2023E01

Intercomparison of Radioactivity Analysis in Environmental Samples based on the 2023 Cooperation Program between JCAC and RMC

Japan Chemical Analysis Center

公益財団法人 日本分析センター

2025

RADIATION MONITORING CENTER
NUCLEAR SAFETY COMMISSION

CONTENTS

This report summarizes the achievements made in the 2023 cooperation program within the framework of the memorandum for the Technical Exchange between the Radiation Monitoring Center, Nuclear Safety Commission, Taiwan R.O.C. (hereafter referred to as RMC) and the Japan Chemical Analysis Center (hereafter referred to as JCAC).

The 2023 cooperation program was carried out from June 16, 2023 to November 30, 2025 based on the Minutes of the 32nd Annual Meeting held at JCAC on June 15-16, 2023.

The program consists of:

(1) Intercomparison of radioactivity measurements using environmental samples collected by RMC
(2) Intercomparison of radiation dose measurements using thermoluminescence dosimeters
(3) Technical support

1. Intercomparison of radioactivity measurements

1.1 Samples

The samples used for intercomparison between RMC and JCAC included fresh water, seawater, tea leaves ash and soil. Details of the sampling and analytical methods are shown in Table 1.

All samples were collected by RMC. Fresh water, seawater, and tea leaves ash samples were divided into halves after simple pretreatment; one half was analyzed by RMC, and the other was sent to JCAC for analysis. The soil sample was also divided into halves after pretreatment at RMC; one half was analyzed by RMC, and the other was sent to JCAC for analysis.

Table 1 List of intercomparison samples

Sample	Sampling location	Sampling date	Sample condition	Amount of sample	γ	^{90}Sr	^{137}Cs	U	^{3}H	Gross β	Pu
Fresh water	Long-Tan	Jan. 1, 2024	Liquid	2 L	—	—	—	—	○	—	—
				5 L	—	—	—	—	—	○	—
				20 L	—	○	—	—	—	—	—
Seawater-A	Hengchun			2 L	—	—	—	—	○	—	—
	Kaohsiung			5 L	—	—	—	○	—	—	—
				40 L	—	—	○	—	—	—	—
Tea leaves	Shin-Ban-San		Ash	100 g	○	○	—	—	—	○	—
Soil	Long-Tan		Ash	500 g	—	○	—	—	—	—	—
	Taipei			500 g	○	—	—	—	—	○	○
Seawater-B	Hengchun	Jan. 1, 2025	Liquid	2 L	—	—	—	—	○	—	—
	Kaohsiung			5 L	—	—	—	○	—	—	—
				40 L	—	—	○	—	—	—	—

γ : Determination of γ-ray emitting nuclides with Ge semiconductor detector

^{90}Sr : Determination of ^{90}Sr by radiochemical analysis

^{137}Cs : Determination of ^{137}Cs by radiochemical analysis

U : Determination of total U with Si semiconductor detector

^{3}H : Determination of ^{3}H with liquid scintillation counter

Gross β : Measurement of gross β activity with low-background gas-flow counter

Pu : Determination of ^{239}Pu, ^{240}Pu and ^{240}Pu/^{239}Pu atom ratio with ICP-MS

1.2 Analytical methods

1.2.1 γ-ray spectrometry and determination of ^{137}Cs

(1) Pretreatment

1) Tea leaves: (See Fig. 1)

At RMC, the tea leaves ash sample was homogenized and divided into three portions. An aliquot of the one portion of the sample was put in a plastic container (6 cm ϕ ×4.5 cm height), and used for γ-ray spectrometry. The remaining two portions were used for radiochemical analysis of ^{90}Sr and for gross β activity measurement, respectively.

At JCAC, the tea leaves ash sample was homogenized and divided into three portions. An aliquot of the sample was put in a plastic container (U-8: 5 cm ϕ ×6 cm height), and used for γ-ray spectrometry. The remaining two portions were used for radiochemical analysis of ^{90}Sr and gross β activity measurement, respectively.

2) Soil (Taipei): (See Fig. 2)

At RMC, after the soil sample was dried at 110℃ and sifted through a 10 mesh sieve, a 500 g aliquot of the sample was sent to JCAC. The sieved sample was homogenized and divided into three portions. One portion was placed in a plastic container (6 cm ϕ ×4.5 cm height) for γ-ray spectrometry, and the remaining two portions were used for radiochemical analysis of plutonium (Pu), as well as for gross β activity measurement.

