

**BIPM comparison BIPM.RI(II)-K1.Se-75 of**  
**activity measurements of the radionuclide <sup>75</sup>Se**  
**and links for the international comparison CCRI(II)-K2.Se-75**

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### **Abstract**

Since 1976, seven national metrology institutes (NMI), and an international organization have submitted twenty samples of known activity of <sup>75</sup>Se to the International Reference System (SIR) for activity comparison at the Bureau International des Poids et Mesures (BIPM), with comparison identifier BIPM.RI(II)-K1.Se-75. The activities ranged from about 1.4 MBq to 15 MBq. The results of a CCRI(II) comparison held in 1992 for this radionuclide, with comparison identifier CCRI(II)-K2.Se-75, are linked to the BIPM comparison for eighteen participants through individual measurements of the comparison ampoules in the SIR. This has enabled six NMIs to update their earlier SIR results and another eleven NMIs, and the BIPM to have degrees of equivalence in the key comparison database (KCDB). The degrees of equivalence between each equivalent activity measured in the SIR and the key comparison reference value (KCRV) have been calculated and the results are given in the form of a matrix for eighteen NMIs and the BIPM. A graphical presentation is also given. The results of these comparisons have been approved for publication by Section II of the Consultative Committee for Ionizing Radiation (CCRI(II)).

## **1. Introduction**

The SIR for activity measurements of  $\gamma$ -ray-emitting radionuclides was established in 1976. Each NMI may request a standard ampoule from the BIPM that is then filled (3.6 g) with the radionuclide in liquid (or gaseous) form. The NMI completes a submission form that details the standardization method used to determine the absolute activity of the radionuclide and the full uncertainty budget for the evaluation. The ampoules are sent to the BIPM where they are compared with standard sources of <sup>226</sup>Ra using pressurized ionization chambers. Details of the SIR method, experimental set-up and the determination of the equivalent activity,  $A_e$ , are all given in [1].

Since its inception until 31 December 2003, the SIR has measured 849 ampoules to give 615 independent results for 62 different radionuclides. The SIR makes it possible

for national laboratories to check the reliability of their activity measurements at any time. This is achieved by the determination of the equivalent activity of the radionuclide and by comparison of the result with the key comparison reference value determined from the results of primary realizations. These comparisons are described as BIPM ongoing comparisons and the results form the basis of the BIPM key comparison database (KCDB) of the Mutual Recognition Arrangement (MRA) [2]. The comparison described in this report is known as the BIPM.RI(II)-K1.Se-75 key comparison.

In addition, an international comparison, CCRI(II)-K2.Se-75, was held in 1992 for this radionuclide [3]. Each ampoule of solution was measured in the SIR before issue (between April and May 1992). Although twenty-one laboratories took part in this CCRI(II) comparison, six of them had previously submitted ampoules to the SIR and have now updated their earlier SIR results for this radionuclide and a further eleven NMIs that are signatory to the MRA, and the BIPM are eligible to be linked to the BIPM key comparison with entries in the KCDB.

## 2. Participants

Seven NMIs, and the IAEA have submitted twenty ampoules for the comparison of  $^{75}\text{Se}$  activity measurements since 1976. The laboratory details are given in Table 1. In cases where the laboratory has changed its name since the original submission, both the earlier and the current acronyms are given, as it is the latter that are used in the KCDB.

**Table 1. Details of the participants in the BIPM.RI(II)-K1.Se-75**

Original acronym	NMI	Full name	Country	Regional metrology organization	Date of measurement at the BIPM
ASMW*	PTB	Physikalisch-Technische Bundesanstalt	Germany	EUROMET	1976-11-15 1988-01-04*
NBS	NIST	National Institute of Standards and Technology	United States	SIM	1977-04-14 1979-03-16 1981-09-10 1988-01-04
UVVVR	CMI-IIR	Český Metrologický Institut/Czech Metrological Institute, Inspectorate for Ionizing Radiation	Czech Republic	EUROMET	1978-06-19 1980-06-20

continued overleaf.

**Table 1 continued. Details of the participants in the BIPM.RI(II)-K1.Se-75**

<b>Original acronym</b>	<b>NMI</b>	<b>Full name</b>	<b>Country</b>	<b>Regional metrology organization</b>	<b>Date of measurement at the BIPM</b>
IAEA	–	International Atomic Energy Agency	International	–	1979-02-09
–	OMH	Országos Mérésügyi Hivatal	Hungary	EUROMET	1983-01-27 1987-04-16 1988-02-04
LMRI	BNM-LNHB	Bureau national de métrologie- Laboratoire national Henri Becquerel	France	EUROMET	1989-03-13
NAC*	CSIR-NML	National Metrology Laboratory	South Africa	SADCMET	1990-06-08
–	IRA	Institut de Radiophysique Appliquée	Switzerland	EUROMET	1992-04-15

\* another laboratory in the country.

The eleven additional NMIs and the BIPM that took part in the CCRI(II) international comparison, CCRI(II)-K2.Se-75 in 1992 and are also eligible for the KCDB are shown in Table 1b together with the six laboratories that used this comparison to update their results.

**Table 1b. Details of the participants in the 1992 CCRI(II)-K2.Se-75 to be linked to BIPM.RI(II)-K1.Se-75**

<b>Original acronym</b>	<b>NMI</b>	<b>Full name</b>	<b>Country</b>	<b>Regional metrology organization</b>
–	BARC	Bhabha Atomic Research Centre	India	APMP
–	BIPM	Bureau International des Poids et Mesures	International	–
LPRI	BNM-LNHB	Bureau national de métrologie- Laboratoire national Henri Becquerel	France	EUROMET

continued overleaf.

**Table 1b continued. Details of the participants in the 1992 CCRI(II)-K2.Se-75 to be linked to BIPM.RI(II)-K1.Se-75**

Original acronym	NMI	Full name	Country	Regional metrology organization
–	CMI-IIR	Český Metrologický Institut/Czech Metrological Institute, Inspectorate for Ionizing Radiation	Czech Republic	EUROMET
–	CNEA	Comisión Nacional de Energía Atómica	Argentina	SIM
NAC*	CSIR-NML	National Metrology Laboratory	South Africa	SADCMET
–	IFIN	Institutul de Fizica si Inginerie Nucleara	Romania	EUROMET
–	KRISS	Korea Research Institute of Standards and Science	Republic of Korea	APMP
–	LNMRI	Laboratorio Nacional de Metrologia das Radiações Ionizantes	Brazil	SIM
–	NIM	National Institute of Metrology	China	APMP
–	NIST	National Institute of Standards and Technology	USA	SIM
ETL	NMIJ	National Metrology Institute of Japan	Japan	APMP
–	NPL	National Physical Laboratory	United Kingdom	EUROMET
–	NRC	National Research Council	Canada	SIM
–	OMH	Országos Mérésügyi Hivatal	Hungary	EUROMET
–	PTB	Physikalisch-Technische Bundesanstalt	Germany	EUROMET
–	RC	Radioisotope Centre POLATOM	Poland	EUROMET
–	VNIIM	D.I. Mendeleev Institute for Metrology	Russian Federation	COOMET

\* another laboratory in the country.

