参考資料3

国内分析実施機関の分析結果

分析実施機関　：　福島県

IAEA ILC 2024 (NA3/38)
H-3, Sr-90, Cs-134 and Cs-137 in seawater

Nuclide: H-3

Method:

About 1,000 g of sample was purified by vacuum distillation. 1,000 g of puified sample was enriched to the final weight of 120 g using alkaline electrolysis enrichment system. Electrolytes were removed from the concentrated samples by vacuum distillation. 50 g of enriched water sample was mixed with 50mL of scintillator(Ultima gold LLT, perkinelmer) and used for counting by liquid scintillation counter(500 min/sample). Tritium activity was determined using tritium spike method.

Detection system (including type of calibration applied):

Detection System : Liquid Scintillation Counter(LSC-LB7, ALOKA Co., Ltd.)
Methods of calibration : ESCR method

Nuclear data used (e.g., half-life):

half life of tritium : 12.33 year
β emission probability : 100%

RESULTS

At reference time 7 October 2024 12:00 UTC

	Bq/L				
	M-101	M-102	M-103	M-104	T-D1
Activity concentration (Bq/L)	0.42	0.07	0.09	1.27	
Uncertainty (k=1) (Bq/L)	0.033	0.018	0.019	0.082	
Detection limit (Bq/L):	0.05	0.05	0.05	0.05	

Uncertainty Budget (optional)	**Relative uncertainty (%) (k=1)**				
Uncertainty component associated with net count rate	5.0	23.9	20.2	2.1	
Uncertainty component associated with detector efficiency	5.4	5.4	5.4	5.4	
Uncertainty component associated with weighing	0.04	0.04	0.04	0.04	
Uncertainty component associated with tritium activity of spike sample	2.6	2.6	2.6	2.6	
Uncertainty component associated with tritium recovery on enrichment	1.5	1.5	1.5	1.5	
Relative combined standard uncertainty (k=1)	7.9	24.7	21.1	6.5	0.0

IAEA ILC 2024 (NA3/38)
H-3, Sr-90, Cs-134 and Cs-137 in seawater

Nuclide: Sr-90

Method:

Measurement of Y-90 chemical-separated from Sr-90 and another elements with Fe-precipitationand ion-exchange method

Detection system (including type of calibration applied):

low-background beta counter calibrated with standard Y-90 source

Nuclear data used (e.g., half-life):

ICRP Publication 107:Nuclear Decay Data for Dosimetric Calculations, Ann.ICRP38(3),2008

RESULTS

At reference time 7 October 2024 12:00 UTC

	Bq/L				
	M-101	M-102	M-103	M-104	T-D1
Activity concentration (Bq/L)	0.00075	0.00055	0.00129	0.00066	
Uncertainty (k=1) (Bq/L)	0.00019	0.00018	0.00024	0.00019	
Detection limit (Bq/L):	0.00056	0.00053	0.00070	0.00056	

Uncertainty Budget (optional)	**Relative uncertainty (%) (k=1)**				
Uncertainty component associated with net count rate	25	32	18	28	
Uncertainty component associated with detector efficiency	1.6	1.6	1.6	1.6	
Uncertainty component associated with chemical yield determination	2.7	2.7	2.7	2.7	
Uncertainty component associated with weighing	0.58	0.58	0.58	0.58	
Any other uncertainty component (please specify)	0	0	0	0	
Relative combined standard uncertainty (k=1)	25	32	18	28	0.0

IAEA ILC 2024 (NA3/38)
H-3, Sr-90, Cs-134 and Cs-137 in seawater

Nuclide: Cs-134

Method:

Chemical separation of caesium by using ammmonium molybdophosphate(AMP) and manganese dioxide(MnO2) followed by gamma-ray spectrometry with a HPGe detector

Detection system (including type of calibration applied):

CANBERRA Genie 2000
(Calibration with multi -gamma source)

Nuclear data used (e.g., half-life):

Table of Isotopes,7th Edition (harf-life:2.062year,emission probabilities:85.44%)

RESULTS

At reference time 7 October 2024 12:00 UTC

	Bq/L				
	M-101	M-102	M-103	M-104	T-D1
Activity concentration (Bq/L)	ND	ND	ND	ND	
Uncertainty (k=1) (Bq/L)					
Detection limit (Bq/L):	0.0020	0.0018	0.0018	0.0021	