At JCAC, the soil sample was dried at 105℃, homogenized and divided into three portions. An aliquot of the one portion of sample was put in a plastic container (U-8: 5 cm ϕ ×6 cm height) for γ-ray spectrometry. The remaining two portions were used for radiochemical analysis of Pu and gross β activity measurement.

3) Seawater (Kaohsiung) : (See Fig. 3)

At RMC, AMP (ammonium phosphomolybdate) was added into the seawater and stirred. AMP was separated, dissolved and transferred into a plastic container (6 cm ϕ ×4.5 cm height) for γ-ray spectrometry.

At JCAC, AMP (ammonium phosphomolybdate) was added into the seawater and stirred. AMP was separated, filtered and transferred into a plastic container (U-9: 5 cm ϕ ×3 cm height) for γ-ray spectrometry.

(2) Measurement

γ-ray spectrometry was carried out by using Ge semiconductor detectors at RMC and JCAC. The instruments and operating conditions are shown in Table 2.

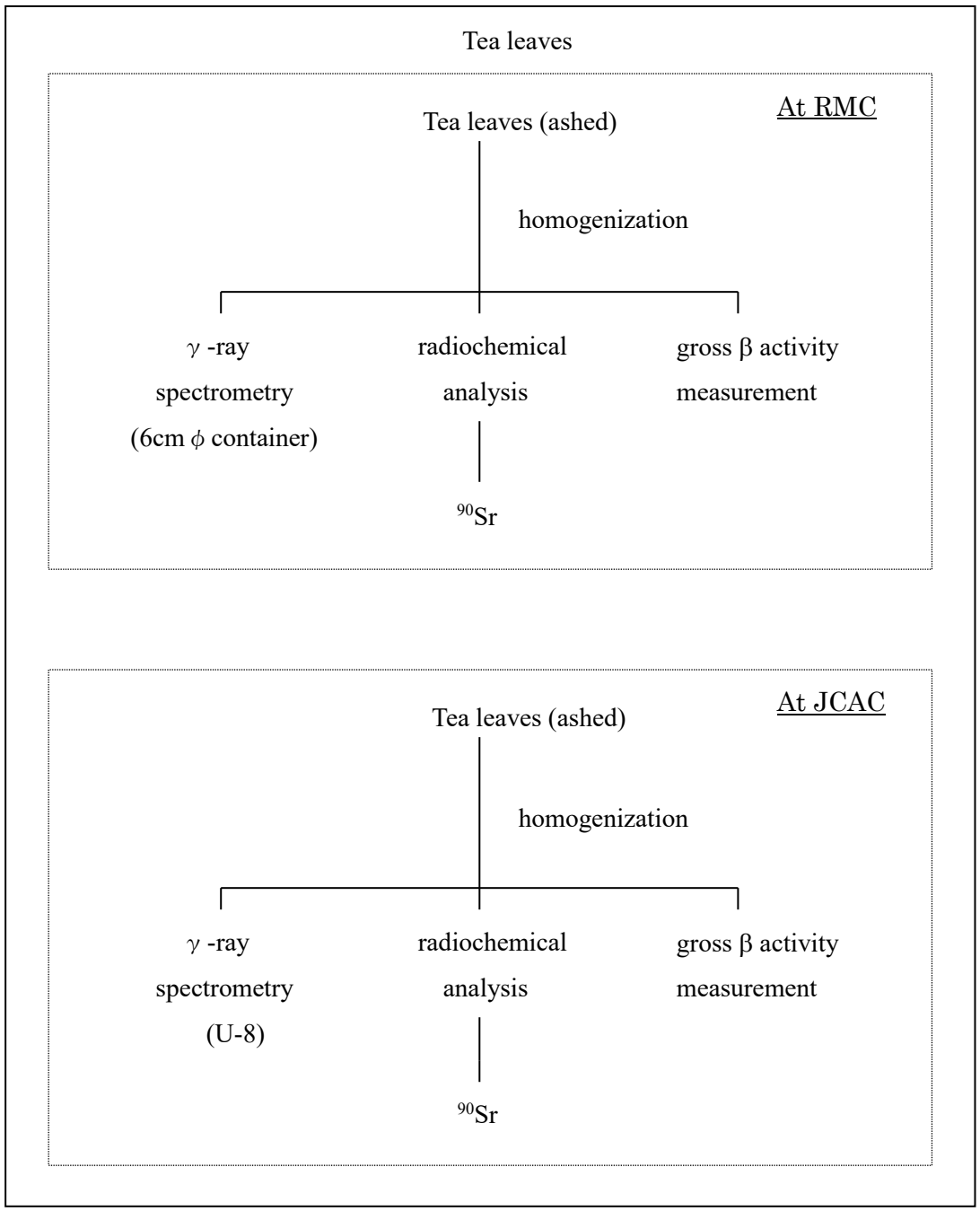


Fig. 1 Pretreatment method for tea leaves sample

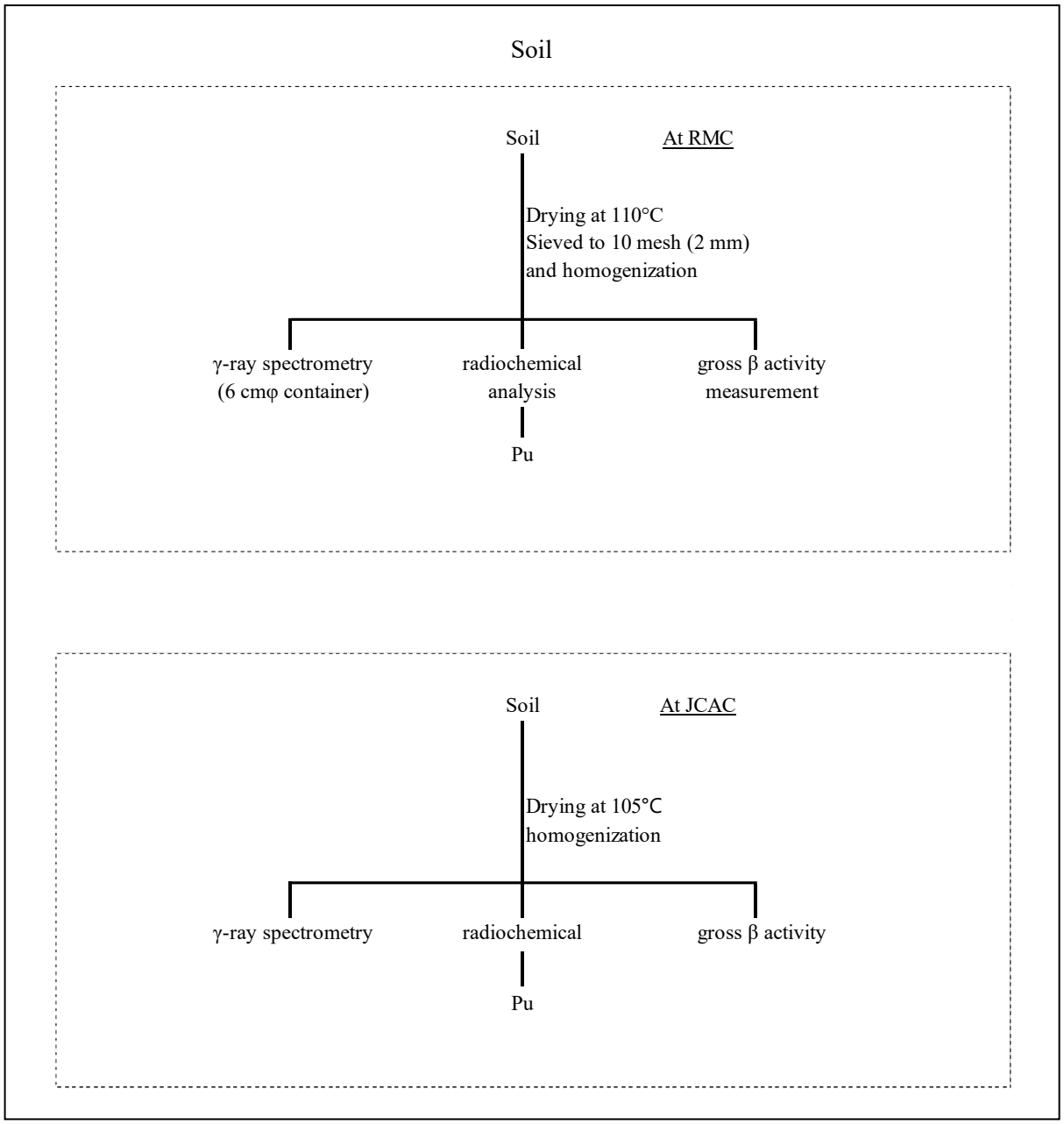


Fig. 2 Pretreatment method for soil samples

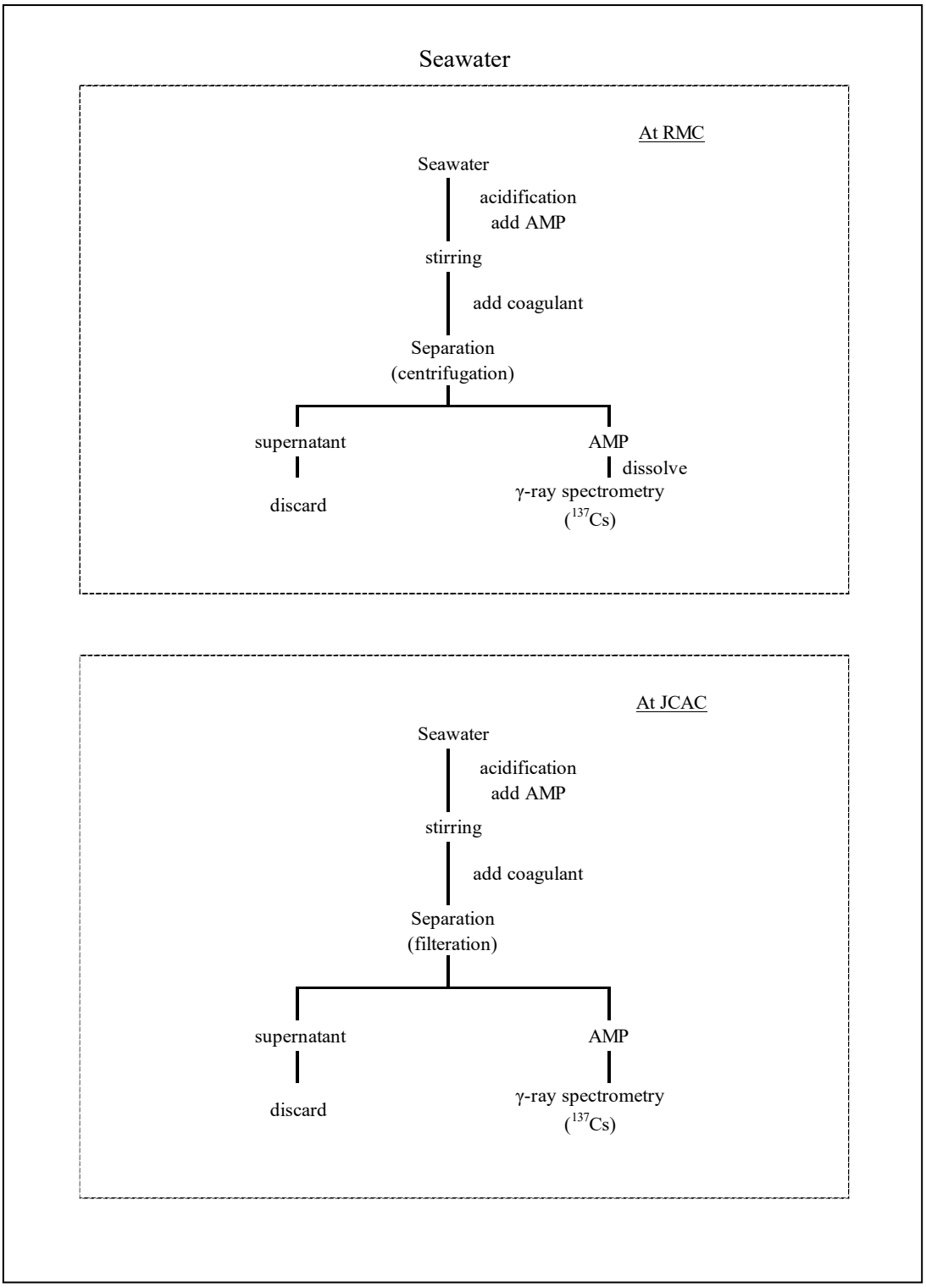


Fig. 3 Pretreatment method for seawater sample

Table 2 Instruments and operating conditions for γ-ray spectrometry

Items	RMC			JCAC		
Sample	Tea leaves	Soil	Seawater	Tea leaves	Soil	Seawater
Detector	Mirion Technologies CANBERRA GC4020 S/N:11485			No.50 ORTEC GEM-40190	No.28 Mirion Technologies (Canberra) GC2519 -7915-30	No.50 ORTEC GEM-40190
Pulse height Analyzer	Mirion Technologies CANBERRA			SEIKO EG&G		
Energy resolution (FWHM for 1332keV)	1.71 keV			1.7 keV	1.7 keV	1.7 keV
Relative efficiency to 3 inch ϕ × 3inch NaI(Tl) detector	42 %			45 %	31 %	45 %
Calibration standard	Eckert & Ziegler Multinuclide Standard Source			JRIA multi-gamma volume sources		
Container	Tea leaves and Soil 6cmφ×4.5cm height Sea water 6cmφ×2.0cm height			Tea leaves and Soil 5cm ϕ ×6cm height Sea water 5cm ϕ ×3cm height		
Counting time	80,000 s			70,000 s		
Computer	Personal Computer Genie 2000 LabSOCS™ Calibration Software			Personal Computer		