### 3. NMI standardization methods

Each NMI that submits ampoules to the SIR has measured the activity either by a primary standardization method or by using a secondary method, for example a calibrated ionization chamber. In the latter case, the traceability of the calibration needs to be clearly identified to ensure that any correlations are taken into account.

A brief description of the standardization methods for each laboratory, the activities submitted and the relative standard uncertainties ( $k = 1$ ) are given in Table 2. The list of acronyms used to summarize the methods is given in Appendix 3. Full uncertainty budgets have been requested as part of the comparison protocol only since 1998. However, an uncertainty budget for the IRA is given in Appendix 1 attached to this report.

The half-life used by the BIPM and for the CCRI(II)-K2 comparison is 119.8 (1) days [4]. This is in agreement with 119.64 (24) d, the value recommended by the IAEA [5]. The SIR data could be revised using the IAEA half-life. However, the updated degrees of equivalence would not differ significantly as most of the SIR measurements were performed within two months following the reference date. In the extreme case of 8 months, for the IAEA ampoule, the relative change in  $A_e$  is about  $1.9 \times 10^{-3}$ .

Details concerning the standardization methods and the uncertainties used in the international comparison are given in [6]. The VNIIM has also published their standardization method in [7], the IFIN in [8] and the BARC in [9].

**Table 2. Standardization methods of the participants for  $^{75}\text{Se}$**

NMI	Method used and acronym (see Appendix 3)	Half-life	Activity $A_i$ / kBq	Reference date YY-MM-DD	Relative standard uncertainty $\times 100$ by method of evaluation	
					A	B
PTB	4 $\pi$ PPC extrapolation 4P-PP-MX-NA-GR-CO	–	3 036 3 056 <sup>†</sup>	76-10-01 0 h UT	0.02	0.36
	4 $\pi$ (x,e)- $\gamma$ coincidence 4P-PP-MX-NA-GR-CO	–	14 910	87-12-02 12 h UT	0.4	0.9
NIST	Pressurized IC 4P-IC-GR-00-00-00 calibrated by 4 $\pi$ x- $\gamma$ coincidence 4P-PP-MX-NA-GR-CO	–	2 865 2 832 <sup>†</sup>	77-03-22 21 h UT	0.01	2.46
		119.8 d	4 888	81-08-26 20 h UT	0.01	0.96
	119.8 (1) d	4 052	87-12-03 17 h UT	0.03	0.68	
CMI-IIR	4 $\pi$ (x,e)- $\gamma$ coincidence 4P-PP-MX-NA-GR-CO	120 d	3 491	78-05-12 11 h UT	0.4	0.5
		119.3 d	6 090	80-04-30 10 h UT	0.4	0.5

continued overleaf.

**Table 2 continued. Standardization methods of the participants for <sup>75</sup>Se**

NMI	Method used and acronym (see Appendix 3)	Half-life	Activity $A_i$ / kBq	Reference date YY-MM-DD	Relative standard uncertainty $\times 100$ by method of evaluation	
					A	B
IAEA	Pressurized ionization chamber* 4P-IC-GR-00-00-00	120 d	3 542	78-05-12 11 h UT	0.4	0.5
OMH	4 $\pi$ (x,e <sub>x</sub> )- $\gamma$ coincidence 4P-PP-MX-NA-GR-CO	118.45 (25) d [10]	3 691	83-02-01 12 h UT	0.05	0.63
		119.78 (1) d [11]	7 240	87-04-15 12 h UT	0.07	0.40
			2 635	88-02-01 12 h UT	0.07	0.40
BNM-LNHB	4 $\pi$ $\beta$ - $\gamma$ coincidence 4P-PP-XR-NA-GR-CO	119.78 (1) d [11]	1 393.0 1 392.5 <sup>†</sup>	89-02-22 12 h UT	0.10	1.04
CSIR-NML	4 $\pi$ LS(x,e)- $\gamma$ coincidence [12] 4P-LS-MX-NA-GR-CO	119.64 d	11 050 2 714 <sup>†</sup>	90-06-14 12 h UT	0.02	1.41
IRA	4 $\pi$ PC(x,e)- $\gamma$ and 4 $\pi$ NaI $\gamma$ [13] 4P-PC-MX-NA-GR-CO 4P-NA-GR-00-00-HE	2874.72 (24) h	4 271.3 4 240.4 <sup>††</sup>	92-06-01 0 h UT	0.66 0.77 <sup>††</sup>	

<sup>†</sup> two ampoules submitted

\* calibrated by the CMI-IIR in 1978

<sup>††</sup> activity values corresponding to the measurement methods given in column 2. The weighted mean value 4258 (21) kBq is used for the  $A_e$  evaluation.

Details regarding the solution submitted are shown in Table 3, including any impurities, when present, as identified by the laboratories. When given, the standard uncertainties on the evaluations are shown. Recently the BIPM has developed a standard method for evaluating the activity of impurities using a calibrated Ge(Li) spectrometer [14]. The CCRI(II) agreed in 1999 [15] that this method should be followed according to the protocol described in [16] when an NMI makes such a request or when there appear to be discrepancies.

The solution used in the 1992 comparison was the same as that submitted by the IRA, shown in the last line of Table 3.

**Table 3. Details of the solution of <sup>75</sup>Se submitted**

NMI	Chemical composition	Solvent conc. / (mol dm <sup>-3</sup> )	Carrier: conc. / (μg g <sup>-1</sup> )	Density / (g cm <sup>-3</sup> )	Relative activity of impurity <sup>†</sup>
PTB	Na <sub>2</sub> SeO <sub>3</sub> in NaOH	pH = 8	Na <sub>2</sub> SeO <sub>3</sub> : 50	–	< 6 × 10 <sup>-2</sup> %
	Na <sub>2</sub> SeO <sub>3</sub> in HCHO <sup>††</sup>	0.033	Na <sub>2</sub> SeO <sub>3</sub> : 25	1	<sup>137</sup> Cs : 0.16 (16) %
NIST	H <sub>2</sub> SeO <sub>3</sub> (selenious acid) in HCl	1	H <sub>2</sub> SeO <sub>3</sub> : 180	1.015	–
			H <sub>2</sub> SeO <sub>3</sub> : 60	1.016 (2)	–
			idem	idem	–
			H <sub>2</sub> SeO <sub>3</sub> : 330	1.015	<sup>46</sup> Sc : 1.2 (1) × 10 <sup>-3</sup> %
CMI-IIR	Na <sub>2</sub> SeO <sub>3</sub> in NaOH	0.1	Na <sub>2</sub> SeO <sub>3</sub> : 20	–	< 0.1 %
	Na <sub>2</sub> SeO <sub>4</sub> in NaOH	0.1	Na <sub>2</sub> SeO <sub>4</sub> : 30	–	–
IAEA	Na <sub>2</sub> SeO <sub>3</sub> in NaOH	0.1	Na <sub>2</sub> SeO <sub>3</sub> : 20	–	< 0.1 %
OMH	Na <sub>2</sub> SeO <sub>3</sub> in water	–	Na <sub>2</sub> SeO <sub>3</sub> : 103	–	–
			Na <sub>2</sub> SeO <sub>3</sub> : 10	–	–
	Se in HCl	0.1	Se : 10	–	–
BNM-LNHB	H <sub>2</sub> SeO <sub>3</sub> in HNO <sub>3</sub>	0.1	H <sub>2</sub> SeO <sub>3</sub> : 0.33	1.016	–
CSIR-NML	Na <sub>2</sub> SeO <sub>4</sub> .10 H <sub>2</sub> O in HCl	1	Se : 214	1.013	<sup>60</sup> Co : 2.3 (1) × 10 <sup>-4</sup> %
IRA	Na <sub>2</sub> SeO <sub>3</sub> * in water	pH = 9	Na <sub>2</sub> SeO <sub>3</sub> : 50	–	–

