Designation: D5811 – 08 (Reapproved 2013)

Standard Test Method for Strontium-90 in Water[1]

This standard is issued under the fixed designation D5811; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of radioactive ^{90}Sr in environmental water samples (for example, non-process and effluent waters) in the range of 0.037 Bq/L (1.0 pCi/L) or greater.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 This test method has been used successfully with tap water. It is the user's responsibility to ensure the validity of this test method for samples larger than 1 L and for waters of untested matrices.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific hazard statements, see Section 9.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1129 Terminology Relating to Water
D1193 Specification for Reagent Water
D1890 Test Method for Beta Particle Radioactivity of Water
D2777 Practice for Determination of Precision and Bias of Applicable Test Methods of Committee D19 on Water
D3370 Practices for Sampling Water from Closed Conduits
D3648 Practices for the Measurement of Radioactivity
D4448 Guide for Sampling Ground-Water Monitoring Wells
D5847 Practice for Writing Quality Control Specifications for Standard Test Methods for Water Analysis
D6001 Guide for Direct-Push Groundwater Sampling for Environmental Site Characterization
D7282 Practice for Set-up, Calibration, and Quality Control of Instruments Used for Radioactivity Measurements

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, refer to Terminology D1129.

4. Summary of Test Method

4.1 This test method is based on the utilization of solid phase extraction of strontium from water samples with detection of the radioactive strontium by gross beta gas proportional counting.

4.2 An aliquant of the sample is measured into a beaker, strontium carrier added, digested with nitric acid, sorbed on an ion exchange column, eluted, evaporated to dryness, dissolved in nitric acid (8M), selectively sorbed on a solid phase extraction column, eluted with dilute nitric acid, dried on a planchet, and counted for beta radiation.

4.3 Fig. 1 shows a flow diagram for this test method.

5. Significance and Use

5.1 This test method was developed to measure the concentration of ^{90}Sr in non-process water samples. This test method may be used to determine the concentration of ^{90}Sr in environmental samples.

6. Interferences

6.1 Significant amounts of stable strontium present in the sample will interfere with the yield determination. If it is known or suspected that natural strontium is present in the sample at levels that will compromise the determination of the chemical yield, blank sample aliquots to which no strontium carrier is added shall be analyzed to determine the natural strontium content. The amount of natural strontium contained in the sample shall be reflected when calculating the yield correction factor.

6.2 Strontium-89 present in the sample will cause a high bias in proportion to the ^{89}Sr/^{90}Sr ratio. This technique is not applicable when it is suspected or known that ^{89}Sr is present in the sample.

6.3 Strontium nitrate ($Sr(NO_3)_2$) is hygroscopic. This chemical property may add uncertainty in the gravimetric yield determination.