1.2.2 Determination of ^{90}Sr

(1) Pretreatment

1) Fresh water (Long-Tan) for the determination of ^{90}Sr:

At RMC, the fresh water sample was used directly for chemical separation.

At JCAC, the fresh water sample was used directly for chemical separation.

2) Tea leaves

At RMC, no additional pretreatment was applied, because the sample was taken from that which had already been pretreated in paragraph 1.2.1(1).

At JCAC, no additional pretreatment was applied, because of the same reason mentioned above.

3) Soil (Long-Tan) for the determination of ^{90}Sr:

At RMC, the soil sample was mixed thoroughly and used for the determination of ^{90}Sr.

At JCAC, the soil sample was also mixed thoroughly and used for the determination of ^{90}Sr.

(2) Chemical separation (See Fig. 4)

1) Fresh water

At RMC, 1 L of fresh water was taken for Sr analysis. A specified amount of Ca^{2+} carrier and 50 mg of Sr^{2+} carrier were added, and the Sr fraction was separated as shown in Fig. 4. $H_2C_2O_4$ and NH_4OH were then added to adjust the solution to pH 4.2, followed by heating and overnight standing to complete the oxalate precipitation. After decantation and centrifugation, the ^{90}Sr-bearing precipitate was collected. The precipitate on the filter paper was dried and used directly for measurement of β-ray activity.

At JCAC, 4 L of the fresh water sample was used for Sr analysis, and added given quantity of carrier solution containing Sr^{2+}.Then Sr were chemically separated as shown in Fig. 4. Finally, the precipitate of the ^{90}Y fraction was filtered using filter paper. The precipitate on the filter paper was dried and used directly for measurement of β -ray activity.

2) Tea leaves

At RMC, small quantity of nitric acid was added to the ashed tea leaves sample after adding given quantity of carrier solution containing Sr^{2+}. Then Sr was chemically separated as shown in Fig. 4. Finally, the precipitate of the ^{90}Y fraction was filtered using filter paper. The precipitate on the filter paper was dried and used directly for measurement of β-ray activity.

At JCAC, the chemical separation procedure of Sr was basically the same as that of RMC. And following processes were added.

The samples were decomposed with aqua regia and nitric acid. Sr was purified using a cation exchange resin column.

3) Soil

At RMC, 100 g of the dried soil (Long-Tan) was heated at 450℃ for 10 hours to decompose organic matter, Sr was then chemically separated as shown in Fig. 4. The preparation of filter papers for β activity measurement methods was basically the same as those for ashed sample.

At JCAC, 100 g of the dried soil (Long-Tan) was heated at 500℃ for 12 hours to decompose organic matter, Sr was then chemically separated as shown in Fig. 4. The chemical separation procedure of Sr was basically the same as that of RMC, and following processes were added. In order to avoid the reduction in chemical yield, Sr was precipitated with oxalic acid to remove iron. Sr was purified using a cation exchange resin column.

(3) Measurement

The measurements of β-ray activity from ^{90}Sr were carried out using low background gas-flow counter at RMC.

The ^{90}Sr activity was measured using low background GM counter at JCAC. The instruments and operating conditions are shown in Table 3.