<sup>†</sup> the ratio of the activity of the impurity to the activity of <sup>75</sup>Se at the reference date

<sup>††</sup> formaldehyde

\* same solution as that used in the CCRI(II) comparison of 1992.

#### 4. Results

All the submissions to the SIR since its inception in 1976 are maintained in a database known as the "mother-file". The activity measurements for  $^{75}\text{Se}$  arise from twenty ampoules and the SIR equivalent activity for each ampoule,  $A_{ei}$ , is given in Table 4a for each NMI,  $i$ . The dates of measurement in the SIR are given in Table 1 and are used in the KCDB and all references in this report.

The relative standard uncertainties arising from the measurements in the SIR are also shown. This uncertainty is additional to that declared by the NMI for the activity measurement shown in Table 2. Although activities submitted are compared with a given source of  $^{226}\text{Ra}$ , all the SIR results are normalized to the radium source number 5 [1].

**Table 4a. Results of SIR measurements of  $^{75}\text{Se}$**

NMI	Mass of solution $m_i / \text{g}$	Activity submitted $A_i / \text{kBq}$	N° of Ra source used	SIR $A_e / \text{kBq}$	Relative uncertainty from SIR	Combined uncertainty $u_{c,i} / \text{kBq}$
PTB	3.594 3 (2)	3 036	2	43 089	$10 \times 10^{-4}$	160
	3.618 3 (2)	3 056		43 163		160
	3.605 (2)	14 910	4	44 050 <sup>†</sup>	$31 \times 10^{-4}\#$	470
NIST	3.707 87	2 865	2	42 380	$9 \times 10^{-4}$	1000
	3.664 44	2 832		42 390		1000
	3.661 66	4 676	3	42 460	$8 \times 10^{-4}$	350
	3.765 42	4 888	3	42 110	$8 \times 10^{-4}$	410
	3.785 9	4 052	3	43 260 <sup>†</sup>	$8 \times 10^{-4}$	300
CMI-IIR	3.587 79	3 491	2	43 670	$10 \times 10^{-4}$	270
	3.547 01	6 090	3	43 910 <sup>†</sup>	$8 \times 10^{-4}$	280
IAEA	3.554 92	3 542	2	43 710	$16 \times 10^{-4}$	280
OMH	3.604 6	3 691	3	42 430	$8 \times 10^{-4}$	270
	3.602 7	7 240	4	42 970	$8 \times 10^{-4}$	180
	3.604 8	2 635	3	42 860 <sup>†</sup>	$8 \times 10^{-4}$	180
BNM-LNHB	3.627 48	1 393.0	2	42 158	$10 \times 10^{-4}$	440
	3.626 42	1 392.5		42 062 <sup>†</sup>		440
CSIR-NML	3.673 00	11 050	4	41 854	$8 \times 10^{-4}$	590
	3.605 65	2 714	3	42 141 <sup>†</sup>		590
IRA	3.428	4 258 *	3	42 610	$8 \times 10^{-4}$	210

# reflects the uncertainty given by the ASMW for the impurity

\* weighted mean of the two results given in Table 2

† result superseded by the CCRI(II) comparison.

Measurements repeated at the BIPM over a period of eight months produced the same comparison results for the OMH (1983). These measurements confirm the validity of the half-life value used and the absence of significant impurity in the solution.

The corrections for impurities are negligible in all cases except for ASMW where the correction is 1.003 (3).

No recent submission has been identified as a pilot study so the most recent result of each NMI is normally eligible for Appendix B of the MRA. However, the IAEA no longer undertakes the metrology of activity, therefore its result is not included in the KCDB.

The results of the international comparison CCRI(II)-K2.Se-75 have been published [3]. The seventeen NMIs and the BIPM to be added to the matrix of degrees of equivalence from this international comparison are those given in Table 1b. The results for these laboratories are linked to the BIPM comparison, through the measurement of each of the ampoules in the SIR prior to issue. The results for the six laboratories already in the SIR and the twelve other laboratories, all of which participated in the international comparison, are given in Table 4b.

The mass of solution in the ampoules of the CCRI(II) comparison ranged between 3.21 g and 3.44 g. The SIR measurements of these ampoules used the radium source number 3.

The uncertainties for the results from the international comparison linked to the SIR are comprised of the original uncertainties (as published in [6]) together with the uncertainty in the SIR measurement ( $8 \times 10^{-4}$ ).

The results for the NIST, CMI-IIR, OMH, BNM-LNHB and the CSIR-NML from the international comparison agree within the standard uncertainty with their most recent original SIR equivalent activity values, which is not the case for the PTB. However, as the CCRI comparison result is more recent for each of these NMIs, the earlier SIR results have been superseded by the values in Table 4b for the results presented in the KCDB.

**Table 4b. Results of the 1992 international comparison measurements of <sup>75</sup>Se linked to the SIR**

NMI	Activity * concentration ( $A/m$ ) <sub><i>i</i></sub> / (MBq g <sup>-1</sup> )	Standard uncertainty / (MBq g <sup>-1</sup> )	SIR $A_{ei}$ / kBq	Combined uncertainty $u_c(A_{ei})$ /kBq
AECL**	1.271	0.013	43 610	440
BARC	1.2382	0.0030	42 480	130
BIPM	1.2245	0.0061	42 010	210
BNM-LNHB	1.2356	0.0014	42 406	59
CMI-IIR	1.291	0.017	44 280	600
CNEA	1.242	0.019	42 590	650
CSIR-NML	1.2318	0.0035	42 260	130
IFIN	1.300	0.017	44 600	580
KRISS	1.262	0.016	43 320	560
LNMRI	1.2399	0.0085	42 550	290
NIM	1.257	0.022	43 120	760
NIST ***	1.2601	0.0086	43 240	300
NMIJ	1.284	0.021	44 070	720
NPL	1.245	0.014	42 710	470
NRC	1.2593	0.0013	43 175	57
OMH	1.2476	0.0071	42 780	250
PTB	1.238	0.004	42 471	49
RC	1.239	0.007	42 490	240
VNIIM	1.250	0.013	42 890	450

\* referenced to 1 April 1992, 0 h UT

\*\* Atomic Energy of Canada Ltd

\*\*\*ionization chamber calibrated in 1982 by  $4\pi(x,e)-\gamma$  anti-coincidence measurements.