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

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

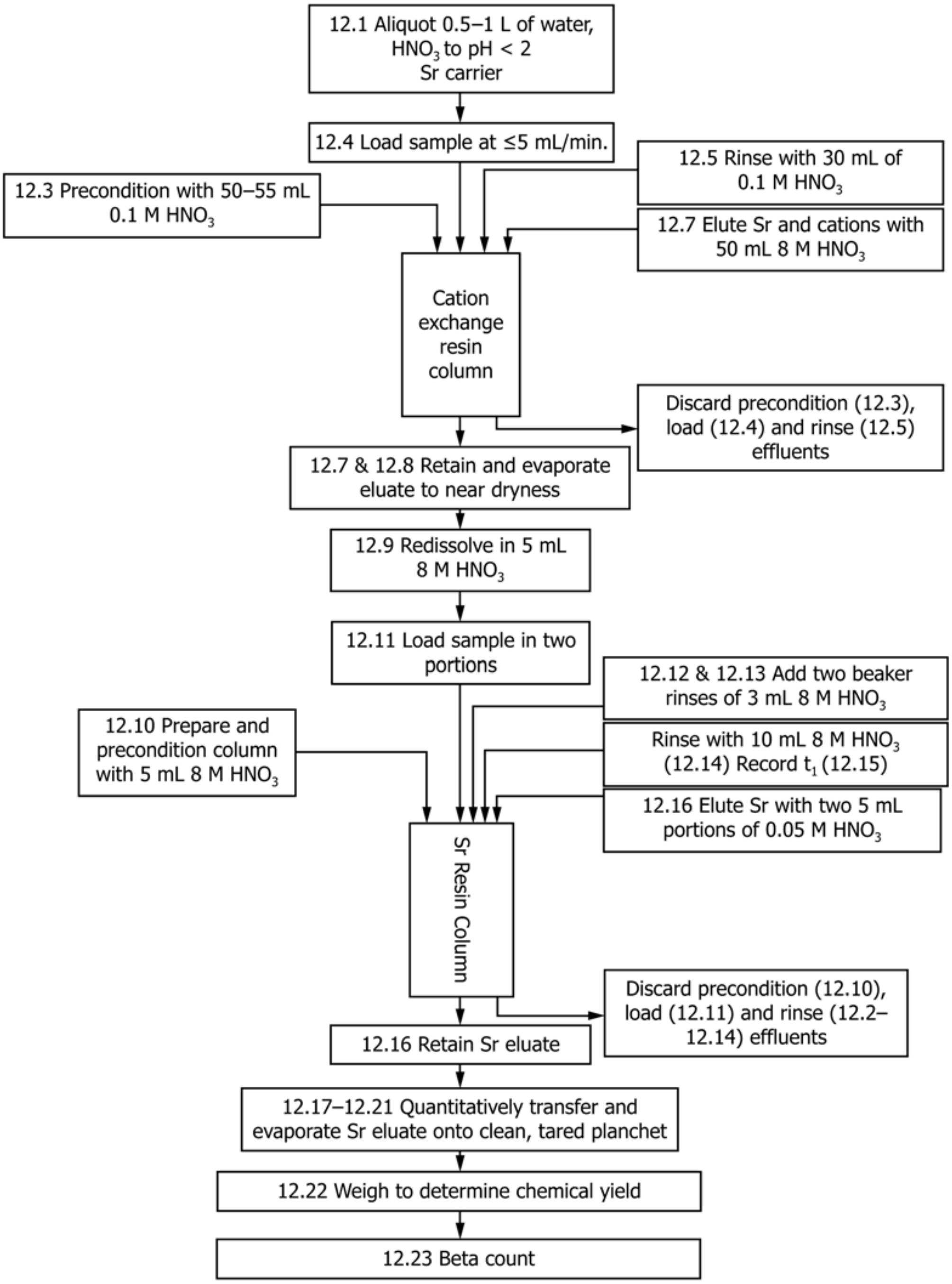

FIG. 1 Flow Diagram for the Procedure

7. Apparatus

7.1 *Analytical Balance,* 0.0001 g.

7.2 *Low Background Gas Proportional Beta Counting System.*

7.3 *Ion Exchange Columns,* 10 mL resin capacity, glass or acid-resistant plastic. An attached reservoir of at least 50 mL is desirable.

7.4 *Planchets,* stainless steel to match calibration source.[3]

8. Reagents and Materials

8.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that

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[3] Stainless steel planchets available commercially have been found satisfactory.

all reagents shall conform to specifications of the Committee on Analytical Reagents of the American Chemical Society.[4] Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination. Reagent blanks shall be run with all determinations.

8.2 *Purity of Water*—Unless otherwise indicated, reference to water shall be understood to mean reagent water conforming to Specification D1193, Type III.

8.3 *Cation Exchange Resin,* 100 to 200 mesh, hydrogen form. 8% cross linked, analytical grade.

8.4 *Nitric Acid (8M HNO_3)*—Add 500 mL of concentrated HNO_3 to 400 mL of water. Dilute to 1L with water.

8.5 *Nitric Acid (0.1 HNO_3)*—Add 6.4 mL of concentrated HNO_3 to 600 mL of water. Dilute to 1L with water.

8.6 *Nitric Acid (0.05M HNO_3)*—Add 3.2 mL of concentrated HNO_3 to 600 mL of water. Dilute to 1L with water.

