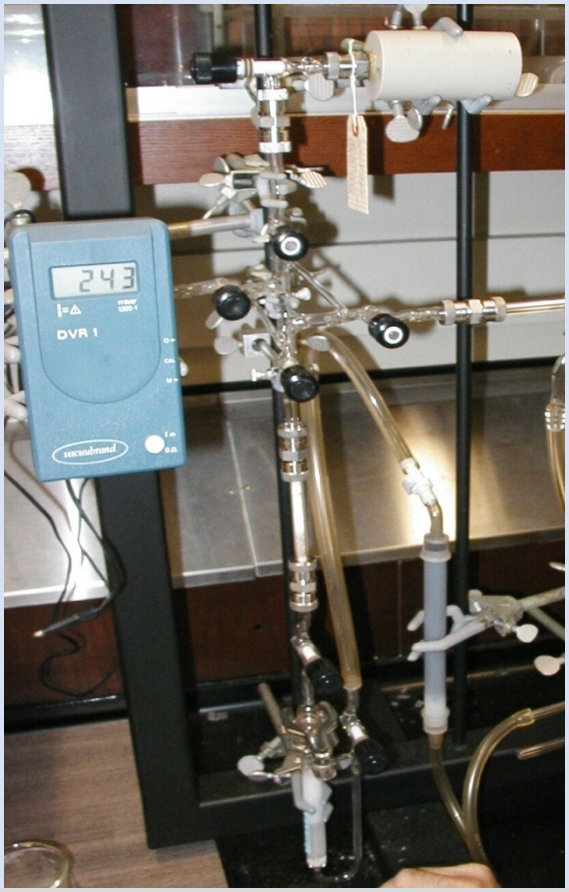
12.3 Moisture and airflow

The transfer system (from the bubbler to the alpha-scintillation cell) shall have an in-line column containing a desiccant (e.g., magnesium perchlorate or anhydrous calcium sulfate) to remove moisture from the air stream and a micrometer value to control the air flow (bubbling rate). A column (e.g., ascarite) to remove CO_2 from the air stream can be included, if desired. The alpha-scintillation cell and

the bubbler are at opposite ends of the transfer system. With the micrometer valve closed, open the valves to the alpha-scintillation cell and the bubbler. Slightly open the micrometer valve until bubbling is observed. Adjust the micrometer valve to continue a slow bubbling of the water and transfer of the radon into the alpha-scintillation cell. To eliminate the introduction of radon into the sample, air entering the inlet of the bubbler shall come from a cylinder of aged air or, if using ambient air shall have an activate-charcoal trap so as to remove ambient radon from the inlet air stream. Adjust the micrometer valve to maintain a slow bubbling of the water until no more bubbling is observed (usually 5-10 minutes). At this point the alpha-scintillation cell is at atmospheric pressure (no remaining vacuum). Close the inlet of the alpha-scintillation cell, remove it from the transfer system. Dark-adapt the cell at least 3 hours before measurement to allow ingrowth of the short-lived decay products.

Figure 12

- System to transfer radon from a bubbler (bottom) to an alpha-scintillation cell (top).
- A column for moisture removal and a micrometer valve are in-line.
- The gauge (left) measures vacuum and the charcoal trap (right) removes ambient radon from the air before entering the bubbler.



12.3.1 *Alpha-scintillation (Lucas) cell*

Following the transfer of radon into the Lucas cell, the analyst shall dark-adapt the cell a minimum of 3 hours after sample preparation before beginning measurement. Using equations in Section 11, equations 3-4 are to be applied if applicable and the radon concentration is determined using equation 5.

SECTION 13.0 ELECTRET ION CHAMBER (EIC) METHOD

The use of Electret Ion Chambers (EIC) for determining radon concentrations is water requires strict adherence to specific practices and calculations developed by manufacturers and successful participation in proficiency testing or laboratory intercomparison programs.

Note 1—EIC Devices: EIC devices measure radon in air using an electret (i.e. dielectric material with a quasi-permanent electric charge) that is attached to a chamber where ions resulting from the decay of radon deplete the electric charge of the electret. The difference between the electret charge prior to and after a measurement period is compared for calculating a measurement of radon in air overtime period of the test.

