Designation: D7784 – 12

# Standard Practice for the Rapid Assessment of Gamma-ray Emitting Radionuclides in Environmental Media by Gamma Spectrometry[1]

This standard is issued under the fixed designation D7784; 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 practice covers the quantification of radionuclides in environmental media (e.g., water, soil, vegetation, food) by means of simple preparation and counting with a high-resolution gamma ray detector. Because the practice is designed for rapid analysis, extensive efforts to ensure homogeneity or ideal sample counting conditions are not taken.

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

1.3 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*



## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

C998 Practice for Sampling Surface Soil for Radionuclides
D1129 Terminology Relating to Water
D3370 Practices for Sampling Water from Closed Conduits
D3648 Practices for the Measurement of Radioactivity
D3649 Practice for High-Resolution Gamma-Ray Spectrometry of Water
D7282 Practice for Set-up, Calibration, and Quality Control of Instruments Used for Radioactivity Measurements

2.2 *Other Documents:*

PCNUDAT data files National Nuclear Data Center, Brookhaven National Lab, Upton, NY, USA

## 3. Terminology

3.1 *Definitions*—for definitions of terms used in this practice, refer to Terminology D1129.

## 4. Summary of Practice

4.1 Following sample collection, sample material is placed in a suitable container for analysis by a gamma spectrometry system. A suitable container is defined as a container which will both hold the sample in a fixed geometry and for which the gamma spectrometry system has been calibrated. For solid samples, the samples may be ground, sieved, or otherwise prepared for the purpose of volume reduction, homogenization, or conformance to the calibration standard, as desired.

## 5. Significance and Use

5.1 This practice was developed for the rapid determination of gamma-emitting radionuclides in environmental media. The results of the test may be used to determine if the activity of these radionuclides in the sample exceeds the action level for the relevant incident or emergency response. The detection limits will be dependent on sample size, counting configuration, and the detector system in use.

5.2 In most cases, a sample container which is large in diameter and short in height relative to the detector will provide the best gamma-ray detection efficiency. For samples of water or other low-Z materials (e.g., vegetation), the re-entrant or Marinelli-style beaker may yield the best gamma-ray detection efficiency.

5.3 The density of the sample material and physical parameters of the sample container (e.g., diameter, height, material) may have significant consequences for the accuracy of the sample analysis as compared to the calibration. For this reason, the ideal calibration material and container (often referred to as 'geometry') will be exactly the same as the samples to be analyzed. Differences in sample container or sample matrix may introduce significant errors in detector response, especially at low gamma-ray energies. Every effort should be made to account for these differences if the exact calibration geometry is not available.

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[1] This practice 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.

5.4 This method establishes an empirical gamma-ray spectrometer calibration using standards traceable to a national standardizing body in a specific geometry selected to ensure that the container, density, and composition of the standard matches that of the samples as closely as possible. However, in some cases it may be beneficial to modify such initial calibrations using mathematical modeling or extrapolations to an alternate geometry. Use of such a model may be acceptable, depending on the measurement quality objectives of the analysis process, and provided that appropriate compensation to uncertainty estimates are included. The use of such calibration models is best supported by the successful analysis of a method validation reference material (MVRM).

5.5 This practice addresses the analysis of numerous gamma-emitting radionuclides in environmental media. This practice should be applicable to non-environmental media (for example, urine, debris, or rubble) that have similar physical properties. The key determination of "similar physical properties" is the ability to demonstrate that the gamma spectrometry system response to the sample configuration is suitably similar to that for which the system is calibrated.

5.6 For the analysis of radionuclides with low gamma-ray emission energies (<100 keV), self-absorption of the gamma-rays in the sample matrix can have a significant adverse effect on detection and quantification. The user should verify that instrument calibrations appropriately account for any self-absorption that may result from the sample matrix.

5.7 Commonly available energy and efficiency calibration standards cover the energy range of approximately 60 keV to 1836 keV. Results obtained using gamma-ray peaks outside the efficiency calibrated energy range will have greater uncertainty not accounted for in the uncertainty calculations of this practice. Great care should be taken to review the efficiency calibration values and the shape of the efficiency curve outside this range. For greater accuracy in the analysis of radionuclides whose gamma-ray energies are outside this range, a calibration standard which includes radionuclide(s) whose gamma-ray energies span the energy range of radionuclides of interest is advised.

