

**IAEA**

International Atomic Energy Agency

Atoms for Peace

International Atomic Energy Agency
Department of Nuclear Sciences and Applications
IAEA Environment Laboratories

Vienna International Centre, P.O. Box 100, 1400 Vienna, Austria

REFERENCE SHEET FOR QUALITY CONTROL MATERIALS

IAEA-C1	Marble	(¹⁴ C activity, $\delta^{13}\text{C}_{\text{PDB}}$)
IAEA-C2	Travertine	(¹⁴ C activity, $\delta^{13}\text{C}_{\text{PDB}}$)
IAEA-C3	Cellulose	(¹⁴ C activity, $\delta^{13}\text{C}_{\text{PDB}}$)
IAEA-C4	Wood	(¹⁴ C activity, $\delta^{13}\text{C}_{\text{PDB}}$)
IAEA-C5	Wood	(¹⁴ C activity, $\delta^{13}\text{C}_{\text{PDB}}$)
IAEA-C6	Sucrose	(¹⁴ C activity, $\delta^{13}\text{C}_{\text{PDB}}$)
IAEA-C7	Oxalic acid	(¹⁴ C activity, $\delta^{13}\text{C}_{\text{PDB}}$)
IAEA-C8	Oxalic acid	(¹⁴ C activity, $\delta^{13}\text{C}_{\text{PDB}}$)
IAEA-C9	Wood	(¹⁴ C activity, $\delta^{13}\text{C}_{\text{PDB}}$)

Recommended values for the ¹⁴C activity in the quality control materials

TABLE1: RECOMMENDED VALUES FOR THE ¹⁴C ACTIVITY OF THE QUALITY CONTROL MATERIALS

¹⁴C activities are expressed here as pMC ("percent Modern Carbon") as reported in the literature [1].

Name	Material	¹⁴ C activity [pMC]	Estimated standard error [pMC]	Number of results accepted (reported)	Reference
IAEA-C1	Carbonate	0.00	0.02	36 (73)	[1]
IAEA-C2	Carbonate	41.14	0.03	64 (92)	[1]
IAEA-C3	Cellulose	129.41	0.06	49 (84)	[1]
IAEA-C4	Wood	0.20 - 0.44*		36 (79)	[1]
IAEA-C5	Wood	23.05	0.02	49 (75)	[1]
IAEA-C6	Sucrose	150.61	0.11	22 (39)	[1]
IAEA-C7	Oxalic acid	49.53	0.12**	7 (7)	[3]
IAEA-C8	Oxalic acid	15.03	0.17**	7 (7)	[3]
IAEA-C9	Wood	0.12 - 0.21*		12 (12)	[4]

*) Marked value is the 95% confidence interval for the median, as reported in the respective literature [1]

**) Marked values are expressed as standard uncertainty (1- σ level).

The ^{14}C activity values are reported in pMC (“percent Modern Carbon”) following the original report [1] and as reported in the literature previously [1], and not using the more recent proposed nomenclature of $^{14}\text{a}^0$ [see 5].

Origin and preparation of the material (excerpt from report [1])

IAEA-C1 Carrara marble: A slab of Carrara marble (approximately 300 kg) was freshly cut in the quarry of Carcaraia, locality of Acquabianca, municipality of Gorfigliano, province of Lucca, Italy, by the company IMEG of Viareggio, and supplied free of charge to the IAEA. The reported category of marble is “Marmo Bianco P.” and contains 100% of CaCO_3 . The marble was subsequently prepared at the IAEA, mechanically crushed, and milled down to a dust-free fraction of 1.6 - 5.0 mm.

IAEA-C2 Travertine was obtained from a fresh water carbonate (travertine) deposited on gravels of the lower terrace of the Molasse Basin in Bavaria, Germany, located approximately 50km north of Munich. The material was covered by five meters of glacial deposits. It was kindly supplied by the Institute of Hydrology of the GSF (Forschungszentrum für Umwelt und Gesundheit), Neuherberg, and homogenized by the IAEA. The ground material was mechanically ground and mixed. After adding water the suspension was thoroughly mixed again. After drying, the material was milled to powder.

