<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Certified value\textsuperscript{(a)} [Bq kg\textsuperscript{-1}]</th>
<th>Uncertainty\textsuperscript{(b)} [Bq kg\textsuperscript{-1}]</th>
<th>Half-life [1]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{137}$Cs</td>
<td>328</td>
<td>8</td>
<td>30.05(8) y</td>
</tr>
<tr>
<td>$^{210}$Pb</td>
<td>306</td>
<td>15</td>
<td>22.23(12) y</td>
</tr>
<tr>
<td>$^{210}$Po\textsuperscript{(c)}</td>
<td>311</td>
<td>16</td>
<td>138.3763(17) d</td>
</tr>
<tr>
<td>$^{212}$Pb\textsuperscript{(d)}</td>
<td>37.3</td>
<td>1.5</td>
<td>-</td>
</tr>
<tr>
<td>$^{226}$Ra</td>
<td>25.1</td>
<td>2.0</td>
<td>1600(7) y</td>
</tr>
<tr>
<td>$^{228}$Ac\textsuperscript{(d)}</td>
<td>37.3</td>
<td>2.0</td>
<td>-</td>
</tr>
<tr>
<td>$^{234}$U</td>
<td>21.8</td>
<td>0.8</td>
<td>2.455(6) × 10\textsuperscript{5} y</td>
</tr>
<tr>
<td>$^{238}$U</td>
<td>22.2</td>
<td>0.8</td>
<td>4.468(5) × 10\textsuperscript{9} y</td>
</tr>
</tbody>
</table>

\textsuperscript{(a)} Certified values are calculated from the accepted data sets, each being obtained by a different laboratory following ISO Guide 35 [2], and have been recalculated to the new reference date.

\textsuperscript{(b)} The uncertainty is expressed as a combined standard uncertainty using a coverage factor $k = 1$ estimated in accordance with the JCGM 100:2008 [3] and ISO Guide 35 [2].

\textsuperscript{(c)} The $^{210}$Po activity concentration is recalculated according to the transient equilibrium with $^{210}$Pb, using the 1.017 ratio derived from their half-lives using Bateman equations.

\textsuperscript{(d)} Decay calculated with the half-life of $^{232}$Th.
### Information values for activity concentration
(based on dry mass)

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Information value(^{(a)}) [Bq kg(^{-1})]</th>
<th>Uncertainty(^{(b)}) [Bq kg(^{-1})]</th>
<th>Half-life [1]</th>
</tr>
</thead>
<tbody>
<tr>
<td>(^{40})K</td>
<td>550</td>
<td>18</td>
<td>(1.2504(30) \times 10^9) y</td>
</tr>
<tr>
<td>(^{90})Sr</td>
<td>3.8</td>
<td>0.2</td>
<td>28.8(7) y</td>
</tr>
<tr>
<td>(^{232})Th</td>
<td>37.3</td>
<td>2.0</td>
<td>(14.02(6) \times 10^9) y</td>
</tr>
<tr>
<td>(^{241})Am</td>
<td>2.3</td>
<td>0.2</td>
<td>432.6(6) y</td>
</tr>
<tr>
<td>(^{238})Pu</td>
<td>0.15</td>
<td>0.02</td>
<td>87.74(3) y</td>
</tr>
<tr>
<td>(^{239+240})Pu(^{(c)})</td>
<td>5.3</td>
<td>0.2</td>
<td>-</td>
</tr>
<tr>
<td>(^{241})Pu</td>
<td>4.6</td>
<td>0.6</td>
<td>14.33(4) y</td>
</tr>
</tbody>
</table>

(a) Information values are calculated from the accepted data sets, each being obtained by a different method of determination following ISO Guide 35 [2], and have been recalculated to the new reference date.

(b) The uncertainty is expressed as a combined standard uncertainty using a coverage factor \(k = 1\) estimated in accordance with the JCGM 100:2008 [3] and ISO Guide 35 [2].

(c) The ratio of \(^{239}\)Pu/\(^{240}\)Pu is not determined, therefore the exact decay correction cannot be calculated. Due to their long half-lives (24100 and 6561 years respectively), no visible changes are expected during the next ten years, confirmed by conservative calculation using the shorter half-life.