## 6. Interferences

6.1 A list of some gamma-ray emitting radionuclides with relevant data is provided, for information only, in Table 1. This list includes radionuclides which may be of interest to agencies responding to a large scale radiological event. Through inspection of the list, it becomes apparent that there are numerous opportunities for interferences based on the gamma energy emissions. For this reason, it is important that the determination of the presence of a given radionuclide be supported by all available evidence (e.g., additional gamma-ray emissions).

6.2 The data provided in Table 1, Table 2, and Table 3 are not mandatory and are provided for information only. The composition of the nuclide library used by the laboratory should be matched to the analytical need and the data should be validated using a current reference source (e.g., Laboratoire National Henri Becquerel, http://www.nucleide.org/DDEP_WG/DDEPdata.htm, or NuDAT data files, National Nuclear Data Center, Brookhaven National Lab, Upton, NY, USA)

**TABLE 1 Example of most likely radionuclides for emergency response**

| Nuclide | Gamma Energy (keV) | Gamma Fraction | Half-Life (d) |
|---|---|---|---|
| Ac-227 | 100 | 3.17E-04 | 7.96E+03 |
| Ac-227 | 83.96 | 2.21E-04 | 7.96E+03 |
| Ag-110m | 657.75 | 9.47E-01 | 2.50E+02 |
| Ag-110m | 884.67 | 7.29E-01 | 2.50E+02 |
| Am-241 | 59.54 | 3.63E-01 | 1.58E+05 |
| Am-242m | 49.3 | 1.90E-03 | 5.55E+04 |
| Am-243 | 74.67 | 6.60E-01 | 2.70E+06 |
| Au-198 | 411.80 | 9.55E-01 | 2.70E+00 |
| Au-198 | 70.82 | 1.38E-02 | 2.70E+00 |
| Ba-133 | 30.97 | 6.29E-01 | 3.91E+03 |
| Ba-133 | 355.86 | 6.23E-01 | 3.91E+03 |
| Ba-137m | 661.62 | 9.00E-01 | 1.77E-03 |
| Ba-137m | 32.19 | 3.82E-02 | 1.77E-03 |
| Ba-140 | 537.38 | 1.99E-01 | 1.28E+01 |
| Ba-140 | 29.96 | 1.43E-01 | 1.28E+01 |
| Bi-207 | 569.67 | 9.80E-01 | 1.39E+04 |
| Bi-207 | 1063.62 | 7.70E-01 | 1.39E+04 |
| Cd-109 | 24.95 | 1.43E-01 | 4.53E+02 |
| Cd-113m | 263.7 | 6.00E-05 | 5.33E+03 |
| Cd-113m | 23.17 | 6.00E-05 | 5.33E+03 |
| Ce-141 | 145.45 | 4.80E-01 | 3.24E+01 |
| Ce-141 | 36.03 | 8.88E-02 | 3.24E+01 |