Uncertainty Budget (optional)	**Relative uncertainty (%) (k=1)**				
Uncertainty component associated with net count rate					
Uncertainty component associated with detector efficiency					
Uncertainty component associated with emission probability					
Uncertainty component associated with weighing					
Any other uncertainty component (please specify)					
Relative combined standard uncertainty (k=1)	0.0	0.0	0.0	0.0	0.0

IAEA ILC 2024 (NA3/38)
H-3, Sr-90, Cs-134 and Cs-137 in seawater

Nuclide: Cs-137

Method:

Chemical separation of caesium by using ammmonium molybdophosphate(AMP) and manganese dioxide(MnO2) followed by gamma-ray spectrometry with a HPGe detector

Detection system (including type of calibration applied):

CANBERRA Genie 2000
(Calibration with multi -gamma source)

Nuclear data used (e.g., half-life):

Table of Isotopes,7th Edition (harf-life:30.174year,emission probabilities:85.0%)

RESULTS

At reference time 7 October 2024 12:00 UTC

	Bq/L				
	M-101	M-102	M-103	M-104	T-D1
Activity concentration (Bq/L)	0.00734	0.00683	0.0224	0.00796	
Uncertainty (k=1) (Bq/L)	0.00079	0.00073	0.0018	0.00089	
Detection limit (Bq/L):	0.0014	0.0013	0.0014	0.0015	

Uncertainty Budget (optional)	**Relative uncertainty (%) (k=1)**				
Uncertainty component associated with net count rate	8.2	8.2	3.9	8.0	
Uncertainty component associated with detector efficiency	2.9	2.9	2.9	2.9	
Uncertainty component associated with emission probability	2.7	2.7	2.7	2.7	
Uncertainty component associated with weighing	1.1	0.37	0.96	2.6	
Any other uncertainty component (please specify)	5.8	5.7	5.7	6.2	
Relative combined standard uncertainty (k=1)	11	11	8.0	11	0.0

IAEA ILC 2024 (NA3/38)
Cs-134, Cs-137, Pu-238 and Pu-239,240 in sediment

Nuclide: Cs-134

Method:

gammma-ray spectrometry with a HPGe detector

Detection system (including type of calibration applied):

CANBERRA Genie 2000
(Calibration with multi-gamma source)

Nuclear data used (e.g., half-life and emission probabilities):

Table of Isotopes,7th Edition (harf-life:2.062year,emission probabilities:85.44%)

RESULTS

At reference time 7 October 2024 12:00 UTC

	Bq/kg d.w.		
	F-P04	T-S3	T-S8
Massic activity (Bq/kg d.w.)	ND	ND	
Uncertainty (k=1) (Bq/kg d.w.)			
Detection limit (Bq/kg d.w.)	0.95	0.74	

Uncertainty Budget (optional)	**Relative uncertainty (%) (k=1)**		
Uncertainty component associated with net count rate			
Uncertainty component associated with detector efficiency			
Uncertainty component associated with emission probability			
Uncertainty component associated with weighing			
Any other uncertainty component (please specify)			
Relative combined standard uncertainty (k=1)	0.0	0.0	0.0

IAEA ILC 2024 (NA3/38)
Cs-134, Cs-137, Pu-238 and Pu-239,240 in sediment

Nuclide: Cs-137

Method:

gammma-ray spectrometry with a HPGe detector

Detection system (including type of calibration applied):

CANBERRA Genie 2000
(Calibration with multi-gamma source)

Nuclear data used (e.g., half-life and emission probabilities):

Table of Isotopes,7th Edition (harf-life:30.174year,emission probabilities:85.0%)

RESULTS

At reference time 7 October 2024 12:00 UTC

	Bq/kg d.w.		
	F-P04	T-S3	T-S8
Massic activity (Bq/kg d.w.)	50.3	8.42	
Uncertainty (k=1) (Bq/kg d.w.)	2.9	0.55	
Detection limit (Bq/kg d.w.)	0.64	0.46	