8.7 *Strontium Carrier (10 g/L)*—Preferably use 10 000 µg/mL ICP standard. Alternatively, dissolve 24.16 g strontium nitrate ($Sr(NO_3)_2$) in water, add 20 mL concentrated nitric acid, and dilute with water to 1 L. Use the following procedure to standardize the prepared strontium carrier: Carefully pipet a 5.0 mL portion of the strontium carrier solution onto a clean, dried, and tared planchet. Dry the planchet under the same conditions used for the final evaporation in 12.20. Allow the planchet to cool to room temperature and reweigh the planchet to the nearest 0.0001 g. Divide the net weight by 10. This result is the amount of strontium nitrate actually added. Use an average of three values in the denominator of the recovery equation in 11.12 and 13.1. This value should be within 3 % of 12.08 mg/0.5 mL.

8.8 *Strontium Extraction Chromatography Column,* 2 mL bed volume consisting of an octanol solution of 4,4'(5')-bis (t-butyl-cyclohexano)-18-crown-6-sorbed on an inert polymeric support.[5]

8.9 *Strontium-90 Standardizing Solution*—Traceable to a national standard body such as National Institute of Standards and Technology or National Physical Laboratory solution with less than 0.1 mg of stable strontium per mL of final solution with a typical concentration range from 85 to 125 Bq/mL.

9. Hazards

9.1 Use extreme caution when handling all acids. They are extremely corrosive and skin contact could result in severe burns.

9.2 When diluting concentrated acids, always use safety glasses and protective clothing, and add the acid *to* the water.

10. Sampling

10.1 Collect a sample in accordance with Practice D3370, D4448, D6001, or other documented procedure.

11. Calibration

11.1 Calibrate the low background gas proportional beta counting system in accordance with Practice D7282. Prepare a set of three calibration samples according to the calibration procedure outlined in the subsequent steps.

11.2 Pipet 0.5 mL of strontium carrier into a small beaker.

11.3 Add 1 mL of traceable ^{90}Sr solution and evaporate to near dryness on a hot plate.

11.4 Redissolve the residual in 5 mL of 8M nitric acid.

11.5 Follow the steps described in 12.10 through 12.23.

11.6 Count to accumulate 10 000 net counts in the counting period. Counting should be completed within 3 h of column elution. Record the time and date of the midpoint of this counting period as t_2. Count each sample mount twice, once for this step having a counting date designated as t_2 and a second time as specified below.

11.7 Calculate the net count rate of the count at time t_2 ($R_{n(2)}$) by subtracting the instrument background count rate from the gross count rate.

11.8 Store the calibration mount for at least 7 days to allow for ^{90}Y ingrowth.

11.9 Recount the calibration mount to amass 10 000 counts in a counting period. Record the time and date of the midpoint of this count period as t_3.

11.10 Calculate the net count rate of the second count at time t_3 ($R_{n(3)}$) by subtracting the instrument background count rate from the gross count rate.

11.11 Calculate the ^{90}Sr detection efficiency, ε_{Sr}, and the ^{90}Y detection efficiency, ε_Y, for each calibration mount using the equations presented below. Calculate the mean and standard deviation of the three ε_{Sr} and ε_Y values. Use the relative standard deviation of these parameters to estimate the relative uncertainty of the ingrowth efficiency factor, (defined in Eq 5), $u_r(\varepsilon_I)$ and used in Eq 7.

11.12 *Efficiency Calculations*—^{90}Sr detection efficiency ε_{Sr}:

$$\varepsilon_{Sr} = \frac{\left(R_{n(2)} \times IF_3\right) - \left(R_{n(3)} \times IF_2\right)}{Y_{Sr} \times A_{C(2)} \times \left(IF_3 - IF_2\right)} \quad (1)$$

^{90}Y detection efficiency ε_Y:

$$\varepsilon_Y = \frac{R_{n(3)} - R_{n(2)}}{Y_{Sr} \times A_{C(2)} \times \left(IF_3 - IF_2\right)} \quad (2)$$

where:

$A_{C(2)}$ = activity of ^{90}Sr in becquerels (Bq) at the time of the first count of the calibration mount,

IF_2 = ingrowth factor for ^{90}Y at the midpoint of the count at time t_2, $e^{-[\lambda_Y \times (t_2 - t_1)]}$

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[4] *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For Suggestions on the testing of reagents not listed by the American Chemical Society, see *Annual Standards for Laboratory Chemicals,* BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary,* U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

[5] The sole source of supply of the apparatus known to the committee at this time is Sr Resin available from Eichrom Technologies, Inc. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

IF_3 = ingrowth factor for ^{90}Y at the midpoint of the count at time t_3, $e^{-[\lambda_Y \times (t_3 - t_1)]}$

λ_Y = decay constant for ^{90}Y (0.2600 d^{-1}),

$R_{n(2)}$ = net count rate of the calibration test source at the midpoint of the first count, in counts per second,

$R_{n(3)}$ = net count rate of calibration test source at the midpoint of the second count, in counts per second,

t_1 = date and time of ^{90}Y separation,

t_2 = date and time of midpoint of first count,

t_3 = date and time of midpoint of second count.

Y_{Sr} = fractional chemical yield of strontium carrier (see Eq 4).

NOTE 1—The time differences ($t_2 - t_1$) and ($t_3 - t_1$) are expressed in days.

12. Procedure

12.1 Add 0.5 mL of strontium carrier to a maximum of 1 L of sample. Add 1 mL of 8M HNO_3 per 100 mL of sample and mix. Bring sample to a boil for 30 min and then cool.

12.2 Prepare a cation exchange column containing 10 mL of cation exchange resin.

12.3 Precondition the column by passing 50 to 55 mL of 0.1M HNO_3 through the column.

12.4 Pass the sample through the column at a rate of not more than 5 mL/min.

12.5 Rinse the column with 25 to 30 mL of 0.1M HNO_3.

12.6 Properly dispose of the feed and rinse.

12.7 Elute the strontium (and other cations) with 50 mL of 8M HNO_3 into a 150 mL beaker.

12.8 Evaporate the eluate to near dryness on a hot plate in a fume hood. The residue will dissolve more easily in the next step if the evaporation is stopped just as the sample starts to go dry.

12.9 Dissolve the salts in 5 mL of 8M HNO_3. If necessary, cover with a watchglass and heat gently to facilitate complete dissolution.

12.10 Prepare a strontium extraction chromatography column by removing the bottom plug and the cap. Press the top frit down snugly to the resin surface using a glass rod (or equivalent) and let the water drain out. Add 5 mL of HNO_3 (8M) and let the solution drain by gravity.

12.11 Carefully transfer the sample solution to the reservoir of the column. Add half and let the solution drain before adding the second half.

12.12 Rinse the beaker with 3 mL of 8M HNO_3 and add to the column after the feed has passed through.

12.13 Repeat step 12.12.

12.14 Rinse the column with 10 mL of 8M HNO_3.

12.15 Record the end time of the last rinse as the time of ^{90}Y separation (start of ^{90}Y ingrowth, t_1).

12.16 Elute the strontium with two 5 mL portions of 0.05M HNO_3 into a suitable container (for example, a liquid scintillation counting vial or centrifuge tube).

12.17 Clean a planchet with a paper towel moistened with alcohol. Wipe the planchet and let it dry.

12.18 Weigh the planchet to the nearest 0.0001 g and record the weight.

12.19 Place the planchet under a heat lamp in a fume hood.

12.20 Evaporate the strontium eluate (see 12.16) onto the planchet by adding small portions (approximately 3 mL) to the planchet and allowing each portion to evaporate to near dryness between additions.

12.21 Rinse the liquid scintillation counting vial or centrifuge tube with approximately 3 mL of 0.05M HNO_3, add to the planchet and evaporate.

12.22 After all the solution has dried, cool the planchet to room temperature and reweigh the planchet. Record the weight to the nearest 0.0001 g.