IAEA-C3 Cellulose was prepared by W.G. Mook and J. van der Plicht of the Centre for Isotope Research CIO, University of Groningen, Netherlands. The starting material was produced in 1989 from one season’s harvest of ca. 40-year-old trees from Sweden, imported to Netherlands. The trees were chopped and bleached to cellulose at a paper factory in Bergum, Netherlands, and supplied to CIO in sheets. The bulk material of about 1 m^3 is kept at CIO, where part of it was cut into 50 gram pieces, sealed in plastic and shipped to IAEA.

IAEA-C4 Kauri Wood is a sub fossil Waikato Kauri wood sample excavated from peat bogs in the north island of New Zealand, where the trees fell naturally some 40 to 50 thousand years ago and were preserved in deep peats. Some 70 kg of milled beams were prepared under guidance of W.G. Hogg and H.A. Polach, in cooperation by the University of Waikato, the Australian National University (ANU), and the New Zealand Paper Industry Research Centre. A homogeneous sample was prepared based on pulping at high steam pressure and temperature the wood chips derived from the beams. The wood chips - half pencil size slivers - were mixed, the resulting pulp was mixed, compressed into soft board, and dried. During preparation, the mill was steam and water cleaned and the first 10 kg of pulp were discarded. The wet pulp being dark brown, a puff of white fibres appeared now and then. It originated from the dislodgment of previously milled *Pinus Radiata*. Staff picked out the clearly visible fibres and it is believed that the resulting sample, if prepared in 5g bulk, would be homogeneous and uncontaminated by modern carbon.

IAEA-C5 Two Creeks Wood was obtained by R.M. Kalin, S.W. Leawitt, A. Long and the IAEA from sub fossil wood (*Picea* sp.) originating from buried bed forest in eastern Wisconsin, USA, near the western shore of Lake Michigan. Before preparing this sample, many ^{14}C laboratories have dated Two Creeks wood for about 40 years. It is believed that all individual trees preserved at that location grew within a time range of less than 500 years, with individual ages of logs at that site between 110 and 250 years based on ring counts. For this sample, 100 kg (wet) of wood specimens were taken from a single locality, selected for best preservation. In order to minimize microbiological activity after sampling, it was immediately air-dried for 30 days in a low humidity environment. Large pieces (20-50 cm) were sent to IAEA for pulverization and homogenizing. At the IAEA, the pieces were milled on a laboratory ice mill to chips (ca 5 cm long) and thoroughly mixed. Final milling and homogenization took place in a high-pressure steam mill.

IAEA-C6 Sucrose (its former name was “ANU Sucrose”) was originally prepared by H.A. Polach, by selecting a batch of 2 tons of cane sucrose, which was sealed in drums (20kg each) to serve as a secondary ^{14}C standard [6] calibrated in relation to NBS Oxalic Acid I (HOxI). The material was originally available from the IAEA, the Australian National University ANU and the University of Arizona at Tucson.

IAEA-C7 and IAEA-C8 Oxalic Acids were prepared by M. Le Clercq and J. van der Plicht, by using industrially oxalic acids, one produced using the carbohydrate oxidation route in India by the Vaishali firm, Aurangabad, and synthetic oxalic acids produced using the alkaline CO₂-H₂O synthesis by the company Rhône-Poulenc, Switzerland. Both materials, one containing modern ¹⁴C levels and the other one being free of ¹⁴C, were mixed both together in desired ratios by dissolution and re-crystallization at Chemie Uettikon GmbH, Lahr, Germany [3], in quantities of 150 kg for each product.

IAEA-C9 is a sub-fossil Kauri wood (*Agathis australis*) sample, from a peat swamp in Northland, New Zealand, obtained by A. Hogg and T. Higham with a very low ¹⁴C concentration [4] similar to IAEA-C4. The new material was prepared from a single 6m long plank with a weight of 80 kg. Small wood slabs of the original material were prepared as samples by E.M. Scott, University of Glasgow, with no further sample milling applied to avoid any possibility of contamination during this process. Further extensive details on this material are given in the report of the Fourth International Radiocarbon Intercomparison (FIRI) [7], especially in section 6 (pages 227-248).

Assignment of values

The recommended values for ¹⁴C activity of the quality control materials are summarized in Table 1. The mean values were obtained in different laboratories using gas proportional counting, liquid scintillation counting or accelerator mass spectrometry. The stated standard uncertainty at the 1σ-level is based on the standard deviation derived from the individual laboratory mean values as provided in the corresponding interlaboratory comparisons. For IAEA-C4 and IAEA-C9, with ¹⁴C values being close to the detection level, confidence values were given. IAEA-C9 was additionally subject to an assessment during the FIRI radiocarbon interlaboratory comparison [7]. There, its ¹⁴C activity result was similarly reported as confidence interval, with a span ranging from 0.23-0.30 pMC, being significantly higher than in the original assessment report [4]. Due to information provided in the FIRI assessment report, the given range was considered as being potentially being affected by slight contamination effects in participating laboratories and was not taken into consideration for the reference value in Table 1.