Uncertainty Budget (optional)	**Relative uncertainty (%) (k=1)**		
Uncertainty component associated with net count rate	1.3	3.3	
Uncertainty component associated with detector efficiency	2.9	2.9	
Uncertainty component associated with emission probability	2.7	2.7	
Uncertainty component associated with weighing	0.43	0.60	
Any other uncertainty component (please specify)	4.0	3.9	
Relative combined standard uncertainty (k=1)	5.7	6.5	0.0

IAEA ILC 2024 (NA3/38)
Cs-134, Cs-137, Pu-238 and Pu-239,240 in sediment

Nuclide: Pu-238

Method:

After conditioning plutonium valence using reducing agent, purificated plutonium by anion exchange culumn was adhered to stainless steel plate electrically.

Detection system (including type of calibration applied):

Silicon semiconductor detector caliblated by alpha reference source certified by LRQA.

Nuclear data used (e.g., half-life and emission probabilities):

Half life:87.7 year
emission porobabilities:99.9%

RESULTS

At reference time 7 October 2024 12:00 UTC

	Bq/kg d.w.		
	F-P04	T-S3	T-S8
Massic activity (Bq/kg d.w.)	<0.012	<0.018	
Uncertainty (k=1) (Bq/kg d.w.)			
Detection limit (Bq/kg d.w.)	0.012	0.018	

Uncertainty Budget (optional)	**Relative uncertainty (%) (k=1)**		
Uncertainty component associated with net count rate			
Uncertainty component associated with activity of yield tracer (if used)			
Uncertainty component associated with net count rate of yield tracer (if used)			
Uncertainty component associated with weighing			
Any other uncertainty component (please specify)			
Relative combined standard uncertainty (k=1)	0.0	0.0	0.0

IAEA ILC 2024 (NA3/38)
Cs-134, Cs-137, Pu-238 and Pu-239,240 in sediment

Nuclide: Pu-239,240

Method:

After conditioning plutonium valence using reducing agent, purificated plutonium by anion exchange culumn was adhered to stainless steel plate electrically.

Detection system (including type of calibration applied):

Silicon semiconductor detector caliblated by alpha reference source certified by LRQA.

Nuclear data used (e.g., half-life and emission probabilities):

Half life:6561 year
emission porobabilities:99.9%

RESULTS

At reference time 7 October 2024 12:00 UTC

	Bq/kg d.w.		
	F-P04	T-S3	T-S8
Massic activity (Bq/kg d.w.)	0.353	0.387	
Uncertainty (k=1) (Bq/kg d.w.)	0.030	0.034	
Detection limit (Bq/kg d.w.)	0.090	0.11	

Uncertainty Budget (optional)	Relative uncertainty (%) (k=1)		
Uncertainty component associated with net count rate	5.92	6.27	
Uncertainty component associated with activity of yield tracer (if used)	1.13	1.13	
Uncertainty component associated with net count rate of yield tracer (if used)	6.14	6.14	
Uncertainty component associated with weighing	0.04	0.04	
Any other uncertainty component (please specify)	0	0	
Relative combined standard uncertainty (k=1)	8.6	8.8	0.0

分析実施機関　：　株式会社化研

IAEA ILC 2024 (NA3/38)
H-3, Sr-90, Cs-134 and Cs-137 in seawater

Nuclide: H-3

Method:

Analysis Method of Tritium (Radiation Measurement Method Series 9)
(Nuclear Regulation Authority)
In accordance with the method, 1100g sample was concentrated 10 times by electrolytic enrichment.
Finaly, Sample weight is 65g (Distilled sample)

Detection system (including type of calibration applied):

Liquid scintillation counter(Quench Curve – Counting Efficiency)

Nuclear data used (e.g., half-life):

DDEP「Table of Radionuclides,Monographie BIPM-5」

RESULTS

At reference time 7 October 2024 12:00 UTC

	Bq/L				
	M-101	M-102	M-103	M-104	T-D1
Activity concentration (Bq/L)	0.40				0.065
Uncertainty (k=1) (Bq/L)	0.047				0.014
Detection limit (Bq/L):	0.033				0.036