| Ce-143 | 293.3 | 4.34E-01 | 1.40E+00 |
| Ce-143 | 36.03 | 3.23E-01 | 1.40E+00 |
| Ce-144 | 133.53 | 1.08E-01 | 2.84E+02 |
| Ce-144 | 36.03 | 4.80E-02 | 2.84E+02 |
| Cf-252 | 43.4 | 1.30E-04 | 8.99E+02 |
| Cm-242 | 44.03 | 3.25E-04 | 1.63E+02 |
| Cm-243 | 103.75 | 2.08E-01 | 1.04E+04 |
| Cm-244 | 42.82 | 2.55E-04 | 6.61E+03 |
| Cm-245 | 103.76 | 2.30E-01 | 3.11E+06 |
| Co-58 | 810.75 | 9.95E-01 | 7.08E+01 |
| Co-58 | 511 | 3.00E-01 | 7.08E+01 |
| Co-60 | 1332.51 | 1.00E+00 | 1.93E+03 |
| Co-60 | 1173.23 | 9.99E-01 | 1.93E+03 |
| Co-60 | 2158.7 | 8.00E-06 | 1.93E+03 |
| Cr-51 | 320.07 | 9.83E-02 | 2.77E+01 |
| Cs-134 | 604.66 | 9.76E-01 | 7.53E+02 |
| Cs-134 | 795.76 | 8.54E-01 | 7.53E+02 |
| Cs-136 | 818.5 | 1.00E+00 | 1.30E+01 |
| Cs-136 | 1048.07 | 8.00E-01 | 1.30E+01 |
| Cs-137 | 661.62 | 8.46E-01 | 1.10E+04 |
| Cs-137 | 32.19 | 3.70E-02 | 1.10E+04 |
| Eu-152 | 40.12 | 3.00E-01 | 4.64E+03 |
| Eu-152 | 121.78 | 2.92E-01 | 4.64E+03 |
| Eu-154 | 123.1 | 4.05E-01 | 3.11E+03 |
| Eu-154 | 1274.8 | 3.55E-01 | 3.11E+03 |
| Eu-155 | 86.45 | 3.27E-01 | 1.81E+03 |
| Eu-155 | 105.31 | 2.18E-01 | 1.81E+03 |
| Fe-59 | 1099.22 | 5.65E-01 | 4.51E+01 |
| Fe-59 | 1291.56 | 4.32E-01 | 4.51E+01 |
| Gd-153 | 41.54 | 6.00E-01 | 2.42E+02 |
| Gd-153 | 40.9 | 3.20E-01 | 2.42E+02 |
| Hf-181 | 482.16 | 8.60E-01 | 4.25E+01 |
| Hf-181 | 133.05 | 4.30E-01 | 4.25E+01 |
| Hg-203 | 279.17 | 8.15E-01 | 4.66E+01 |
| Hg-203 | 72.87 | 6.40E-02 | 4.66E+01 |
| Ho-166m | 184.41 | 7.39E-01 | 4.38E+05 |
| Ho-166m | 810.31 | 5.97E-01 | 4.38E+05 |
| I-125 | 27.47 | 7.30E-01 | 6.01E+01 |
| I-125 | 27.2 | 3.92E-01 | 6.01E+01 |
| I-129 | 29.78 | 3.60E-01 | 5.73E+09 |
| I-129 | 29.46 | 1.90E-01 | 5.73E+09 |
| I-131 | 364.48 | 8.12E-01 | 8.04E+00 |
| I-131 | 636.97 | 7.27E-02 | 8.04E+00 |
| I-131 | 284.29 | 6.06E-02 | 8.04E+00 |
| I-131 | 80.18 | 2.62E-02 | 8.04E+00 |
| I-131 | 29.78 | 2.59E-02 | 8.04E+00 |
| I-132 | 667.69 | 9.87E-01 | 9.92E-02 |
| I-132 | 772.61 | 7.62E-01 | 9.92E-02 |
| In-114m | 24.21 | 2.00E-01 | 4.95E+01 |
| In-114m | 189.9 | 1.77E-01 | 4.95E+01 |
| Ir-192 | 316.49 | 8.70E-01 | 7.40E+01 |