Reference date for all specified radionuclide decay corrections: 01 March 2021

### Origin and preparation of the material

In June 2007, 300 kg of moss-soil material was collected from an abandoned red marble mine in Gerecse Mountain in the north-west part of Hungary, by staff of the Radioanalytical Laboratory of the Food and Feed Safety Division (Hungary) in cooperation with the IAEA Terrestrial Environment Laboratory. The collected moss-soil material consists of decomposition products of moss, rock minerals from erosion/weathering processes and any washed-in soil from the neighbouring highland areas (including forest humus particles). The sampling area was undisturbed for over 40 years and therefore represents the nuclear history (before 2007), and the geochemical environment of the region.

The cleaned moss-soil was dried overnight in an oven at 80 °C and then milled in a large volume ceramic drum mill. The milled material was sieved to obtain a maximum particle size distribution of 150 µm. The final volume of the treated material was approximately 180 kg. The material density was measured from 5 test portions and found to be 1.03 ±0.05 g cm\(^{-3}\).

Bottling of IAEA-447 was carried out under normal laboratory conditions. Portions of 150 g were transferred into plastic bottles, sealed with security polyethylene caps and labeled with the code...
IAEA-447. After bottling, the material was sterilized by gamma-ray irradiation with a total dose of 25 kGy using a $^{60}$Co source, to ensure long-term stability of the material by inhibiting microbial action.

**Homogeneity of the material**

The homogeneity of the material was tested by analyzing 30 test portions using gamma-ray spectrometry: three test portions of ~30 g each were taken from 10 bottles randomly selected from the entire production sequence. $^{210}$Po, $^{226}$Ra, $^{234}$U, $^{238}$U, $^{238}$Pu, $^{239+240}$Pu and $^{241}$Am were determined by alpha spectrometry, and $^{210}$Pb and $^{90}$Sr by liquid scintillation spectrometry, following sample dissolution with microwave digestion and/or fusion, and sequential radiochemical separation procedures.

The analysis of the homogeneity study was performed under repeatability conditions to minimize variations. The homogeneity test results provided experimental evidence that satisfactory levels of between and within bottle homogeneity were attained, and that the uncertainties due to between and within bottle heterogeneity were within acceptable limits. Thus, the material was considered sufficiently homogeneous for the tested radionuclides [4,5].

**Characterization study**

IAEA-447 Certified Reference Material (CRM) was characterized on the basis of results reported by the IAEA Terrestrial Environment Laboratory in Seibersdorf, Austria. In addition, the material was analyzed by two expert laboratories (Radioanalytical Laboratory, Food and Feed Safety Division, Budapest, Hungary, and Laboratory of Radiological Measurements, Jožef Stefan Institute, Ljubljana, Slovenia). Each laboratory was asked to determine the measurands of interest in three different bottles.

The results obtained from the expert laboratories were used to confirm the IAEA certified values. In total, 30 bottles were analyzed in the Terrestrial Environment Laboratory and the expert laboratories during the characterization campaign of the moss-soil material. All the IAEA derived assigned values were in agreement with the expert laboratories’ results.

The following methods were used for the characterization of the reference material: gamma-ray spectrometry for the measurement of the gamma emitting radionuclides; liquid scintillation counting for the measurement of $^{90}$Sr, $^{210}$Pb and $^{241}$Pu after radiochemical separation; alpha-spectrometry for the measurement of $^{210}$Po, $^{226}$Ra, $^{234}$U, $^{238}$U, $^{238}$Pu, $^{239+240}$Pu, and $^{241}$Am after radiochemical separation; inductively coupled plasma mass spectrometry for the measurement of $^{232}$Th [4,5]. $^{228}$Ra was not independently determined, its value is derived from $^{228}$Ac at secular equilibrium.

**Stability of the material and analytes**

In 2021, after ten years storage in environmentally controlled conditions, the radioactive content of the IAEA-447 (Moss Soil) was reassessed by gamma-ray spectrometry. For assessing the long-term stability, the sample measurement results were compared to the decay corrected assigned values considering their uncertainty ($k=2$) by Zeta-score evaluation. The results showed no significant discrepancy to the decay corrected assigned values.

The short-term stability of the material was also tested in 2021 by keeping two bottles at -25 °C and two bottles at +70 °C for a period of two weeks. After the stability test period, 3 sub-samples from each bottle at both conditions were analysed and compared to the measurement results from the
same samples before exposure to the stability conditions. The results were evaluated by Zeta-score to the reference value, and demonstrate the material is stable under the transport conditions listed above.

The long-term stability is assured during the validity period of this certificate (as indicated below), based on the reevaluation described above, assuming the material is stored as described in the handling and storage section. Neither the harsh conditions during transportation, nor the long-term storage shows any significant effect to the assigned values and associated uncertainties.