12.23 Beta count the sample as soon as possible after preparation on a low background gas proportional counting system. Count an empty planchet for an equal length of time to measure the instrument's beta background count rate. (See Test Method D1890 and Practices D3648.)

13. Calculation

13.1 *Strontium-90 Radioactivity Concentration (AC_{Sr}):*

$$AC_{Sr} = \frac{R_a - R_b}{\varepsilon_I \times V_a \times Y_{Sr} \times e^{-[\lambda_{Sr} \times (t_1 - t_0)]}} \quad (3)$$

$$Y_{Sr} = \frac{m_a - m_b}{m_c} \quad (4)$$

$$\varepsilon_I = \varepsilon_{Sr} + \left(\varepsilon_Y \times \left(1 - e^{-[\lambda_Y \times (t_m - t_1)]}\right)\right) \quad (5)$$

where:

ε_{Sr} = the mean of the values calculated using Eq 1,

ε_Y = the mean of the values calculated using Eq 2,

ε_I = ingrowth efficiency factor,

λ_{Sr} = decay constant for ^{90}Sr (6.594×10^{-5} d^{-1}),[6]

λ_Y = decay constant for ^{90}Y (0.2595 d^{-1}),

R_a = count rate of sample aliquant, in counts per second,

R_b = count rate of instrument background, in counts per second,

t_0 = date and time of sample collection,

t_1 = date and time of ^{90}Y separation,

t_m = midpoint of count of sample aliquant (date and time),

V_a = volume of sample aliquant, in litres,

Y_{Sr} = fractional chemical yield of strontium carrier,

m_a = mass of $Sr(NO_3)_2$ for the sample aliquant,

m_b = mass of $Sr(NO_3)_2$ for the blank (where appropriate—see Step 6.1), and

m_c = mass of $Sr(NO_3)_2$ added as carrier.

NOTE 2—The time differences ($t_1 - t_0$) and ($t_m - t_1$) are expressed in days.

13.2 The result of the measurement has an uncertainty due to counting statistics (counting uncertainty). The standard uncertainty of the ^{90}Sr radioactivity concentration in the sample due to counting statistics, $u_{cC}(AC_{Sr})$, is given by:

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[6] Firestone, R. B., and Shirley, V. S., *Table of Isotopes* (Eighth Edition), John Wiley and Sons, Inc., New York, 1995.

$$u_{cC}(AC_{Sr}) = \frac{\sqrt{\frac{R_a + R_b}{t_a}}}{\varepsilon_I \times V_a \times Y_{Sr} \times e^{-[\lambda_{Sr} \times (t_l - t_0)]}} \quad (6)$$

where:

t_a = count duration, in seconds, of the sample aliquant.

13.3 *Combined Standard Uncertainty:*

$$u_c(AC_{Sr}) = \sqrt{u_{cC}^2(AC_{Sr}) + AC_{Sr}^2 \times (u_r^2(\varepsilon_I) + u_r^2(V_a) + u_r^2(Y_{Sr}) + u_r^2(\ldots))^2} \quad (7)$$

where:

$u_c(AC_{Sr})$ = combined standard uncertainty of the Sr-90 activity concentration (Bq/L)

$u_r(\varepsilon_I)$ = relative standard uncertainty of the ingrowth efficiency factor,

$u_r(V_a)$ = relative standard uncertainty of the volume measurement,

$u_r(Y_{Sr})$ = relative standard uncertainty of the chemical yield of the strontium carrier,

$u_r(\ldots)$ = any additional relative uncertainty that has been determined or estimated, and

t_b = count duration, in seconds, of the background subtraction count.