**TABLE 1** *Continued*

| Nuclide | Gamma Energy (keV) | Gamma Fraction | Half-Life (d) |
|---|---|---|---|
| Ir-192 | 468.06 | 5.18E-01 | 7.40E+01 |
| K-40 | 1460.75 | 1.07E-01 | 4.68E+11 |
| La-140 | 1596.2 | 9.55E-01 | 1.68E+00 |
| La-140 | 487.03 | 4.30E-01 | 1.68E+00 |
| Mn-54 | 834.81 | 1.00E+00 | 3.12E+02 |
| Mo-99 | 140.51 | 9.09E-01 | 2.76E+00 |
| Mo-99 | 739.47 | 1.30E-01 | 2.76E+00 |
| Na-22 | 511 | 1.80E+00 | 9.50E+02 |
| Na-22 | 1274.54 | 9.99E-01 | 9.50E+02 |
| Nb-94 | 871.1 | 1.00E+00 | 7.42E+06 |
| Nb-94 | 702.5 | 1.00E+00 | 7.42E+06 |
| Nb-95 | 765.82 | 9.90E-01 | 3.52E+01 |
| Nd-147 | 91.1 | 2.83E-01 | 1.11E+01 |
| Nd-147 | 38.72 | 2.30E-01 | 1.11E+01 |
| Nd-147 | 531 | 1.35E-01 | 1.11E+01 |
| Np-237 | 86.49 | 1.31E-01 | 7.82E+08 |
| Np-237 | 29.38 | 9.80E-02 | 7.82E+08 |
| Np-237 | 95.87 | 2.96E-02 | 7.82E+08 |
| Np-239 | 103.7 | 2.40E-01 | 2.36E+00 |
| Np-239 | 106.13 | 2.27E-01 | 2.36E+00 |
| Pa–234m | 1001.03 | 5.90E-03 | 8.13E-04 |
| Pa-234m | 766.6 | 2.07E-03 | 8.13E-04 |
| Pb-210 | 46.52 | 4.00E-02 | 7.45E+03 |
| Pm-145 | 37.36 | 3.86E-01 | 6.47E+03 |
| Pm-145 | 36.85 | 2.11E-01 | 6.47E+03 |
| Pm-147 | 121.2 | 4.00E-05 | 9.58E+02 |
| Pm-149 | 285.9 | 3.10E-02 | 2.21E+00 |
| Pm-149 | 859.4 | 1.00E-03 | 2.21E+00 |
| Pm-151 | 340.08 | 2.24E-01 | 1.18E+00 |
| Pm-151 | 40.12 | 1.66E-01 | 1.18E+00 |
| Po-210 | 803 | 1.10E-05 | 1.38E+02 |
| Pr-144 | 696.49 | 1.49E-02 | 1.20E-02 |
| Pr-144 | 2185.61 | 7.70E-03 | 1.20E-02 |
| Pu-236 | 47.6 | 6.90E-04 | 1.04E+03 |
| Pu-236 | 109 | 1.20E-04 | 1.04E+03 |
| Pu-238 | 43.45 | 3.80E-04 | 3.21E+04 |
| Pu-238 | 99.86 | 7.24E-05 | 3.21E+04 |
| Pu-239 | 51.62 | 2.08E-04 | 8.81E+06 |
| Pu-239 | 129.28 | 6.20E-05 | 8.81E+06 |
| Pu-240 | 45.24 | 4.50E-04 | 2.39E+06 |
| Pu-240 | 104.23 | 7.00E-05 | 2.39E+06 |
| Pu-241 | 98.44 | 2.20E-05 | 5.54E+03 |
| Pu-241 | 94.66 | 1.20E-05 | 5.54E+03 |
| Pu-241 | 111 | 8.40E-06 | 5.54E+03 |
| Pu-242 | 44.7 | 3.60E-02 | 1.41E+08 |
| Pu-242 | 103.5 | 7.80E-03 | 1.41E+08 |
| Ra-226 | 185.99 | 3.28E-02 | 5.84E+05 |
| Ra-226 | 83.78 | 3.10E-03 | 5.84E+05 |
| Rb-86 | 1076.63 | 8.76E-02 | 1.86E+01 |
| Rh-106 | 511.8 | 2.06E-01 | 3.46E-04 |
| Rh-106 | 621.8 | 9.81E-02 | 3.46E-04 |
| Ru-103 | 497.08 | 8.64E-01 | 3.94E+01 |
| Ru-103 | 610.33 | 5.30E-02 | 3.94E+01 |
| Sb-124 | 602.71 | 9.81E-01 | 6.02E+01 |
| Sb-124 | 1691.04 | 5.00E-01 | 6.02E+01 |
| Sb-126 | 695.1 | 9.97E-01 | 1.25E+01 |
| Sb-126 | 666.2 | 9.97E-01 | 1.25E+01 |
| Sb-127 | 685.5 | 3.57E-01 | 3.85E+00 |
| Sb-127 | 473 | 2.50E-01 | 3.85E+00 |
| Sc-46 | 1120.52 | 1.00E+00 | 8.39E+01 |
| Sc-46 | 889.26 | 1.00E+00 | 8.39E+01 |
| Se-75 | 264.65 | 5.86E-01 | 1.20E+02 |
| Se-75 | 136 | 5.60E-01 | 1.20E+02 |
| Sn-113 | 391.71 | 6.42E-01 | 1.15E+02 |
| Sn-113 | 24.21 | 3.90E-01 | 1.15E+02 |
| Sn-123 | 1089 | 6.00E-03 | 1.29E+02 |
| Sn-123 | 1032 | 4.00E-04 | 1.29E+02 |
| Sn-125 | 1066.6 | 9.00E-02 | 9.62E+00 |
| Sn-125 | 915.5 | 4.25E-02 | 9.62E+00 |
| Sn-126 | 87.57 | 3.75E-01 | 3.65E+07 |
| Sn-126 | 26.11 | 1.89E-01 | 3.65E+07 |
| Sr-89 | 909.2 | 9.50E-04 | 5.05E+01 |
| Ta-182 | 67.75 | 4.13E-01 | 1.15E+02 |
| Ta-182 | 1121.28 | 3.50E-01 | 1.15E+02 |