Note 2—EIC Method for Water Measurements: The currently developed method for measuring radon in water entails placing a small predetermined volume of sampled water in a larger closed containment jar that has a predetermined air volume. An EIC device is affixed within the containment jar. The EIC measurement of off-gassed radon in air that resulted within the containment jar over time is correlated with known volumes of water and air within the containment jar to achieve reportable measurements of radon in water.

13.1 Measurement Procedure (Electret Method)

The required measurement procedure, based on current methods, includes:

1) Collect, handle and document duplicate water samples in accordance with Sections 3, 4 and 5 using bottles that meet manufacture recommendations;
2) Record voltage readings for electrets as they exist prior to measurement;
3) Attach the electret to the ion chamber;
4) Working quickly, the method entails placing the water sample and an EIC device inside a containment jar that meets manufacture recommendations:
   - Open the water sample bottle and place it upright as far inside the containment jar as possible. Note—There may be a snap holder affixed to the bottom of the jar to hold the collection bottle but this is not required;
   - Affix or hook the EIC device to the inside of the containment jar lid;
   - Open the air inlet to the ion chamber; and
   - Close the containment jar with an airtight lid.
5) Carefully bring the glass jar to the vertical position, permitting the water in the sampling bottle to spill into the jar bottom. Assure the jar cap is tight, which may include installation of a rubber sealing collar around the cap and a clamp around the collar. Keep the jar vertical during the duration of the measurement.

13.1.1 *Informative Advisories*

For radon-in-water concentrations greater than 10,000 pCi/L (370 Bq/L), the use of a long-term electret, instead of a short-term electret, is recommended. Typically, a voltage drop of ±20 will provide good precision and keep agreement of the duplicate samples to within 10%.

If a short-term electret is used for the analysis, a water sample with a very high radon concentration may result in a very large voltage drop (which has a chance to totally discharge the electret). On the other hand, using a long-term electret for a water sample with a very low radon concentration may result in poor precision and agreement between detectors since the voltage drop is less precise. As such, if it is believed that the radon-in-water concentration is going to be low, better accuracy will be achieved by using a larger sample jar and a measurement period of 48 hours.

13.2 Analysis Procedure (Electret Method)

13.2.1 *Required procedure.*

The required procedure to complete the measurement process and analysis, based on current methods, includes:

1) After at least 48 hours or as recommended by the manufacturer, remove the IEC device, close the air inlet to the ion chamber and record the time and date of the removal;
2) Measure and record the final electret voltage; and
3) Apply appropriate calculations supplied by the manufacturer to determine the reported measurement of radon in the water sample.

13.2.2 *Vials.*

Use of collection vials or containment jars of a volumes different than specified by the manufacturer shall include an adjustment in the calculations.

Note—Details regarding method calculations are available elsewhere[6] or from the manufacturer. Calculations for the current method are based on: a) water samples collected in 68 mL (2.3 fl oz) or 136 mL (4.6 fluid oz) glass vials; and b) a containment jar capable of holding 3.75 L (1 gallon).

13.2.3 *Bias.*

Bias observed during successful participation in proficiency testing or laboratory intercomparison programs is to be corrected for when reporting measurements.

Note—A negative experimental bias of 15% has been reported[7] when compared against liquid scintillation counting.

SECTION 14.0 CONTINUOUS MONITOR (CRM)

Informative advisory—The determination of radon in a water sample using a CRM often requires a somewhat larger sampling bottle, although the water collection techniques described above still apply. Since various proprietary analytical methods are available, users are referred to each manufacturer's documentation.

14.1 Demonstration of Proficiency

CRM users shall successful participation in proficiency testing and/or laboratory intercomparison programs for radon in water, both initially and annually thereafter.

SECTION 15.0 NEW METHODOLOGY DEVELOPMENT

A variety of analytical methods are permitted following review and approval of the methodology, and successful participation in interlaboratory intercomparisons or proficiency testing studies. The Qualified Laboratory shall obtain and be capable of providing sufficient data to allow determination that the performance of the proposed method is comparable to test methods already approved for radon measurements in water. The validation study shall include results for the reagent blank, detection limit, and method performance.

Informative advisory—Currently, the U.S. EPA-approved[1] analytical methodologies of liquid scintillation and alpha-scintillation cells are acceptable to use following successful participation in an intercomparison and calibration in accordance with Sections 10.1 and 10.5). Validation of a new proposed analytical method is the process by which an applicant verifies the performance of the test method. Proposed test methods should demonstrate that they have acceptable performance characteristics such as accuracy, precision, and detection capability for the measurement of radon. This is generally achieved by comparing the performance of the proposed method to existing approved methods and can include results of recent performance testing studies.