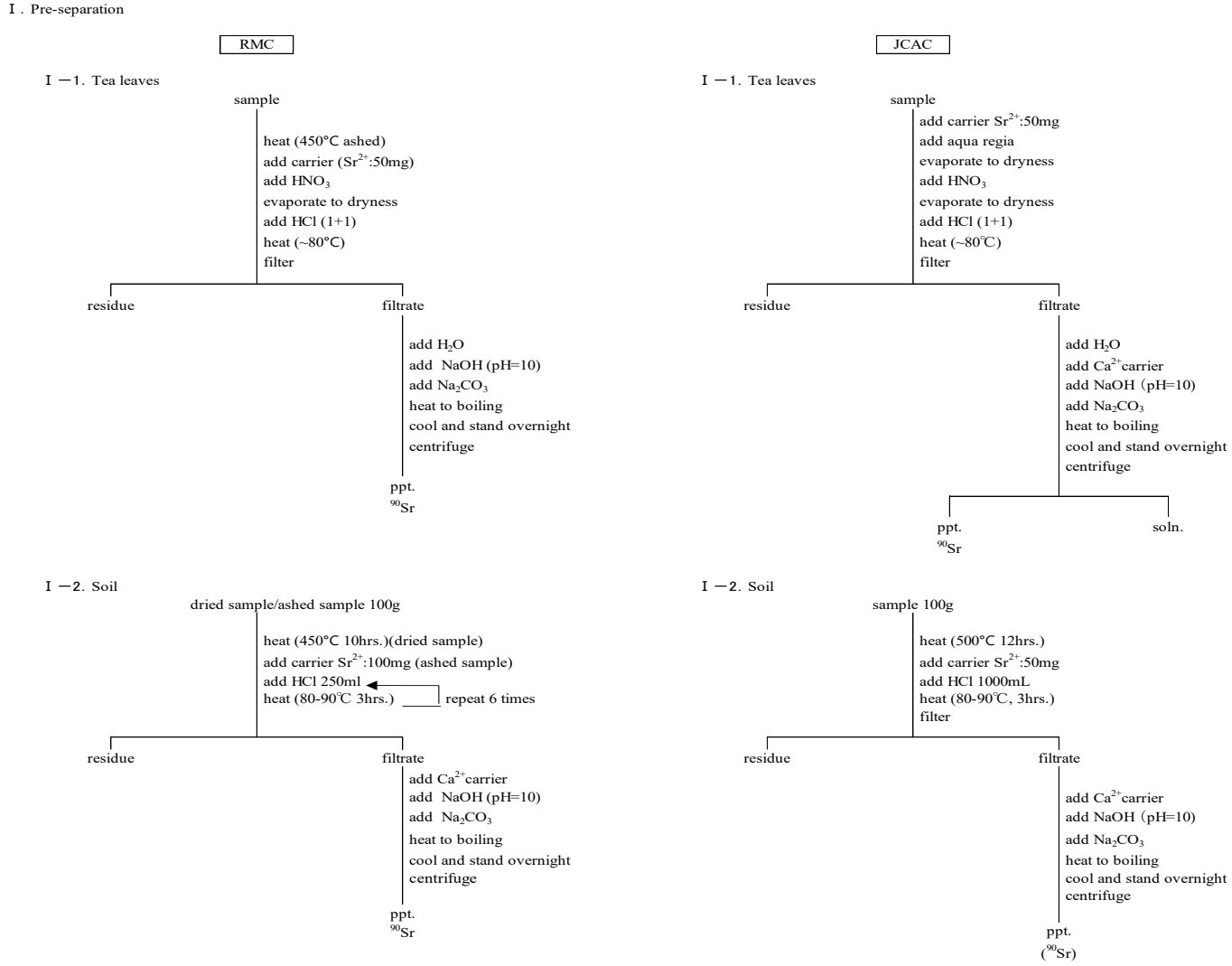
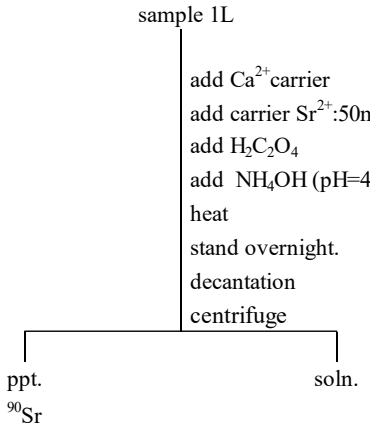