The details concerning all reported results as well as the criteria for certification may be found in the references as cited.

Intended use

The quality control materials IAEA-C1 to IAEA-C9 are intended to provide samples of known ¹⁴C activity. It is recommended to use these quality control materials to assess the performance of measurement techniques and sample preparation procedures. The values are stated in percent Modern Carbon [pMC] as reported in the original literature, and not using the new proposed nomenclature as ¹⁴a⁰ [5].

The stated δ¹³C-values are information values and are intended only for correction of the ¹⁴C activity. They are explicitly not intended for use in stable isotope applications or as δ¹³C reference materials.

Homogeneity of the material

The homogeneity of the materials for ¹⁴C determination was tested during their preparation for the respective interlaboratory comparison exercises in amounts of several grams as necessary for ¹⁴C counting procedures. Details see in the respective literature. No homogenization of any of the materials was performed at sub-gram amounts as would be mandatory for their use in δ¹³C stable isotope analysis. Therefore the materials cannot be used as reference for δ¹³C analyses and respective values are intended only for correction of ¹⁴C data. IAEA-C1 to IAEA-C9 are sold in units of 50 g.

Handling and storage

It is recommended that materials IAEA-C1 to IAEA-C6 and IAEA-C9 are stored in their original containers under dry conditions. The materials IAEA-C7 to IAEA-C8 prepared from oxalic acid should be stored in their original containers in a cool, dry, well-ventilated area away from flames and sources of ignition.

Reference and expiry date

The reference dates of these Reference materials for the purpose of ^{14}C decay correction are the 1 January 1991 (for IAEA-C1 to IAEA-C6), 1 January 1998 (for IAEA-C7 and IAEA-C8), and 1 January 2004 (for IAEA-C9). These quality control materials and the decay-corrected reference values for their ^{14}C activities are valid until **31 December 2024**, provided the materials are handled and stored in accordance with the instructions given in this reference sheet (see "Handling and storage").

Normalization

In older literature, as cited here for the reference values, the ^{14}C activities are reported as "percent Modern Carbon" [pMC]. This denotes the non-normalized ^{14}C content at the time of sampling in reference to 0.95 times the respective activity of the standard Ox-1 oxalic acid.

No attempt was undertaken to convert the originally reported pMC values to any other quantities, e.g. to ^{14}C activities like decay corrected $^{14}\text{a}^0$ values [5].

Information Values

Additional values for the $\delta^{13}\text{C}$ isotopic composition relative to Pee Dee belemnite (PDB) isotope ratio standard are given in Table 2. Please note that the original data obtained from laboratories were reported in reference to PDB and are not altered in this reference sheet. The values can be converted to the VPDB-scale, if the $\delta^{13}\text{C}$ value of the reference material NBS 19 is set to +1.95 ‰ exactly in the PDB scale. No information is available on the individual procedures applied in each participating laboratory for the calibration of stable carbon $\delta^{13}\text{C}$ values.

These $\delta^{13}\text{C}$ values are therefore information values and should be used only for the correction of the ^{14}C activity for isotopic fractionation using established correction procedures. As a quote from [1]: "... It was noted that the $\delta^{13}\text{C}$ values as given in Table 2 are useful for $\Delta^{14}\text{C}$ corrections but the values quoted do not necessarily represent the samples' true stable isotopic composition."

TABLE 2: VALUES FOR THE $\delta^{13}\text{C}$ ISOTOPIC COMPOSITION IN REFERENCE TO THE PDB CALIBRATION MATERIAL. The given $\delta^{13}\text{C}$ values versus PDB correspond to $\delta^{13}\text{C}$ values versus VPDB exactly, if for the reference material NBS19 a $\delta^{13}\text{C}$ value of exactly -1.95‰ versus PDB is applied.