**TABLE 1** *Continued*

| Nuclide | Gamma Energy (keV) | Gamma Fraction | Half-Life (d) |
|---|---|---|---|
| Tb-160 | 876.37 | 3.00E-01 | 7.21E+01 |
| Tb-160 | 298.57 | 2.74E-01 | 7.21E+01 |
| Tc-99 | 89.6 | 6.50E-06 | 7.82E+07 |
| Te-127 | 417.9 | 9.93E-03 | 3.90E-01 |
| Te-127 | 360.3 | 1.35E-03 | 3.90E-01 |
| Te-129 | 27.77 | 1.64E-01 | 4.83E-02 |
| Te-129 | 459.5 | 7.14E-02 | 4.83E-02 |
| Te-129m | 27.47 | 1.53E-01 | 3.36E+01 |
| Te-129m | 27.2 | 7.80E-02 | 3.36E+01 |
| Te-131m | 773.67 | 3.81E-01 | 1.25E+00 |
| Te-131m | 852.21 | 2.06E-01 | 1.25E+00 |
| Te-132 | 228.16 | 8.85E-01 | 3.25E+00 |
| Te-132 | 28.5 | 5.40E-01 | 3.25E+00 |
| Th-227 | 236 | 1.12E-01 | 1.85E+01 |
| Th-227 | 50.2 | 8.50E-02 | 1.85E+01 |
| Th-227 | 256.25 | 6.80E-02 | 1.85E+01 |
| Ti-44 | 78.4 | 9.47E-01 | 1.73E+04 |
| Ti-44 | 67.8 | 8.77E-01 | 1.73E+04 |
| Tl-204 | 70.82 | 7.40E-03 | 1.38E+03 |
| Tl-204 | 68.89 | 4.00E-03 | 1.38E+03 |
| Tm-170 | 84.26 | 1.00E-01 | 1.29E+02 |
| Tm-170 | 52.39 | 6.80E-02 | 1.29E+02 |
| Tm-170 | 51.35 | 3.60E-02 | 1.29E+02 |
| U-235 | 185.72 | 5.40E-01 | 2.57E+11 |
| U-235 | 143.76 | 1.05E-01 | 2.57E+11 |
| U-235 | 163.35 | 4.70E-02 | 2.57E+11 |
| U-238 | 48 | 7.50E-04 | 1.72E+12 |
| V-48 | 983.5 | 1.00E+00 | 1.61E+01 |
| V-48 | 1311.6 | 9.80E-01 | 1.61E+01 |
| V-48 | 511 | 9.80E-01 | 1.61E+01 |
| W-187 | 685.74 | 2.92E-01 | 9.96E-01 |
| W-187 | 479.57 | 2.34E-01 | 9.96E-01 |
| Y-90 | 1760.7 | 1.15E-04 | 2.67E+00 |
| Y-91 | 1204.9 | 3.00E-03 | 5.85E+01 |
| Yb-169 | 50.74 | 7.81E-01 | 3.07E+01 |
| Yb-169 | 63.12 | 4.50E-01 | 3.07E+01 |
| Yb-169 | 49.77 | 4.22E-01 | 3.07E+01 |
| Zn-65 | 1115.52 | 5.08E-01 | 2.44E+02 |
| Zn-65 | 511 | 2.83E-02 | 2.44E+02 |
| Zr-95 | 756.72 | 5.48E-01 | 6.44E+01 |
| Zr-95 | 724.18 | 4.42E-01 | 6.44E+01 |



**TABLE 2 Example of most likely radionuclides for emergency response subsequent to an incident involving a radiological dispersal device**

| Alpha Emitters | | Beta/Gamma Emitters | |
|---|---|---|---|
| Am-241 | Ra-226 | Ac-227 | P-32 |
| Cm-242 | Th-228 | Bi-210 | Pd-103 |
| Cm-243 | Th-230 | Bi-212 | Pb-210 |
| Cm-244 | Th-232 | Bi-214 | Pb-212 |
| Np-237 | U-234 | Co-57 | Pb-214 |
| Po-210 | U-235 | Co-60 | Pu-241 |
| Pu-238 | U-238 | I-125 | Ra-228 |
| Pu-239 | U-Nat | I-129 | Se-75 |
| Pu-240 | | Ir-192 | |

6.3 Several of the radionuclides listed in Table 1, Table 2, and Table 3 have x-ray emissions which may interfere with gamma-ray emissions, particularly below approximately 40 keV. It is the responsibility of the laboratory to ensure that x-ray and gamma-ray interferences are accounted for in the analytical process.

## 7. Apparatus

7.1 *Analytical Balance,* readable to 0.1 g.