Assignment of values – Certification procedure

The assigned certified values were established on the basis of results reported by the IAEA Terrestrial Environment Laboratory in Seibersdorf, Austria and confirmed by two expert laboratories [4]. The information values were established by measurements at a single laboratory, namely the IAEA Terrestrial Environment Laboratory in Seibersdorf, Austria.

The details concerning all reported results as well as the criteria for certification can be found in the report “Worldwide Open Proficiency Test: Determination of Natural and Artificial Radionuclides in Moss-Soil and Water”, IAEA-CU-2009-03, IAEA, Vienna, 2012 [4], which may be downloaded free of charge from: IAEA/AQ/22.

Based on the evidence on calibrators used, quality control procedures applied by the participating laboratories and their generally high-quality performance in the IAEA interlaboratory comparisons, the IAEA Reference Materials Certification Committee decided to accept these assigned values as certified or information values as presented in the table(s) above.

Statement on metrological traceability, commutability and uncertainty of assigned values

The property values and associated uncertainties assigned to the IAEA-447 Certified Reference Material are calculated as activity concentrations, expressed in the derived SI unit Bq kg⁻¹.

Evidence of metrological traceability to the SI units was provided for all results considered for the calculation of the assigned values [4,5].

The commutability of the assigned values is demonstrated via a proficiency test organised for the ALMERA and World-wide group of IAEA Member States in 2009 [4].

Intended use

This certified reference material is intended to be used for quality assurance and quality control purposes. The IAEA-447 CRM is also suitable for method development and validation of analytical procedures, including potential bias evaluation, and for training purposes. This material is not to be used as a calibrator.

Instructions for use

The IAEA-447 CRM is supplied in 150 g units. The material homogeneity is guaranteed if a minimum test portion of 0.5 g and 30 g is used for radiochemical analysis and gamma spectrometry respectively.
To overcome segregation effects due to storage or transportation, the material should be mixed before opening the bottle. All necessary precautions should be taken when opening the bottle to prevent any spread of the fine powder in the laboratory.

The IAEA does not guarantee the stability of the material for repeated sampling from the same RM unit, nor the stability of the material after opening and transfer to new containers.

**Dry mass determination**

The average moisture content of the material was determined by drying several test portions of 2 g in an oven at 105 °C for 12 hours and was found to be 3.4 %. Since the moisture content can vary with ambient humidity and temperature, it is recommended to check it prior to analysis and to report all results on a dry mass basis.

**Handling and storage**

The original unopened bottle should be stored securely at ambient temperature in a dark and dry place. It is recommended to avoid direct exposure to sunlight or to a source of heat. The material should be handled by experienced persons and is for laboratory purposes only. Any remaining material in the opened bottle should be stored in the same conditions, however the stability of the material cannot be guaranteed after initial use.

**Issue and expiry date**

The issue date of this Certified Reference Material is **May 2011**. The revision number (if any) and issue date of this certificate are provided in the footer of this document. Based on the stability testing of this material, the expiry date is **May 2031**. The IAEA is monitoring the long-term stability of the material and customers will be informed in case of any observed change.

**Legal disclaimer**

The IAEA makes no warranties, expressed or implied, with respect to the data contained in this certificate and shall not be liable for any damage that may result from the use of such data.

**Compliance with ISO Guide 31:2015**

The content of this IAEA Certified Reference Material Certificate is in compliance with ISO Guide 31:2015, Reference materials – Contents of certificates, labels and accompanying documentation [6].

**Citation of this certificate**

It is suggested to cite this certificate according to the following example, as appropriate to the citation format used: INTERNATIONAL ATOMIC ENERGY AGENCY, Certified Reference Material Certificate IAEA-447, IAEA, Vienna, 1-7 pp. (The latest version published applies, see “Note” below).

**Note**

Certified values as stated in this certificate may be updated if more information becomes available. Users of this material should ensure that the certificate in their possession is current. The current version may be found in the IAEA’s Reference Materials online catalogue:
Further information:

For further information regarding this material, please contact the producer:

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Tel.: +43 1 2600 28237
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REFERENCES


Revision information

First revision October 2021, by the TEL Radioanalytical Team. The reference date for decay corrections has been updated, activity concentrations and uncertainties are revised with the new reference date and stability contributions added.
The project officer is responsible for the content of this certificate.

The Chair of the RM Certification Committee approves this certificate and authorizes its release on behalf of the Committee.