Guidance on Applying the Measurement Methods Matrix (MMM) in Using Comparison Results to Support CMCs

In the interest of supporting the calibration and measurement capabilities (CMCs) published by National Measurement and Designated Institutes (NMIs and DIs) on the Key Comparison Database (KCDB), the Consultative Committee on Ionizing Radiation Section II [CCRI(II)] developed a generic groupings table of radionuclides called the MMM. Using these groupings, CCRI(II) and corresponding technical committees in the Regional Metrology Organizations (RMOs) might leverage a select set of comparisons to support a wider range of CMCs for the measurement of radionuclides. The MMM has been designed for used by the NMIs and DIs[1].

For the official rules to CMC claims, refer to the latest "Rules for entering CMC Claims in Ionizing Radiation Metrology" located on the BIPM website:
https://www.bipm.org/en/committees/cc/ccri/publications

This document is meant to be used as a tool for evaluating CMCs but should not be construed to imply traceability of radionuclides, which still requires an unbroken chain of comparisons or calibrations against an appropriate standard.

- Radionuclides have been categorized by a primary measurement method (column in the MMM) as appropriate for a specific nuclide.

- Each method is described by the geometry, detector type, radiation, and detection mode. The expected, relative, minimum, expanded (k = 2) uncertainty is given in percent. The relative difficulty of measuring a specific nuclide by the indicated method (without consideration of source preparation issues) is denoted by a color-coded system: "red" for the most difficult, "yellow" for the moderately difficult, and "green" for the least difficult. It should be noted that a "red" nuclide by one method may be indicated as "green" by another.

- Several primary methods may be used for a given radionuclide; the application of more than one method for verification and confidence in results, as appropriate, is encouraged.

- In general, results from a comparison of a radionuclide indicated as red for a given primary measurement method may be used to support the calibration and measurement capability (CMC) claims for other nuclides of the same type (presuming similar decay complexities and measurement challenges) by that measurement method (i.e., other red, yellow and green-indicated nuclides for that method). Results from a comparison of a nuclide indicated as yellow will support claims for the yellow and green-indicated nuclides, and that of a green-indicated nuclide will support CMCs of only green-indicated nuclides by the same method. CMCs should, in all cases, be claimed only for those radionuclides measured by the submitting laboratory.

[1] See L. Karam, "Application of the CIPM MRA to radionuclide metrology", Metrologia **44** S1 (2007), https://doi.org/10.1088/0026-1394/44/4/S01

- A comparison result of a radionuclide measured by a specific primary method generally will not be supportive of claims for that radionuclide measured by other primary methods.

- As comparisons are generally not undertaken for secondary methods specifically, a similar matrix for those methods is not practical. Extension of primary comparison results to support CMCs of secondary methods may be possible with demonstration of traceability of those methods to the primary method used in the comparison; the uncertainties would be expected to be greater than those achieved in the initial, primary-method comparison.

- When a secondary method is used in the context of a comparison, the results for that comparison can support the CMCs of only that nuclide as measured by that method.

Generic Groupings of the Radionuclides for Primary Methods: To Establish Key Comparisons to Underpin MRA CMCs in Radioactivity