13.4 *"A Priori" Minimum Detectable Radioactivity Concentration (MDC):*

$$MDC = \frac{3.29\sqrt{R_b \times t_a \times \left(1 + \frac{t_a}{t_b}\right)} + 2.71}{t_a \times \varepsilon_I \times V_a \times Y_{Sr} \times e^{-[\lambda_{Sr} \times (t_l - t_0)]}} \quad (8)$$

13.5 *Critical Level Concentration (L_c):*

$$L_c = \frac{1.645\sqrt{R_b \times t_a \times \left(1 + \frac{t_a}{t_b}\right)}}{t_a \times \varepsilon_I \times V_a \times Y_{Sr} \times e^{-[\lambda_{Sr} \times (t_l - t_0)]}} \quad (9)$$

14. Quality Control

14.1 In order to provide reasonable assurance that the analytical results obtained using this test method are valid and accurate within the confidence limits of the method, Quality Control (QC) samples are analyzed with each batch of samples undergoing analysis. Each batch should include not more than 20 samples, excluding those used for QC purposes. Laboratory or project quality assurance plans may contain more restrictive process QC requirements. The following minimum QC procedures must be followed when running the test method:

14.2 *Internal Standard*—As indicated in 12.1, an accurately added amount of Sr carrier is used as a tracer in the determination of the ^{90}Sr in the sample.

14.2.1 The yield of the Sr carrier will be calculated for each sample and associated QC samples. This yield may be reported along with the reported analytical data.

14.3 *Calibration and Calibration Verification:*

14.3.1 Standards used in the method shall be traceable to a national standards laboratory (such as NIST or NPL). In-house produced carrier solutions shall be standardized prior to use.

14.3.2 The detector counting efficiency should be determined using at least three standards.

14.3.3 The detector efficiency shall be verified monthly or prior to use, whichever is longer.

14.3.4 Acceptance limits for the verification standard are 90–110 % of the known value. If the results for the verification standard are outside the limits, recalibrate and reanalyze samples back to the last acceptable verification standard.

14.4 *Initial Demonstration of Laboratory/Instrument/Analyst Capability:*

14.4.1 If a laboratory or analyst has not performed this test before or there has been a major change in the measurement system, for example, significant instrument change, new instrument, etc., a precision and bias study must be performed to demonstrate laboratory, analyst, or instrument capability.

14.4.2 Analyze seven replicates of a standard solution prepared from a independent reference material (IRM) containing ^{90}Sr activity sufficient to reduce counting uncertainty to 1 % or less at one sigma. The matrix used for the demonstration should represent a water sample typical for which the method will be used, for example, a surface water. The total dissolved solids (TDS) of the matrix should approximate that which may be encountered in normal use.

14.4.3 Calculate the mean and standard deviation of the seven values and compare to the acceptable ranges of precision and mean bias of 10 % and ±10 %, respectively, based on a review of the collaborative study data. Test Method D5847 should be consulted on the manner by which precision and mean bias are determined from the initial demonstration study. The study should be repeated until the precision and bias are within the given limits.

14.4.4 Analyze three replicates of a blank solution matrix. The matrix used for the demonstration should represent a water sample typical for which the method will be used, for example, surface water. The total dissolved solids (TDS) of the matrix should approximate that which may be encountered in normal use.

14.4.5 Calculate the ^{90}Sr activity for each of these three blank solutions. This study should be repeated until the ^{90}Sr result of each of the three blank solutions is less than the critical level (L_c).

14.4.6 This method shall not be used for official samples until precision, bias, and blank requirements are met.

14.5 *Laboratory Control Sample (LCS):*

14.5.1 To ensure that the test method is within control limits, analyze an LCS with each batch of no more than 20 samples. The activity added to reagent water should be appropriate for the type of samples analyzed and allow sufficient precision to ensure a meaningful assessment of accuracy. The LCS must be taken through all the steps of the analytical method including sample preservation and pretreatment. The result obtained for the LCS should fall within the limit of ±25 % of the expected value.

14.5.2 If the result is not within the limit, analyses should be stopped and the reason for the failure should be identified and resolved.

14.6 *Method Blank:*

14.6.1 Analyze a reagent water test blank with each batch of no more than 20 samples. The concentration of ^{90}Sr found in the blank should be less than the critical level (L_c). If the concentration of the ^{90}Sr is found above this level, provide an explanation in a case narrative.