Name	Material	$\delta^{13}\text{C}_{\text{PDB}}$ [‰]	Standard deviation [‰]	Number of results accepted (reported)	References
IAEA-C1	Carbonate	2.42	0.33	59 (63)	[1]
IAEA-C2	Carbonate	-8.25	0.31	73 (79)	[1]
IAEA-C3	Cellulose	-24.91	0.49	70 (75)	[1]
IAEA-C4	Wood	-23.96	0.62	67 (68)	[1]
IAEA-C5	Wood	-25.49	0.72	66 (68)	[1]
IAEA-C6	Sucrose	-10.80	0.47	35 (36)	[1]
IAEA-C7	Oxalic acid	-14.48	0.21**	6	[3]
IAEA-C8	Oxalic acid	-18.31	0.11**	6	[3]
IAEA-C9	Wood	-23.9	1.5	170	[4]

***) Marked values are standard uncertainties at 1- σ level, calculated from the data given in the respective literature.

Limit of distribution

Each material may be ordered once per year per laboratory. This should ensure that the materials are kept available as long as possible for international use.

Legal disclaimer

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

Compliance with ISO Guide 31:2000

The content of this this IAEA Reference Sheet is in compliance with the ISO Guide 31:2000: Reference materials - Content of certificates and labels [8].

Citation of this reference sheet

It is suggested to cite this reference sheet according to the following example, as appropriate to the citation format used: INTERNATIONAL ATOMIC ENERGY AGENCY, Reference Sheet for IAEA-C1 to IAEA-C9 Quality Control Materials, IAEA, Vienna, 6 pp. (The latest version published applies; see “Note” below).

Note

Users of this material should ensure that the reference sheet in their possession is current. The current version may be found in the IAEA’s Reference Materials online catalogue under these respective ¹⁴C Quality Control Materials: <http://nucleus.iaea.org/rpst/ReferenceProducts/ReferenceMaterials/Radionuclides/index.htm>.

Further information:

For further information regarding this material, please contact:

Terrestrial Environment Laboratory
International Atomic Energy Agency
Environment Laboratories
Vienna International Centre
P.O. Box 100, A-1400 Vienna, Austria
Tel.: +43 1 2600 28237
E-mail: NAEL-TEL.Contact-Point@iaea.org

REFERENCES

- [1] ROZANSKI, K., Consultants' group meeting on ^{14}C reference materials for radiocarbon laboratories, February 18-20, 1991, Vienna, Austria. Internal Report, IAEA, Vienna (1991).
(Note: this report refers to materials C1-C6)
- [2] ROZANSKI, K., STICHLER, W., GONFIANTINI, R., SCOTT, E. M., BEUKENS, R. P., KROMER, B., VAN DER PLICHT, J., The IAEA ^{14}C Intercomparison exercise 1990, Radiocarbon, **34** 3 (1992) 506-519.
(Note: refers to materials C1-C6)
- [3] LE CLERCQ, M., VAN DER PLICHT, J., GRÖNING, M., New ^{14}C reference materials with activities of 15 and 50 pMC, Radiocarbon **40** 1 (1998) 295-297.
- [4] HOGG, A.G., HIGHAM, T., ROBERTSON, S., BEUKENS, R., KANKAINEN, T., MCCORMAC, F.G., Radiocarbon age assessment of a new, near background IAEA ^{14}C quality assurance material, Radiocarbon **37** 2 (1995) 797-805.
- [5] MOOK, W.G., VAN DER PLICHT, J., Reporting ^{14}C activities and concentrations, Radiocarbon, **41** 3 (1999) 227-239.
- [6] CURRY, L.A., POLACH, H.A., Exploratory analysis of the international radiocarbon cross-calibration data: Consensus values and interlaboratory error: preliminary note, Radiocarbon, **22** 3 (1980) 933-935
- [7] SCOTT, E.M., The Fourth International Radiocarbon Intercomparison (FIRI), Radiocarbon 45 2 (2003) 135-380.
- [8] INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO), Reference materials – Content of certificates and labels, ISO Guide 31:2000, ISO, Geneva (2000).



Mr Ales Fajgelj
Chair,
RM Certification Committee

Mr Manfred Gröning
Head, Terrestrial Environment
Laboratory

Revision History:

- Original Reference Sheet issue date: 2007-03-30
- Rev.01 (2014-03-24): Correction of typo in ^{14}C reference value for IAEA-C7 (in Table 1 corrected to 49.53 pMC from previous wrong value 49.35 pMC); added more information on origin and preparation of materials.