Nr	App.	Nuclide	4P-BP/AP-PC/PPILS/SP-GR-NA/GH-CO/AC	4P-XR/AE-PC/PPILS/SP-GR-NA/GH-CO/AC	4P-AP-LS-00-00-HE	4P-BP/AP/XR/AE-NA/CS-00-00-HE	4P-PH-NA-00-00-HE	4P-BP/AP-PP-00-00-HE* (Nuclides emitting only alpha particles, accompanied by emission of gamma photons)	4P-XR/AE-PP-00-00-HE	SA-AP-PS-00-00-00	4P-BP-PC/PP/LS-GR-NA-CT/AT	4P-AP/BP/PH/AE/XR-LS-00-00-CN	4P-BP-LS-00-00-TD** (**pure-beta emitting nuclides only)	4P-BP-CD-00-00-TD** (**Cerenkov Counting in LS channel)	4P-AP/BP/PH/AE/XR-LS-00-00-TD*** (***all pure-beta emitting nuclides)	4P-A/PB/PP/HA/EXR-CD-00-00-TD*** (***TDCR with Cerenkov counting, not pure-beta emitting nuclides)	4P-BP-PP-00-00-HE****** (******pure-beta emitting nuclides only)	4P-BP-PC-00-00-IG	??-X/RIA/EP-O-??-00-00-??	??-GR-??-00-00-??	4P-??-PC/PP/LS/SP-??-NA/GH-CO/AC/CT/AT (DS)*	4P-??-LS-00-00-CN/TD (DS)*	4P-??-PP-00-00-HE (DS)*	SA-??-PS-00-00-00 (DS)*	4P-??-PC-00-00-IG (DS)*
			α or β coincidence/ anticoincidence	x-ray or Auger coincidence/ anticoincidence	α-particle high efficiency liquid scintillation	α or β or x-ray or Auger NaI(Tl) or CsI	photons NaI(Tl) high efficiency	α or β high efficiency proportional counter	x-ray or Auger proportional counter high efficiency	Defined solid angle α-particle with PIPs detector	β-particle proportional counter or liquid scintillation with γ-ray efficiency tracing	α or β or photon or Auger or x-ray CIEMET/NIST	β-particle (pure) TDCR	β-particle (pure) TDCR with Čerenkov counting in the LS channel	α or (mixed) β or photon or Auger or x-ray TDCR	α or (mixed) β or photon or Auger or x-ray TDCR with Čerenkov counting in the LS channel	β-particle (pure) high efficiency proportional counter	β-particle internal gas counting	Any geometry x-ray or Auger or positron by any detector and mode	Any geometry γ-ray by any detector and mode	DELAYED STATE 4π any radiation coincidence methods	DELAYED STATE 4π any radiation scintillation methods	DELAYED STATE 4π any radiation high efficiency methods	DELAYED STATE defined solid angle any radiation	DELAYED STATE 4π any radiation internal gas counting
1	ENV	H-3										3	2					1							
2	RES	Be-7		3					1																
3		Be-10										0.6													
4	MDD	C-11					1					2							3						
5	ENV, RES	C-14									3	1	1					1							
6	MDD	F-18	2				1	2				0.6			3										
7	DCA	Na-22	1				1					0.6													
8	DCA	Na-24	0.5				3	2				2													
9	ENV	Al-26	2									2													
10	MDT, RES	P-32									1.5	0.7	1.5				1.5								
11	MDT, RES	P-33									1.5	1	1				1.5								
12		Si-32																							
13		S-35									3	1	1				3								
14	ENV,MDD,FOF	Cl-36									1.5	0.7	1				2								
15		Ar-37																	3						
16	ENV	K-40										0.8													
17	MDD,WAS,FOF	Ar-41																2							
18	ENV,WAS,FOF	Ca-41										6							3						
19		K-42	1					1				2													
20		Ca-45									2	2	2				2								
21		Sc-46	1				2	3				3													
22		Ca-47/Sc-47																			1.5	3			
23		Sc-47	0.6					3				3													
24	DCA	Cr-51		1								3													
25		Mn-52		1.5								2													
26		Mn-53																							
27	DCA	Mn-54		0.7								3			2										
28	DCA	Fe-55							6			3			2				4						
29	RES	Mn-56	0.7				3	2				2			2										
30		Co-56		0.8			1					3			3										
31		Co-57		1					3			2			2										
32		Co-58		1.2								2			2										
33		Fe-59	1			3						2	2												
34		Ni-59							2						?										
35	DCA	Co-60	0.4				2					1			1										
36		Ni-63									3	1	1												
37	MDD,MDT	Cu-64	2	2								1.2													
38		Cu-67					1																		
39		Zn-65		1								3			2										
40	MDD	Ga-67		2			5														2	3			
41	MDD, DCA	Ge-68/Ga-68	1.5					1.5							1.5				6		1.5	1.5			
42		Se-75		2			1														2	3			
43		As-76	1																			2			
44		Br-82	1																			2			
45	DCA	Sr-85		1																		3			
46	ENV	Kr-85																2							
47		Rb-86	1.2					2														2			
48		Rb-87																				1.4			
49		Sr-87m					3													3					
50	DCA	Y-88		0.8			2															1.5			
51	MDT	Sr-89									2		1				2					0.6			
52		Zr-89																							
53	MDT	Sr90/Y90										0.6	1								2		2		
54	MDT	Y-90									2		0.4				2					0.4			
55		Mo-93																							
56		Zr-93																							
57		Nb-93m																	5			0.7			
58		Nb-94	1																			1.5			
59		Nb-95	0.4																			2			