#### 4.1 The key comparison reference value

The key comparison reference value is derived from the unweighted mean of all the results submitted to the SIR with the following provisions:

- a) only primary standardized solutions are accepted, or ionization chamber measurements that are directly traceable to a primary measurement in the laboratory;
- b) each NMI or other laboratory has only one result (normally the most recent result or the mean if more than one ampoule is submitted);
- c) any outliers are identified using a reduced chi-squared test and, if necessary, excluded from the KCRV using the normalized error test with a test value of four;
- d) exclusions must be approved by the CCRI(II).

The reduced data set used for the evaluation of the KCRVs is known as the KCRV file and is the reduced data set from the SIR mother-file. Although the KCRV may be modified when other NMIs participate, on the advice of the Key Comparison Working Group of the CCRI(II), such modifications are only made by the CCRI(II), normally during one of its biennial meetings.

Consequently, the KCRV for  $^{75}\text{Se}$  has been identified as 43 040 (160) kBq using the SIR result for the ASMW, NIST (1987) and the IRA and the 1992 comparison results for the other laboratories listed in Table 4b. As the AECL also made primary measurements of the  $^{75}\text{Se}$  solution as part of the 1992 comparison, its result has been included in the KCRV as an independent realization, although this laboratory is not eligible for the KCDB and hence does not appear in Table 1b.

#### 4.2 Degrees of equivalence

Every NMI that has submitted ampoules to the SIR is entitled to have one result included in Appendix B of the KCDB as long as the NMI is a signatory or designated institute listed in the MRA. Normally, the most recent result is the one included. Any NMI may withdraw its result only if all the participants agree.

The degree of equivalence of a given measurement standard is the degree to which this standard is consistent with the key comparison reference value [2]. The degree of equivalence is expressed quantitatively in terms of the deviation from the key comparison reference value and the expanded uncertainty of this deviation ( $k = 2$ ). The degree of equivalence between any pair of national measurement standards is expressed in terms of their difference and the expanded uncertainty of this difference and is independent of the choice of key comparison reference value.

##### 4.2.1 *Comparison of a given NMI with the KCRV*

The degree of equivalence of a particular NMI,  $i$ , with the key comparison reference value is expressed as the difference between the results

$$D_i = A_{e_i} - \text{KCRV} \quad (1)$$

and the expanded uncertainty ( $k = 2$ ) of this difference,  $U_i$ , known as the equivalence uncertainty, hence

$$U_i = 2u_{D_i}, \quad (2)$$

taking correlations into account as appropriate (see Appendix 2).

#### 4.2.2 Comparison of any two NMIs with each other

The degree of equivalence,  $D_{ij}$ , between any pair of NMIs,  $i$  and  $j$ , is expressed as the difference in their results

$$D_{ij} = D_i - D_j = A_{ei} - A_{ej} \quad (3)$$

and the expanded uncertainty of this difference  $U_{ij}$  where

$$u_{D_{ij}}^2 = u_i^2 + u_j^2 - \sum_k (f_k u_{\text{corr},k})_i^2 - \sum_k (f_k u_{\text{corr},k})_j^2 \quad (4)$$

and any obvious correlations in the standard uncertainties for a given component,  $u_{\text{corr},k}$ , between the NMIs (such as a traceable calibration) are subtracted using an appropriate correlation coefficient,  $f_k$ , as are normally those correlations coming from the SIR.

The uncertainties of the differences between the values assigned by individual NMIs and the key comparison reference value (KCRV) are not necessarily the same uncertainties that enter into the calculation of the uncertainties in the degrees of equivalence between a pair of participants. Consequently, the uncertainties in the table of degrees of equivalence cannot be generated from the column in the table that gives the uncertainty of each participant with respect to the KCRV. However, the effects of correlations have been treated in a simplified way, as the degree of confidence in the uncertainties themselves does not warrant a more rigorous approach.

Table 5 shows the matrix of all the degrees of equivalence as they will appear in Appendix B of the KCDB. It should be noted that for consistency within the KCDB, a simplified level of nomenclature is used with  $A_{ei}$  replaced by  $x_i$ . The introductory text is that agreed for the comparison. The graph of the first column of results in Table 5, corresponding to the degrees of equivalence with respect to the KCRV (identified as  $x_R$  in the KCDB), is shown in Figure 1. This representation indicates in part the degree of equivalence between the NMIs but does not take into account the correlations between the different NMIs. However, the matrix of degrees of equivalence shown in yellow in Table 5 does take the known correlations into account.

## Conclusion

The BIPM ongoing key comparison for  $^{75}\text{Se}$ , BIPM.RI(II)-K1.Se-75 currently comprises one result. The results of seventeen NMIs and the BIPM that took part in the CCRI(II)-K2.Se-75 comparison in 1992 have been linked to the BIPM ongoing key comparison through the measurements made in the SIR. All these results have been analysed with respect to the KCRV determined for this radionuclide, and with respect to each other. The matrix of degrees of equivalence has been approved by the CCRI(II) and is published in the BIPM key comparison database.

Other results may be added as and when other NMIs contribute  $^{75}\text{Se}$  activity measurements to this comparison.

### Acknowledgements

The authors would like to thank the NMIs and R.H. Martin of the AECL for their participation in the comparisons, Mr Christian Colas of the BIPM for his dedicated work in maintaining the SIR since its inception and for the thousands of measurements he has made over the years, and Dr P.J. Allisy-Roberts of the BIPM for editorial assistance.