Uncertainty Budget (optional)	**Relative uncertainty (%) (k=1)**				
Uncertainty component associated with net count rate	3.43				18.88
Uncertainty component associated with detector efficiency	2.60				2.60
Uncertainty component associated with weighing	0.03				0.03
Any other uncertainty component (Uncertainty during electrolytic enrichment)	11.00				11.00
Relative combined standard uncertainty (k=1)	11.81				22.00

分析実施機関　：　株式会社 KANSO テクノス

IAEA ILC 2024 (NA3/38)
H-3, Sr-90, Cs-134 and Cs-137 in seawater

Nuclide: H-3

Method:

The samples were purified by using distillation apparatus of glass made so as to keep the concentration of tritium in water unchanged before and after the distillation. Next, 1 liter of distilled water was electrolytically concentrated by using a solid polymer electrolytic film. For the liquid scintillation counting, 50mL of the sample was mixed with 50mL of scinti-cocktail(Ultima Gold LLT(PerkinElmer Japan Co., Ltd.)) in a teflon bottle. The scintillation due to low energy beta-ray of tritium was determined by the low background liquid scintillation counter for 500 minutes.

Detection system (including type of calibration applied):

Liquid scintillation counter:AccuFLEX LSC-LB7(Aloka Co., Ltd.)

Nuclear data used (e.g., half-life):

ENSDF (Evaluated Structure Data File)

RESULTS

At reference time 7 October 2024 12:00 UTC

	Bq/L				
	M-101	M-102	M-103	M-104	T-D1
Activity concentration (Bq/L)	—	0.14	0.14	—	—
Uncertainty (k=1) (Bq/L)	—	0.01	0.01	—	—
Detection limit (Bq/L):	—	0.03	0.03	—	—

Uncertainty Budget (optional)	**Relative uncertainty (%) (k=1)**				
Uncertainty component associated with net count rate	—	8.542	8.453	—	—
Uncertainty component associated with detector efficiency	—	0.7375	0.7375	—	—
Uncertainty component associated with weighing	—	0.007141	0.007141	—	—
Any other uncertainty component (please specify)	—	2.826	2.844	—	—
Relative combined standard uncertainty (k=1)	—	9.0	8.9	—	—

IAEA ILC 2024 (NA3/38)
H-3, Sr-90, Cs-134 and Cs-137 in seawater

Nuclide: Sr-90

Method:

Sr was concentrated using ion exchange resin(Dowex 50W-8X) from 40L of aqueous sample. Carbonate and barium chromate treatment was performed to separate and purify Sr. Solution with separated and purified Sr sat more than 2 weeks until Sr-Y became radioactively in equilibrium. After being in radioactive equilibrium, Y was separated using Fe co-precipitation method, and Y-90 radioactivity was measured from a Y-90 collected filter using 2π gas-flow counter for 100 minutes. Sr-90 concentration was determined from Y-90 radioactivity recovery rate, decay correction, and other necessary calculations.

Detection system (including type of calibration applied):

Multi-Detector Low Background Alpha/Beta Counting System:LB4200 (Mirion Technologies.)
Number of points in the efficiency :1 points（Average value of 6 samples）

Nuclear data used (e.g., half-life):

Radioisotope Pocket Data Book 10th Edition（half-life:28.74 y ）

RESULTS

At reference time 7 October 2024 12:00 UTC

	Bq/L				
	M-101	M-102	M-103	M-104	T-D1
Activity concentration (Bq/L)	0.0011	0.0011	0.0013	0.0012	0.00098
Uncertainty (k=1) (Bq/L)	0.0002	0.0002	0.0002	0.0002	0.00017
Detection limit (Bq/L):	0.0004	0.0005	0.0005	0.0004	0.00042

Uncertainty Budget (optional)	**Relative uncertainty (%) (k=1)**				
Uncertainty component associated with net count rate	13.94	15.77	14.97	13.30	16.28
Uncertainty component associated with detector efficiency	2.599	2.599	2.599	2.599	2.599
Uncertainty component associated with chemical yield determination	3.922	3.933	3.928	3.909	3.919
Uncertainty component associated with weighing	0.01443	0.01443	0.01443	0.01443	0.01443
Any other uncertainty component (please specify)	0	0	0	0	0
Relative combined standard uncertainty (k=1)	14.7	16.5	15.7	14.1	16.9

IAEA ILC 2024 (NA3/38)
H-3, Sr-90, Cs-134 and Cs-137 in seawater

Nuclide: Cs-134

Method:

Added nitrate to 20L of aqueous sample and adjust pH to about 1.6. Added 0.39 g of CsCl and mixed well; then added 6 g of AMP and mixed well again. Solution was settled overnight and collected AMP/Cs by filtering. Dried AMP/Cs at room temperature and calculated recovery rate by weighing. Insert AMP/Cs to teflon tube container, then measured Cs-134 and Cs-137 using well-type germanium semi-conductor detector for 100000 seconds.