60		Tc-95m/Tc-95		1.5																	3				
61		Zr-95				8															4				
62	MDD	Mo-99																			1				
63	ENV, MDD (impu	Tc-99									2		1									1			
64	MDD	Tc-99m		2																3					
65	MDT	Ru-103	2																		2				
66		Pd-103							3						6						3		3		
67		Ru/Rh-106	1.5			2															0.7				
68		Ag-108m																			3				
69	DCA	Cd-109							2			?									1.5	1			
70		Ag110m	1				0.6														1				
71		Ag-111	1																						
72	MDD	In-111		1.5			0.4		0.4						1.5							1.5			
73		Cd-113m											?		?										
74		In-113m																		3					
75	DCA	Sn-113		2.5		3									?						2.5				
76		I-123		1.4								?			2							2.5			
77		Te-123m																		3					
78	MDD	I-124		2																		2			
79		Sb-124	2				3	4														1.5			
80	MDD, MDT	I-125		3		2			3						2.5				1.5	1.5		2.5			
81		Sb-125	2																		2				
82		Xe-127																3							
83		I-129	3												2							2			
84		Cs-131							3										3						
85	MDT	I-131	0.7						2												0.7	1			
86		Xe-131m																3							
87		Te-132/I-132	2																		2				
88	DCA	Ba-133		1.2			0.4															2			
89	MDD	Xe-133																2.5							
90		Cs-134	1.2				0.6	3														0.6			
91		Cs-137	1.5			1.5									?						1.5	1.5	1.5		
92	DCA	Ce-139		0.8			1.2								2							3			
93		Ba-140/La-140	1			2															1		2		
94		La-140	1																			2			
95	DCA	Ce-141	1					3														3			
96		Ce/Pr-144	1.2					4													1.2				
97		Pm-147									2		1.5				4					1			
98		Gd-148			1					2															
99	DCA	Eu-152		1.2			1															1			
100	DCA	Gd-153		2																		2			
101	MDT	Sm-153	1.2					3							1							1			
102		Eu-154	0.8				2	3														1			
103		Eu-155	0.8					4														2			
104		Tb-160	1																			1			
105	MDT	Ho-166	2					2														1			
106	DCA	Ho-166m	1				0.5								1							1			
107		Er-169	1.5																			1.5			
108	MDT	Yb-169		1.2			1															1			
109		Tm-170	2					2														1.5			
110		Yb-175																							
111		Lu-176	2				0.4															1.5			
112	MDT	Lu-177	1					3							1							0.8			
113		Hf-181					2														0.8		2		
114		Ta-182	1				2	3														2			
115		W-185									2						2					1.5			
116	MDT	Re-186	1.5					3							2							0.8			
117	MDT	W-188/Re-188													?						1.4		2.5		
118	MDT	Re-188	1.2					2														1.5			
119	MDT	Ir-192	1				0.6															0.6			
120		Au-195		1.5																		2			
121		Hg-197		3																		2			
122	MDT	Au-198	0.7					2														2			
123		Au-199	1.5																			1.5			
124	MDD	Tl-201		1.5																		3			
125		Tl-202		2																		2			
126		Hg-203	1				4	4														3			
127		Pb-203		1.5																		3			
128		Tl-204									2.5		1				2					1			
129		Bi-207					2														2				
130		Po-208			1.5																2		2	2	
131		Tl-208	3																			2			
132		Po-209			1.5			2																	
133		Pb-210						3													2	1			
134		Po-210			1.5			2		2															
135		At-215																							
136	ENV	Rn-222													?									3	3
137		Ra-223	1									1			1									1	
138		Ra-224			3					3															
139		Ac-225																							
140		Ra-226																			4		2	1.2	
141		Ac-227																			5			4	
142		Th-227	1																						
143		Ac-228																			2				
144		Ra-228/Ac-228																			3				
145		Th-228+d																			4		3	3	
146		Th-229			2			2		2					3										
147		Th-230			1			2		2															
148		Pa-231																							
149		Th-232			2			2		2															
150		U-232			1			2		2															
151	ENV	Pa-233	1.5					3														3			
152		U-233			1			2		2															
153		Th-234(/Pa-234)						4													2				
154		U-234			1			2		2															
155		U-235			1																3		3	1	
156		U-236			4			2		4															
157		Np-237																			1.5	0.6	2	1.5	
158		Pu-238	1		1			2		0.5															
159		U-238/(Th,Pa)																			3	2	3	4	
160		Pu-239			1			2		2															
161		Pu-240			1			2		2															
162		Pu-241										2	2												
163	DCA	Am-241	0.8		1			2		0.5					?										
164		Cm-242	1		1			2		2															
165		Pu-242	2		1			2		2															
166		Am-243																			2	1	3	1	
167		Cm-243						3		3		2													
168		Cm-244	2		1			2		1															