14.7 *Matrix Spike:*

14.7.1 The performance of a matrix spike analysis with every batch is not required, given the use of a carrier with each sample. The carrier chemical yield will indicate any problems with interferences in a specific sample matrix. If native stable strontium is present then refer to Section 6.1.

14.8 *Duplicate:*

14.8.1 To check the precision of sample analyses, analyze a sample in duplicate with each batch of no more than 20 samples. Calculate the statistical agreement (duplicate error ratio (DER)) between the two results. This calculation is performed using the combined standard uncertainty of each result as shown below.

$$DER = \frac{|AC_{\mathrm{original}} - AC_{\mathrm{dup}}|}{\sqrt{u_c^2(AC_{\mathrm{original}}) + u_c^2(AC_{\mathrm{dup}})}} \tag{10}$$

where:

AC_{original} = original sample activity concentration,
AC_{dup} = duplicate sample activity concentration,
$u_c(AC_{\mathrm{original}})$ = combined standard uncertainty of the original sample result, and
$u_c(AC_{\mathrm{dup}})$ = combined standard uncertainty of the duplicate sample result.

14.8.2 In those cases where there is insufficient sample volume to allow performance of a duplicate sample analysis, a duplicate LCS (LCS-D) should be performed and analyzed using the same DER criteria.

14.8.3 The value of DER should be less than or equal to 3.0. If the sample duplicate or LCS duplicate result is not within these limits all samples in the batch must be reanalyzed, or an explanation must be provided in a case narrative.

14.9 *Independent Reference Material (IRM):*

14.9.1 In order to verify the quantitative value produced by the test method, analyze an IRM sample, which was submitted on at least a single-blind basis (if practical) to the laboratory at least once per quarter. The concentration of analyte in the traceable reference material should be appropriate to the typical purpose for which the method is used. The value obtained shall demonstrate acceptable performance as defined by the program or the outside source.

14.9.2 In the absence of other acceptance criteria for the IRM sample, compare the IRM sample result to the IRM known value as follows:

$$R = \frac{|IRM_{\mathrm{found}} - IRM_{\mathrm{known}}|}{\sqrt{u_c^2(IRM_{\mathrm{found}}) + u_c^2(IRM_{\mathrm{known}})}} \tag{11}$$

where:

R = relative difference,
IRM_{found} = found concentration of the IRM,
IRM_{known} = known concentration of the IRM,
$u_c(IRM_{\mathrm{found}})$ = combined standard uncertainty of the IRM found concentration, and
$u_c(IRM_{\mathrm{known}})$ = combined standard uncertainty of the IRM known concentration.

14.9.3 The value of *R* should be less than or equal to 3.0. If the value of R is greater than 3.0, the method should be investigated to determine the cause.

15. Precision and Bias

15.1 The overall precision, $S_{(T)}$, and the single-operator precision, $S_{(O)}$, of this test method, within the designated range, have been found to vary with levels according to Table 1.

15.2 The collaborative test conducted on this test method included eleven laboratories, each with one operator.[7] Three radioactivity levels, 0.21 Bq/L (5.8 pCi/L), 1.52 Bq/L (41.1 pCi/L), and 4.05 Bq/L (109.5 pCi/L), were tested with three replicates per level. The determination of the precision and bias statements were made in accordance with Practice D2777. Two laboratories' data were omitted as statistical outliers.

15.3 These collaborative test data were obtained using 1 L of tap water available at each laboratory site. For other matrices, these data may not apply.

15.4 The bias of this test method, based upon the collaborative test data, was found to vary with levels according to Table 1.

16. Keywords

16.1 extraction chromatography; radioactive strontium; radioactivity; radiochemistry; strontium–90; water

TABLE 1 Precision and Bias

Amount Added, Bq/L	Mean Found, Bq/L	± Bias	± % Bias	Statistically Significant (5 % *CL*)	Precision	
					S(T)	S(O)
0.21	0.22	0.01	3.54	no	0.02	0.02
1.52	1.55	0.03	1.80	no	0.09	0.06
4.05	4.05	0.00	−0.06	no	0.26	0.21

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[7] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D19-1178. Contact ASTM Customer Service at service@astm.org.

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