Detection system (including type of calibration applied):

Germanium semiconductor detector:GWL-90-15(ORTEC),Software:Gamma Station(SEIKO EG&G CO., LTD.)
Number of points in the efficiency curve:3 points,Type of calibration:quadratic curve

Nuclear data used (e.g., half-life):

Table of Isotopes 7th Edition (half-life:2.062y,emission probabilities:97.56%,γ-ray energy:604.66 keV)

RESULTS

At reference time 7 October 2024 12:00 UTC

	Bq/L				
	M-101	M-102	M-103	M-104	T-D1
Activity concentration (Bq/L)	-	ND	-	-	-
Uncertainty (k=1) (Bq/L)	-	-	-	-	-
Detection limit (Bq/L):	-	0.0008	-	-	-

Uncertainty Budget (optional)	**Relative uncertainty (%) (k=1)**				
Uncertainty component associated with net count rate	-	-	-	-	-
Uncertainty component associated with detector efficiency	-	-	-	-	-
Uncertainty component associated with emission probability	-	-	-	-	-
Uncertainty component associated with weighing	-	-	-	-	-
Any other uncertainty component (please specify)	-	-	-	-	-
Relative combined standard uncertainty (k=1)	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!

Nuclide: Cs-137

Method:

Added nitrate to 20L of aqueous sample and adjust pH to about 1.6. Added 0.39 g of CsCl and mixed well; then added 6 g of AMP and mixed well again. Solution was settled overnight and collected AMP/Cs by filtering. Dried AMP/Cs at room temperature and calculated recovery rate by weighing. Insert AMP/Cs to teflon tube container, then measured Cs-134 and Cs-137 using well-type germanium semi-conductor detector for 100000 seconds.

Detection system (including type of calibration applied):

Germanium semiconductor detector:GWL-90-15(ORTEC),Software:Gamma Station(SEIKO EG&G CO., LTD.)
Number of points in the efficiency curve:3 points,Type of calibration:quadratic curve

Nuclear data used (e.g., half-life):

Table of Isotopes 7th Edition (half-life:30.174y,emission probabilities:85.00%,γ-ray energy:661.64keV)

RESULTS

At reference time 7 October 2024 12:00 UTC

	Bq/L				
	M-101	M-102	M-103	M-104	T-D1
Activity concentration (Bq/L)	-	0.0059	-	-	-
Uncertainty (k=1) (Bq/L)	-	0.0003	-	-	-
Detection limit (Bq/L):	-	0.0004	-	-	-

Uncertainty Budget (optional)	**Relative uncertainty (%) (k=1)**				
Uncertainty component associated with net count rate	-	3.725	-	-	-
Uncertainty component associated with detector efficiency	-	2.347	-	-	-
Uncertainty component associated with emission probability	-	0.5989	-	-	-
Uncertainty component associated with weighing	-	0.1155	-	-	-
Any other uncertainty component (please specify)	-	2.013	-	-	-
Relative combined standard uncertainty (k=1)	#VALUE!	4.9	#VALUE!	#VALUE!	#VALUE!

Nuclide: H-3

Method:

The samples were purified by using distillation apparatus of glass made so as to keep the concentration of tritium in water unchanged before and after the distillation. Next, 1 liter of distilled water was electrolytically concentrated by using a solid polymer electrolytic film. For the liquid scintillation counting, 50mL of the sample was mixed with 50mL of scinti-cocktail(Ultima Gold LLT(PerkinElmer Japan Co., Ltd.)) in a teflon bottle. The scintillation due to low energy beta-ray of tritium was determined by the low background liquid scintillation counter for 500 minutes.