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[6] Kotrappa, P. and Jester, W.A. (1993) Electret Ion Chamber Radon Monitors Measure Dissolved 222Rn in Water, Health Physics 64:397-405.

[7] Kitto, M.E., Fielman, E.M., Haines, D.K., Menia, T.A. and A. Bari (2008) Performance of a Commercial Radon-in-Water Measurement Kit, J. Environ. Radioact. 99, 1255-1257.

Exhibit 1 Example of Water Sample Collection Form

Property address _____

_____

Owner/Client Name _____ *Phone* _____ *Email* _____

_____

Person collecting the water sample

Name _____ *Phone* _____ *Email* _____

Certification # _____ *Certification Authority* _____

Company _____ *Phone* _____ *Email* _____

Certification # _____ *Certification Authority* _____

Laboratory processing the water sample

Name _____ *Phone* _____ *Email* _____

Certification # _____ *Certification Authority* _____

Radon Information Sources

State Office _____ *Phone* _____ *Website* _____

Other _____ *Phone* _____ *Website* _____

Test purpose:

❑ Initial test, ❑ confirmatory test, ❑ seasonal test, ❑ post-mitigation test, ❑ other _____

Sampling method:

❑ Initial test, ❑ confirmatory test, ❑ seasonal test, ❑ post-mitigation test, ❑ other _____

Sample Location #1

_____*Date* _____ *Time* _____

_____ *Sample ID*_____

Water volume expelled prior to collection _____

A description of water treatment and/or storage tanks prior to the sampling spigot

_____

To assure fresh water, either

A) *Water temperature measurement device* _____

Water temperature immediately before sample collection: _____˚

Water temperature immediately after sample collection: _____˚

Or B) The method used (such as measured or calculated volume of water

_____

*Water volume expelled prior to collection*_____

Extenuating factors (aerators, treatment equipment, vacant, etc.)

_____

Sample Location #2

_____*Date* _____ *Time* _____

_____ *Sample ID*_____

Water volume expelled prior to collection _____

A description of water treatment and/or storage tanks prior to the sampling spigot

_____

To assure fresh water, either

A) *Water temperature measurement device* _____

Water temperature immediately before sample collection: _____˚

Water temperature immediately after sample collection: _____˚

Or B) The method used (such as measured or calculated volume of water

_____

*Water volume expelled prior to collection*_____

Extenuating factors (aerators, treatment equipment, vacant, etc.)

_____

Sample Location #3

_____*Date* _____ *Time* _____

_____ *Sample ID*_____

Water volume expelled prior to collection _____

A description of water treatment and/or storage tanks prior to the sampling spigot

_____

To assure fresh water, either

A) *Water temperature measurement device* _____

Water temperature immediately before sample collection: _____˚

Water temperature immediately after sample collection: _____˚

Or B) The method used (such as measured or calculated volume of water

_____

*Water volume expelled prior to collection*_____

Extenuating factors (aerators, treatment equipment, vacant, etc.)

_____

MW-RN Committee Members

Acknowledgement

This standard was developed through the efforts and deliberations of the MW-RN consensus body. Participation includes a cross-section of experience, stakeholder interests and vantage points.

Sincere appreciation is both expressed and deserved for their contributions of time and wisdom.

Non-voting Chair:	Michael Kitto	NY
Non-voting Assist Team:	Gary Hodgden	KS
Stakeholder Group	Delegate	
Educators	Tom Hess	ME
Non-regulated States	Ryan Paris	VA
Regulated States	Bob Stilwell	ME
Federal EPA	Jani Stoliarova	NY
Federal USGS	Zoltan Szabo	NJ
Proficiency Program	Shawn Price	NC
Mitigation professional	Dave Hill	MA
Mitigation prof. *alternate*	David Innes	CN
Measurement prof.	David Grammer	NJ
Measurement prof. *alternate*	Michael LaFontaine	CN
Radon Chambers	Jim Burkhart	CO
Laboratory	Uttam Kumar Saha	GA
Scientist	Bill Field	IA
Manufacturer (Electret)	Lorin Stieff	MD

Additional appreciation to participants Bahman Parsa (NJ) and Mathieu Brossard (Federal Health Canada)