### References

- [1] Ratel G. The international reference system for activity measurements of  $\gamma$ -emitting radionuclides (SIR), 2004, *BIPM Monograph XX*, (in preparation).
- [2] MRA: *Mutual recognition of national measurement standards and of calibration and measurement certificates issued by national metrology institutes*, International Committee for Weights and Measures, 1999, 45 pp. <http://www.bipm.org/pdf/mra.pdf>.
- [3] Ratel G., International comparison of activity measurements of a solution of  $^{75}\text{Se}$ , 2002, *Nucl. Instr. Meth.* **A481**, 241-252.
- [4] BNM-CEA, *Table de Radionucléides*, Version 1982, BNM-LNHB, Gif-sur-Yvette.
- [5] IAEA-TECDOC-619, 1991, X-ray and gamma-ray standards for detector calibration, Vienna, IAEA.
- [6] Ratel G., Activity measurements of a  $^{75}\text{Se}$  solution in the frame of an international comparison (June 1992), 1993, *Working document CCEMRI(II)/93-14* submitted to the 12th meeting of the CCEMRI(II).
- [7] Sazonova T.E., Zanevsky A.V., Sepman S.V., Standardization of  $^{75}\text{Se}$  and x-ray emission probability data, 1996, *Nucl. Instr. Meth.*, **A369**, 421-423
- [8] Grigorescu E.L., Sahagia Maria, Razdolescu Anamaria, Luca A., Radwan R.M., Standardization of  $^{110\text{m}}\text{Ag}$  and  $^{75}\text{Se}$  by the beta-efficiency extrapolation method, 1998, *Appl. Radiat. Isot.* **49** 1165-1170.
- [9] Srivastava P.K., Sahoo H.K., Khera G.D., Misra S.C., Standardisation of Se-75, some observations, 1994, *Nucl. Instr. Meth.*, **A339**, 391-393.
- [10] BNM-CEA, *Table de Radionucléides*, Version 1975, BNM-LNHB, Gif-sur-Yvette.
- [11] BNM-CEA, *Table de Radionucléides*, Version 1987, BNM-LNHB, Gif-sur-Yvette.
- [12] Simpson B.R.S. and Meyer B.R.,  $^{75}\text{Se}$ : Activity measurements by  $4\pi(\text{LS})\epsilon$ , X-gamma coincidence counting and International comparison of results, 1995, *NAC Report*, NAC/95-02.

- [13] Gostely J.-J. and Décombaz M., Activity measurement of  $^{75}\text{Se}$ , 1993, *Working document CCEMRI(II)/93-10* submitted to the 12th meeting of the CCEMRI(II).
- [14] Michotte C., Efficiency calibration of the Ge(Li) detector of the BIPM for SIR-type ampoules, 1999, [\*Rapport BIPM-1999/03\*](#), 15 pp.
- [15] *Comité Consultatif pour les Étalons de Mesures des Rayonnements Ionisants 16th meeting (1999)*, 2001, CCRI(II) 81-82.
- [16] Michotte C., Protocol on the use of the calibrated spectrometer of the BIPM for the measurement of impurities in ampoules submitted to the SIR, 2001, [\*CCRI\(II\)/01-01\*](#), 2 pp.

Table 5. Table of degrees of equivalence and introductory text for <sup>75</sup>Se

Key comparison BIPM.RI(II)-K1.Se-75

MEASURAND : Equivalent activity of <sup>75</sup>Se

Key comparison reference value: the SIR reference value for this radionuclide is  $x_R = 43\,040$  kBq with a standard uncertainty,  $u_R = 160$  kBq (see Section 4.1 of the Final Report).  
The value  $x_i$  is the equivalent activity for laboratory  $i$ .

The degree of equivalence of each laboratory with respect to the reference value is given by a pair of terms:  
 $D_i = (x_i - x_R)$  and  $U_i$ , its expanded uncertainty ( $k = 2$ ), both expressed in MBq, and  
 $U_i = 2((1 - 2/n)u_i^2 + (1/n^2)\sum u_i^2)^{1/2}$  when the laboratory has contributed to the calculation of  $x_R$ , with  $n$  the number of contributing laboratories

The degree of equivalence between two laboratories is given by a pair of terms:  
 $D_{ij} = D_i - D_j = (x_i - x_j)$  and  $U_{ij}$ , its expanded uncertainty ( $k = 2$ ), both expressed in MBq.

The approximation  $U_{ij} \sim 2(u_i^2 + u_j^2)^{1/2}$  is used in the following table.

Linking CCRI(II)-K2.Se-75 (1992) to BIPM.RI(II)-K1.Se-75

The value  $x_i$  is the equivalent activity for laboratory  $i$  participant in CCRI(II)-K2.Se-75 having also been measured in the SIR (see Final report).

The degree of equivalence of laboratory  $i$  participant in CCRI(II)-K2.Se-75 with respect to the key comparison reference value is given by a pair of terms:  $D_i = (x_i - x_R)$  and  $U_i$ , its expanded uncertainty ( $k = 2$ ), both expressed in MBq.  
 $U_i = 2((1 - 2/n)u_i^2 + (1/n^2)\sum u_i^2)^{1/2}$  when the laboratory has contributed to the calculation of  $x_R$ , with  $n$  the number of contributing laboratories.

The degree of equivalence between two laboratories  $i$  and  $j$ , one participant in BIPM.RI(II)-K1.Se-75 and one in CCRI(II)-K2.Se-75 or both participant in CCRI(II)-K2.Se-75, is given by a pair of terms:  $D_{ij} = D_i - D_j$  and  $U_{ij}$ , its expanded uncertainty ( $k = 2$ ), both expressed in MBq, where the approximation  $U_{ij} \sim 2(u_i^2 + u_j^2)^{1/2}$  is used.

These statements make it possible to extend the BIPM.RI(II)-K1.Se-75 matrices of equivalence to the other participants in CCRI(II)-K2.Se-75.