Detection system (including type of calibration applied):

Liquid scintillation counter:AccuFLEX LSC-LB7(Aloka Co., Ltd.)

Nuclear data used (e.g., half-life):

ENSDF（Evaluated Structure Data File）

RESULTS

At reference time 7 October 2024 12:00 UTC

	Bq/L				
	E-S15	T-0-1A	T-3	M-E1	M-E3
Activity concentration (Bq/L)	—	—	—	0.070	—
Uncertainty (k=1) (Bq/L)	—	—	—	0.012	—
Detection limit (Bq/L):	—	—	—	0.034	—

Uncertainty Budget (optional)	**Relative uncertainty (%) (k=1)**				
Uncertainty component associated with net count rate	—	—	—	16.69	—
Uncertainty component associated with detector efficiency	—	—	—	0.7375	—
Uncertainty component associated with weighing	—	—	—	0.007141	—
Any other uncertainty component (please specify)	—	—	—	2.828	—
Relative combined standard uncertainty (k=1)	—	—	—	16.9	—

IAEA Additional Measures for Independent Sampling and Analysis
H-3, Sr-90 and Cs-137 in seawater

Nuclide: H-3

Method:

The samples were purified by using distillation apparatus of glass made so as to keep the concentration of tritium in water unchanged before and after the distillation. Next, 1 liter of distilled water was electrolytically concentrated by using a solid polymer electrolytic film. For the liquid scintillation counting, 50mL of the sample was mixed with 50mL of scinti-cocktail(Ultima Gold LLT(PerkinElmer Japan Co., Ltd.)) in a teflon bottle. The scintillation due to low energy beta-ray of tritium was determined by the low background liquid scintillation counter for 500 minutes.

Detection system (including type of calibration applied):

Liquid scintillation counter:AccuFLEX LSC-LB7(Aloka Co., Ltd.)

Nuclear data used (e.g., half-life):

ENSDF（Evaluated Structure Data File）

RESULTS

At reference time 15 October 2024 12:00 UTC

	Bq/L
	M-103
Activity concentration (Bq/L)	0.15
Uncertainty (*k*=1) (Bq/L)	0.01
Detection limit (Bq/L):	0.03

Uncertainty Budget (optional)	Relative uncertainty (%) (k=1)
Uncertainty component associated with net count rate	8.246
Uncertainty component associated with detector efficiency	0.7375
Uncertainty component associated with weighing	0.007141
Any other uncertainty component (please specify)	2.826
Relative combined standard uncertainty (*k*=1)	8.7

IAEA Additional Measures for Independent Sampling and Analysis
H-3, Sr-90 and Cs-137 in seawater

Nuclide: Sr-90

Method:

Sr was concentrated using ion exchange resin(Dowex 50W-8X) from 40L of aqueous sample. Carbonate and barium chromate treatment was performed to separate and purify Sr. Solution with separated and purified Sr sat more than 2 weeks until Sr-Y became radioactively in equilibrium. After being in radioactive equilibrium, Y was separated using Fe co-precipitation method, and Y-90 radioactivity was measured from a Y-90 collected filter using 2π gas-flow counter for 100 minutes. Sr-90 concentration was determined from Y-90 radioactivity recovery rate, decay correction, and other necessary calculations.

Detection system (including type of calibration applied):

Multi-Detector Low Background Alpha/Beta Counting System:LB4200 (Mirion Technologies.)
Number of points in the efficiency :1 points（Average value of 6 samples)

Nuclear data used (e.g., half-life):

Radioisotope Pocket Data Book 10th Edition（half-life:28.74 y ）

RESULTS

At reference time 15 October 2024 12:00 UTC

	Bq/L
	M-103
Activity concentration (Bq/L)	0.00091
Uncertainty (k=1) (Bq/L)	0.00017
Detection limit (Bq/L):	0.00045

Uncertainty Budget (optional)	**Relative uncertainty (%) (k=1)**
Uncertainty component associated with net count rate	18.37
Uncertainty component associated with detector efficiency	2.599
Uncertainty component associated with chemical yield determination	4.711
Uncertainty component associated with weighing	0.01443
Any other uncertainty component (please specify)	0
Relative combined standard uncertainty (k=1)	19.1