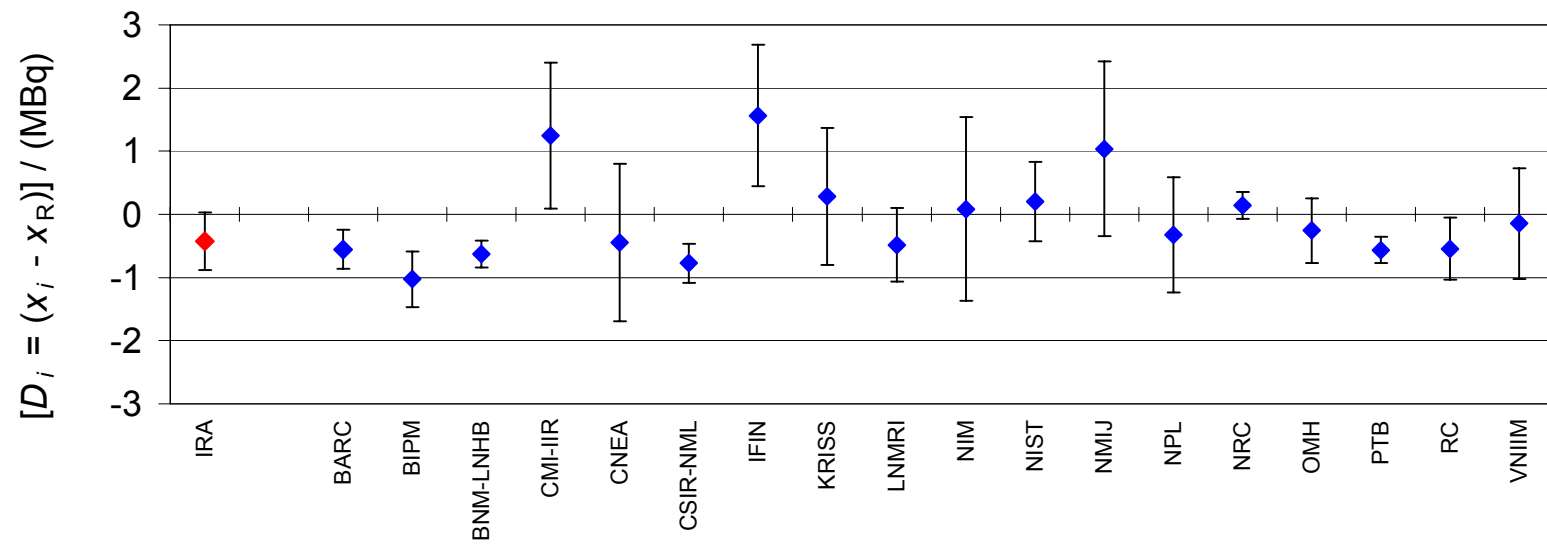
Table 5 continued

Lab <i>i</i> ↓	$D_i$ / MBq		IRI		BARC		BIPM		BNM-LNHB		CMI-IIR		CNEA		CSIR-NML		IFIN		KRISS		LNMRI	
	$D_i$ / MBq	$U_i$	$D_{ij}$ / MBq	$U_{ij}$	$D_{ij}$ / MBq	$U_{ij}$	$D_{ij}$ / MBq	$U_{ij}$	$D_{ij}$ / MBq	$U_{ij}$	$D_{ij}$ / MBq	$U_{ij}$	$D_{ij}$ / MBq	$U_{ij}$	$D_{ij}$ / MBq	$U_{ij}$	$D_{ij}$ / MBq	$U_{ij}$	$D_{ij}$ / MBq	$U_{ij}$	$D_{ij}$ / MBq	$U_{ij}$
IRA	-0.42	0.46			0.13	0.49	0.60	0.59	0.20	0.43	-1.67	1.27	0.02	1.37	0.35	0.49	-1.99	1.23	-0.71	1.20	0.06	0.71
BARC	-0.55	0.31	-0.13	0.49			0.47	0.49	0.07	0.29	-1.80	1.23	-0.11	1.33	0.22	0.37	-2.12	1.19	-0.84	1.15	-0.07	0.64
BIPM	-1.02	0.44	-0.60	0.59	-0.47	0.49			-0.40	0.44	-2.27	1.27	-0.58	1.37	-0.25	0.49	-2.59	1.23	-1.31	1.20	-0.54	0.72
BNM-LNHB	-0.63	0.22	-0.20	0.43	-0.07	0.29	0.40	0.44			-1.87	1.21	-0.18	1.31	0.15	0.29	-2.19	1.17	-0.91	1.13	-0.14	0.59
CMI-IIR	1.25	1.16	1.67	1.27	1.80	1.23	2.27	1.27	1.87	1.21			1.69	1.77	2.02	1.23	-0.32	1.67	0.96	1.64	1.73	1.33
CNEA	-0.44	1.25	-0.02	1.37	0.11	1.33	0.58	1.37	0.18	1.31	-1.69	1.77			0.33	1.33	-2.01	1.74	-0.73	1.72	0.04	1.42
CSIR-NML	-0.77	0.31	-0.35	0.49	-0.22	0.37	0.25	0.49	-0.15	0.29	-2.02	1.23	-0.33	1.33			-2.34	1.19	-1.06	1.15	-0.29	0.64
IFIN	1.57	1.12	1.99	1.23	2.12	1.19	2.59	1.23	2.19	1.17	0.32	1.67	2.01	1.74	2.34	1.19			1.28	1.61	2.05	1.30
KRISS	0.29	1.08	0.71	1.20	0.84	1.15	1.31	1.20	0.91	1.13	-0.96	1.64	0.73	1.72	1.06	1.15	-1.28	1.61			0.77	1.26
LNMRI	-0.48	0.58	-0.06	0.71	0.07	0.64	0.54	0.72	0.14	0.59	-1.73	1.33	-0.04	1.42	0.29	0.64	-2.05	1.30	-0.77	1.26		
NIM	0.09	1.46	0.51	1.58	0.64	1.54	1.11	1.58	0.71	1.52	-1.16	1.94	0.53	2.00	0.86	1.54	-1.48	1.91	-0.20	1.89	0.57	1.63
NIST	0.21	0.63	0.63	0.73	0.76	0.65	1.23	0.73	0.83	0.61	-1.04	1.34	0.65	1.43	0.98	0.65	-1.36	1.31	-0.08	1.27	0.69	0.83
NMIJ	1.04	1.38	1.46	1.50	1.59	1.46	2.06	1.50	1.66	1.44	-0.21	1.87	1.48	1.94	1.81	1.46	-0.53	1.85	0.75	1.82	1.52	1.55
NPL	-0.32	0.91	0.10	1.03	0.23	0.98	0.70	1.03	0.30	0.95	-1.57	1.52	0.12	1.60	0.45	0.98	-1.89	1.49	-0.61	1.46	0.16	1.10
NRC	0.14	0.21	0.57	0.43	0.70	0.28	1.17	0.44	0.77	0.16	-1.11	1.21	0.59	1.30	0.92	0.28	-1.43	1.17	-0.15	1.13	0.63	0.59
OMH	-0.25	0.51	0.17	0.65	0.30	0.56	0.77	0.65	0.37	0.51	-1.50	1.30	0.19	1.39	0.52	0.56	-1.82	1.26	-0.54	1.23	0.23	0.77
PTB	-0.56	0.21	-0.14	0.43	-0.01	0.28	0.46	0.43	0.07	0.15	-1.81	1.20	-0.12	1.30	0.21	0.28	-2.13	1.16	-0.85	1.12	-0.08	0.59
RC	-0.54	0.49	-0.12	0.64	0.01	0.55	0.48	0.64	0.08	0.49	-1.79	1.29	-0.10	1.39	0.23	0.55	-2.11	1.26	-0.83	1.22	-0.06	0.75
VNIIM	-0.14	0.88	0.28	0.99	0.41	0.94	0.88	0.99	0.48	0.91	-1.39	1.50	0.30	1.58	0.63	0.94	-1.71	1.47	-0.43	1.44	0.34	1.07

Lab <i>i</i> ↓	$D_i$ / MBq		NIM		NIST		NMIJ		NPL		NRC		OMH		PTB		RC		VNIIM	
	$D_i$ / MBq	$U_i$	$D_{ij}$ / MBq	$U_{ij}$	$D_{ij}$ / MBq	$U_{ij}$	$D_{ij}$ / MBq	$U_{ij}$	$D_{ij}$ / MBq	$U_{ij}$	$D_{ij}$ / MBq	$U_{ij}$	$D_{ij}$ / MBq	$U_{ij}$	$D_{ij}$ / MBq	$U_{ij}$	$D_{ij}$ / MBq	$U_{ij}$	$D_{ij}$ / MBq	$U_{ij}$
IRA	-0.42	0.46	-0.51	1.58	-0.63	0.73	-1.46	1.50	-0.10	1.03	-0.57	0.43	-0.17	0.65	0.14	0.43	0.12	0.64	-0.28	0.99
BARC	-0.55	0.31	-0.64	1.54	-0.76	0.65	-1.59	1.46	-0.23	0.98	-0.70	0.28	-0.30	0.56	0.01	0.28	-0.01	0.55	-0.41	0.94
BIPM	-1.02	0.44	-1.11	1.58	-1.23	0.73	-2.06	1.50	-0.70	1.03	-1.17	0.44	-0.77	0.65	-0.46	0.43	-0.48	0.64	-0.88	0.99
BNM-LNHB	-0.63	0.22	-0.71	1.52	-0.83	0.61	-1.66	1.44	-0.30	0.95	-0.77	0.16	-0.37	0.51	-0.07	0.15	-0.08	0.49	-0.48	0.91
CMI-IIR	1.25	1.16	1.16	1.94	1.04	1.34	0.21	1.87	1.57	1.52	1.11	1.21	1.50	1.30	1.81	1.20	1.79	1.29	1.39	1.50
CNEA	-0.44	1.25	-0.53	2.00	-0.65	1.43	-1.48	1.94	-0.12	1.60	-0.59	1.30	-0.19	1.39	0.12	1.30	0.10	1.39	-0.30	1.58
CSIR-NML	-0.77	0.31	-0.86	1.54	-0.98	0.65	-1.81	1.46	-0.45	0.98	-0.92	0.28	-0.52	0.56	-0.21	0.28	-0.23	0.55	-0.63	0.94
IFIN	1.57	1.12	1.48	1.91	1.36	1.31	0.53	1.85	1.89	1.49	1.43	1.17	1.82	1.26	2.13	1.16	2.11	1.26	1.71	1.47
KRISS	0.29	1.08	0.20	1.89	0.08	1.27	-0.75	1.82	0.61	1.46	0.15	1.13	0.54	1.23	0.85	1.12	0.83	1.22	0.43	1.44
LNMRI	-0.48	0.58	-0.57	1.63	-0.69	0.83	-1.52	1.55	-0.16	1.10	-0.63	0.59	-0.23	0.77	0.08	0.59	0.06	0.75	-0.34	1.07
NIM	0.09	1.46			-0.12	1.63	-0.95	2.09	0.41	1.79	-0.06	1.52	0.34	1.60	0.65	1.52	0.63	1.59	0.23	1.77
NIST	0.21	0.63	0.12	1.63			-0.83	1.56	0.53	1.12	0.07	0.61	0.46	0.78	0.77	0.61	0.75	0.77	0.35	1.08
NMIJ	1.04	1.38	0.95	2.09	0.83	1.56			1.36	1.72	0.90	1.44	1.29	1.52	1.60	1.44	1.58	1.52	1.18	1.70
NPL	-0.32	0.91	-0.41	1.79	-0.53	1.12	-1.36	1.72			-0.47	0.95	-0.07	1.06	0.24	0.95	0.22	1.06	-0.18	1.30
NRC	0.14	0.21	0.06	1.52	-0.07	0.61	-0.90	1.44	0.47	0.95			0.40	0.51	0.70	0.15	0.69	0.49	0.29	0.91
OMH	-0.25	0.51	-0.34	1.60	-0.46	0.78	-1.29	1.52	0.07	1.06	-0.40	0.51			0.31	0.51	0.29	0.69	-0.11	1.03
PTB	-0.56	0.21	-0.65	1.52	-0.77	0.61	-1.60	1.44	-0.24	0.95	-0.70	0.15	-0.31	0.51			-0.02	0.49	-0.42	0.91
RC	-0.54	0.49	-0.63	1.59	-0.75	0.77	-1.58	1.52	-0.22	1.06	-0.69	0.49	-0.29	0.69	0.02	0.49			-0.40	1.02
VNIIM	-0.14	0.88	-0.23	1.77	-0.35	1.08	-1.18	1.70	0.18	1.30	-0.29	0.91	0.11	1.03	0.42	0.91	0.40	1.02		

Figure 1. Graph of degrees of equivalence with the KCRV for  $^{75}\text{Se}$   
 (as it appears in Appendix B of the MRA)

**BIPM.RI(II)-K1.Se-75 and 1992 CCRI(II)-K2.Se-75**  
**Degrees of equivalence for equivalent activity of  $^{75}\text{Se}$**



**Appendix 1. Uncertainty budgets for the activity of <sup>75</sup>Se submitted to the SIR****IRA coincidence method**

<b>Relative standard uncertainties</b>	$u_i \times 10^4$
counting statistics	12
weighing	6
dead time	0.2
background	8
timing	0.2
extrapolation	50
decay correction	1.5
adsorption	3
decay scheme parameters	40
<b>Relative combined standard uncertainty, <math>u_c</math></b>	<b>66</b>

**IRA 4 $\pi$  counting**

<b>Relative standard uncertainties</b>	$u_i \times 10^4$
counting statistics	7
weighing	6
dead time	10
background	2
timing	1
decay correction	1.5
efficiency calculation	30
adsorption	3
decay scheme parameters	70
<b>Relative combined standard uncertainty, <math>u_c</math></b>	<b>77</b>

## Appendix 2. Evaluation of the uncertainty of the degree of equivalence

Table 5 indicates for each laboratory the degree of equivalence  $D_i$  with its associated uncertainty  $U_i$ . This appendix presents the procedure used to evaluate these uncertainties.

The degree of equivalence of one laboratory is defined as the difference between the individual value of the equivalent activity  $A_{ei}$  for an NMI  $i$  and a suitable reference value which has been evaluated by the KCDB Working Group and the expanded uncertainty of this difference. Currently, the reference value, KCRV, for a given radionuclide is calculated as the arithmetic mean value of the SIR experimental entries for this radionuclide. Briefly at least four situations can occur depending on the consistency of the experimental SIR data sets :

1. All data are consistent and contribute to the reference value; this is the general case;
2. The value obtained by a laboratory that no longer exists, is used as long as it fits the usual quality criteria; it is taken into account when evaluating the reference value but does not appear in the matrices of results;
3. A value, that has been identified for example as an outlier, is not taken into account for the evaluation of the reference value but, nevertheless, the corresponding laboratory appears in the matrices of results.

The situation where a laboratory that no longer exists but contributes to the reference value and where an outlier has been identified in the data set can occur. This is a combination of both situation 2) and situation 3). The results, deduced from these two preceding cases, are also presented here, case 4.

In the following, the expression of the uncertainty for these four cases is considered on the assumption that the uncertainties of the different equivalent activities  $A_{ei}$  are not correlated. For the sake of coherence with the definition of the variables used in the text, the following notation is used :

$x_i = A_{ei}$  and  $u_i = u_{A_{ei}}$  its uncertainty.

**Case 1.** All  $n$  laboratories contribute to the reference value, and appear in Table 5. In this case obviously we have

$$x_{\text{ref}} = \bar{x} = \frac{\sum_{j=1}^n x_j}{n} \quad (\text{A-1})$$

$$D_i = x_i - x_{\text{ref}} \quad (\text{A-2})$$

$$D_i = x_i - \frac{\sum_{j=1}^n x_j}{n} = x_i \left(1 - \frac{1}{n}\right) - \frac{\sum_{j \neq i} x_j}{n} \quad (\text{A-3})$$

At this stage the uncertainty of  $D_i$  has to be calculated. Applying the method of Gauß for the propagation of the uncertainties it is necessary to calculate the partial derivatives of  $D_i$  with respect to the  $x_i$ .

$$\text{So } \frac{\partial D_i}{\partial x_i} = \left(1 - \frac{1}{n}\right), \text{ and} \quad (\text{A-4})$$

$$\frac{\partial D_i}{\partial x_j} = -\frac{1}{n}, (j \neq i). \quad (\text{A-5})$$

Then the total combined uncertainty becomes

$$u_{c_i}^2 = \left(\frac{\partial D_i}{\partial x_i}\right)^2 u_i^2 + \sum_{j \neq i} \left(\frac{\partial D_i}{\partial x_j}\right)^2 u_j^2 \quad (\text{A-6})$$

$$= \left(1 - \frac{1}{n}\right)^2 u_i^2 + \frac{1}{n^2} \sum_{j \neq i} u_j^2 \quad (\text{A-7})$$

or, after recombination

$$= \left(1 - \frac{2}{n}\right) u_i^2 + \frac{1}{n^2} \sum_{j=1}^n u_j^2. \quad (\text{A-8})$$

When a coverage factor of 2 is used (A-8) becomes

$$U_i^2 = 2^2 \left[ \left(1 - \frac{2}{n}\right) u_i^2 + \frac{1}{n^2} \sum_{j=1}^n u_j^2 \right]. \quad (\text{A-9})$$

**Case 2.** A laboratory was used to evaluate the reference value but does not appear in Table 5.

Let us assign the subscript  $n$  to the additional laboratory that contributes to the reference value. The uncertainty of this laboratory will appear only in the second part of equation (A-9). Accordingly, equation (A-9) becomes

$$U_i^2 = 2^2 \left[ \left(1 - \frac{2}{n}\right) u_i^2 + \frac{1}{n^2} \left(\sum_{j=1}^n u_j^2\right) \right], \text{ for } i = 1, n - 1. \quad (\text{A} - 10)$$

**Case 3.** The reference value was evaluated with all reported values except one.

For the sake of simplicity let us assign the subscript  $n + 1$  to the ineligible laboratory so that the subscript for the other laboratories will run from 1 to  $n$ . Under this assumption the treatment of the ineligible laboratory will be slightly different and two formulae are deduced.

The ineligible laboratory does not contribute to the reference value, so the term  $(1 - 2/n)$  in (A-9) reduces to 1 and the uncertainty is simply given by

$$U_{n+1}^2 = 2^2 \left[ u_{n+1}^2 + \frac{1}{n^2} \sum_{j=1}^n u_j^2 \right]. \quad (\text{A} - 11)$$

In the evaluation of the uncertainty related to the  $n$  other laboratories the contribution from laboratory  $n + 1$  disappears totally and the uncertainty remains given by the expression (A-10) without restriction over the subscript range i. e.

$$U_i^2 = 2^2 \left[ \left(1 - \frac{2}{n}\right) u_i^2 + \frac{1}{n^2} \sum_{j=1}^n u_j^2 \right]. \quad (\text{A} - 12)$$

**Case 4.** A laboratory that no longer exists contributes to the reference value and an outlier has been identified for another laboratory.

Let us assign the subscript  $n$  to the defunct existing laboratory so that the expression for the mean (A-1) remains applicable. In addition the outlier will be labelled by  $n + 1$ . For the  $(n - 1)$  first laboratories which contribute to the mean value and appear in Table 5 the uncertainty of  $D_i$  is given by

$$U_i^2 = 2^2 \left[ \left(1 - \frac{2}{n}\right) u_i^2 + \frac{1}{n^2} \sum_{j=1}^n u_j^2 \right], \text{ for } i = 1, n - 1. \quad (\text{A} - 13)$$

For the laboratory  $n + 1$  that is ineligible for the KCRV, its coefficient  $(1 - 2/n)$  in (A-13) reduces to 1 and the expression of the uncertainty in Table 5 becomes

$$U_{n+1}^2 = 2^2 \left[ u_{n+1}^2 + \frac{1}{n^2} \sum_{j=1}^n u_j^2 \right], \quad (\text{A} - 14)$$

similar to (A-11).

### Appendix 3. Acronyms used to identify different measurement methods

Each acronym has six components, geometry-detector (1)-radiation (1)-detector (2)-radiation (2)-mode. When a component is unknown, ?? is used and when it is not applicable 00 is used.

Geometry	acronym	Detector	acronym
$4\pi$	4P	proportional counter	PC
defined solid angle	SA	press. prop counter	PP
$2\pi$	2P	liquid scintillation counting	LS
undefined solid angle	UA	NaI(Tl)	NA
		Ge(HP)	GH
		Ge-Li	GL
		Si-Li	SL
		CsI	CS
		ionization chamber	IC
		grid ionization chamber	GC
		bolometer	BO
		calorimeter	CA
		PIPS detector	PS
Radiation	acronym	Mode	acronym
positron	PO	efficiency tracing	ET
beta particle	BP	internal gas counting	IG
Auger electron	AE	CIEMAT/NIST	CN
conversion electron	CE	sum counting	SC
bremstrahlung	BS	coincidence	CO
gamma ray	GR	anti-coincidence	AC
X - rays	XR	coincidence counting with efficiency tracing	CT
alpha - particle	AP	anti-coincidence counting with efficiency tracing	AT
mixture of various radiation e.g. X and gamma	MX	triple-to-double coincidence ratio counting	TD
		selective sampling	SS
		high efficiency	HE
		digital coincidence counting	DC

Examples	method	acronym
$4\pi$ (PC) $\beta$ - $\gamma$ -coincidence counting		4P-PC-BP-NA-GR-CO
$4\pi$ (PPC) $\beta$ - $\gamma$ -coincidence counting eff. trac.		4P-PP-MX-NA-GR-CT
defined solid angle $\alpha$ -particle counting with a PIPS detector		SA-PS-AP-00-00-00
$4\pi$ (PPC)AX- $\gamma$ (GeHP)-anticoincidence counting		4P-PP-MX-GH-GR-AC
$4\pi$ CsI- $\beta$ ,AX, $\gamma$ counting		4P-CS-MX-00-00-HE
calibrated IC		4P-IC-GR-00-00-00
internal gas counting		4P-PC-BP-00-00-IG