Fig.4 Flowchart for chemical separation of ^{90}Sr

Ⅰ. Pre-separation

Ⅰ－3. Fresh water



Ⅰ－3. Fresh water

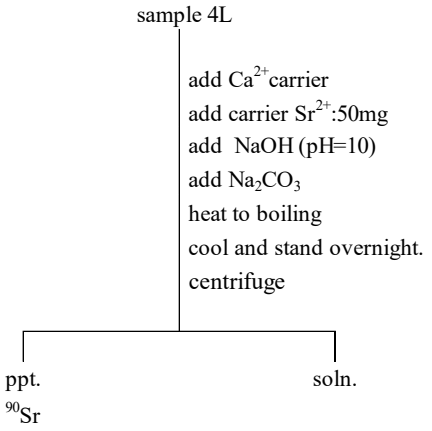


Fig.4 Flowchart for chemical separation of ^{90}Sr

Ⅱ. Chemical separation of ^{90}Sr

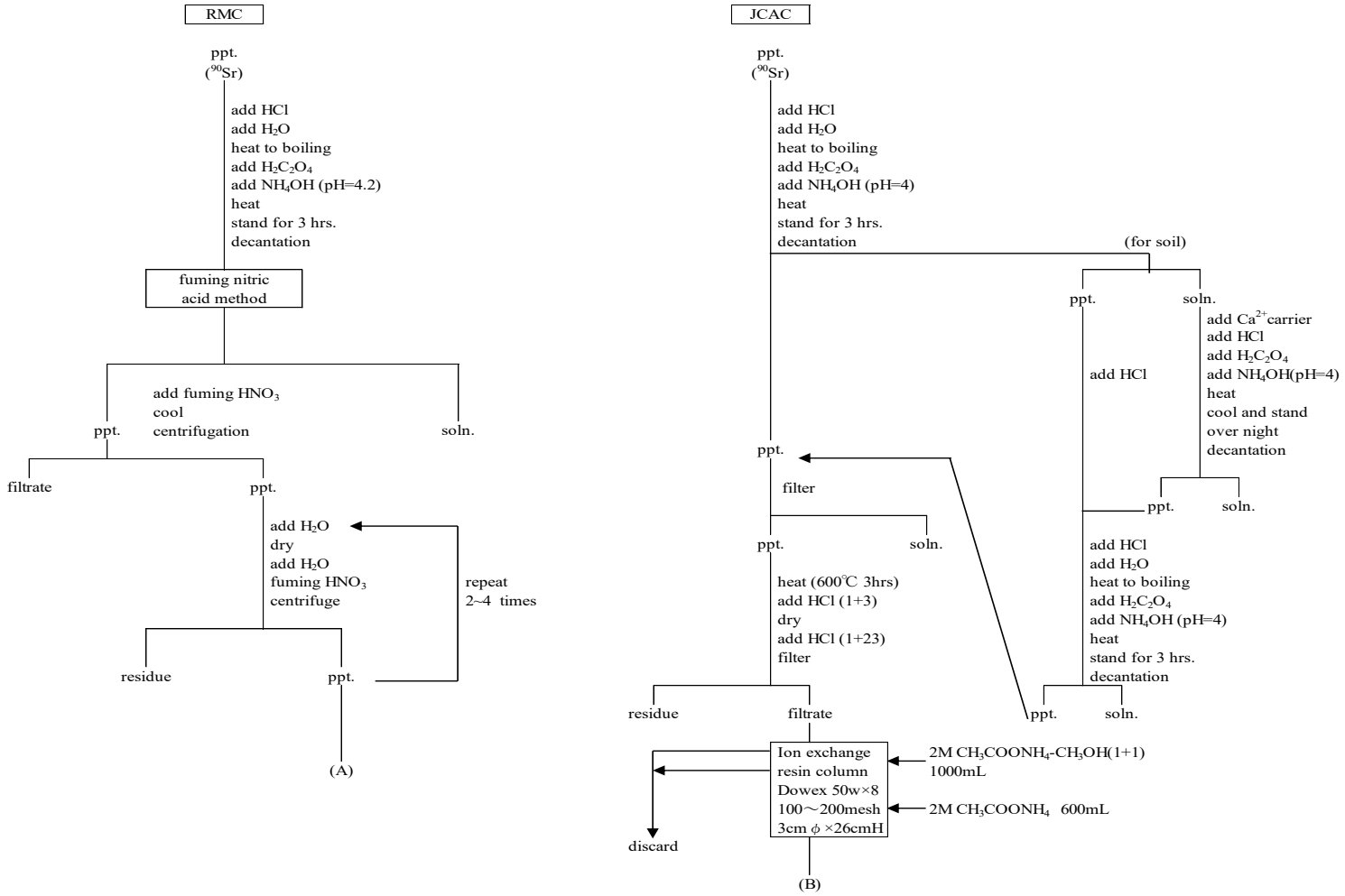


Fig.4 Flowchart for chemical separation of ^{90}Sr

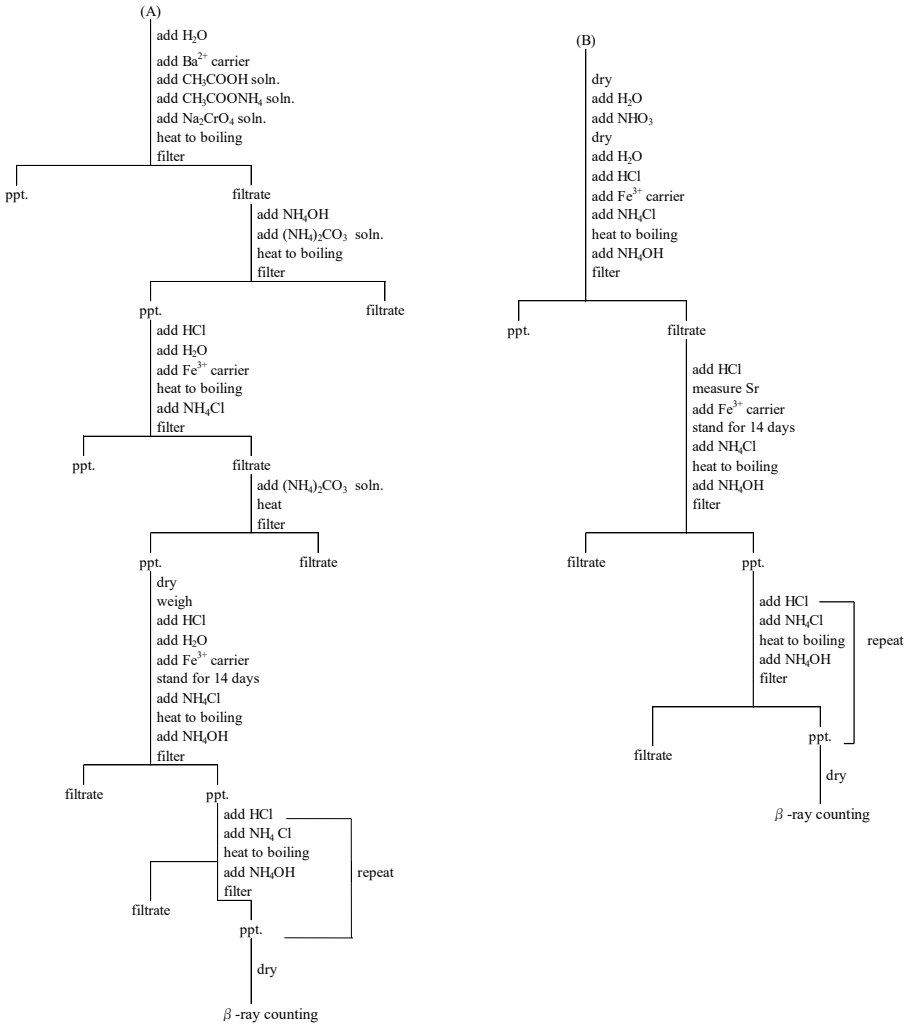


Fig.4 Flowchart for chemical separation of ^{90}Sr

Table 3 Instruments and operating conditions for radiochemical analysis of ^{90}Sr, and gross β activity

Organization		RMC		JCAC	
Nuclide		^{90}Sr	Gross β	^{90}Sr	Gross β
Counting system		Tennelec Series 5 XLB		Aloka LBC-471Q Aloka LBC-4211	Aloka LBC-471Q Aloka LBC-4501
Detector	Type	2 π gas-flow type proportional counter(with window)		2 π gas-flow type GM counter	
	Diameter	1 inch ϕ , 2 inch ϕ		1 inch ϕ	
	Counting gas	P-10 gas [*1]		Q gas [*2]	
	Background	0.94 cpm	fresh water:0.94 cpm tea leaves and soil:0.80 cpm	0.1 ～ 0.3 cpm	
	Efficiency	47.2 %	fresh water:34.1% tea leaves:40.2% soil:42.4%	26% ～ 63%	20% ～ 28%
Calibration standard		^{90}Y $Fe(OH)_3$	KCl	^{90}Y $Fe(OH)_3$	KCl
Counting dish		2 inch ϕ	fresh water: 1 inch ϕ tea leaves and soil: 2 inch ϕ	1 inch ϕ	
Counting time		100 min.	100 min.	60 min.	

[*1] P-10 gas : Ar (90%) , methane (10%)

[*2] Q gas : He (99%) , isobutane (1%)

1.2.3 Determination of Uranium

(1) Pretreatment

Seawater (Kaohsiung)

At RMC, the seawater sample was used directly for chemical separation.

At JCAC, the seawater sample was used directly for chemical separation.

(2) Chemical separation (See Fig. 5)

Seawater

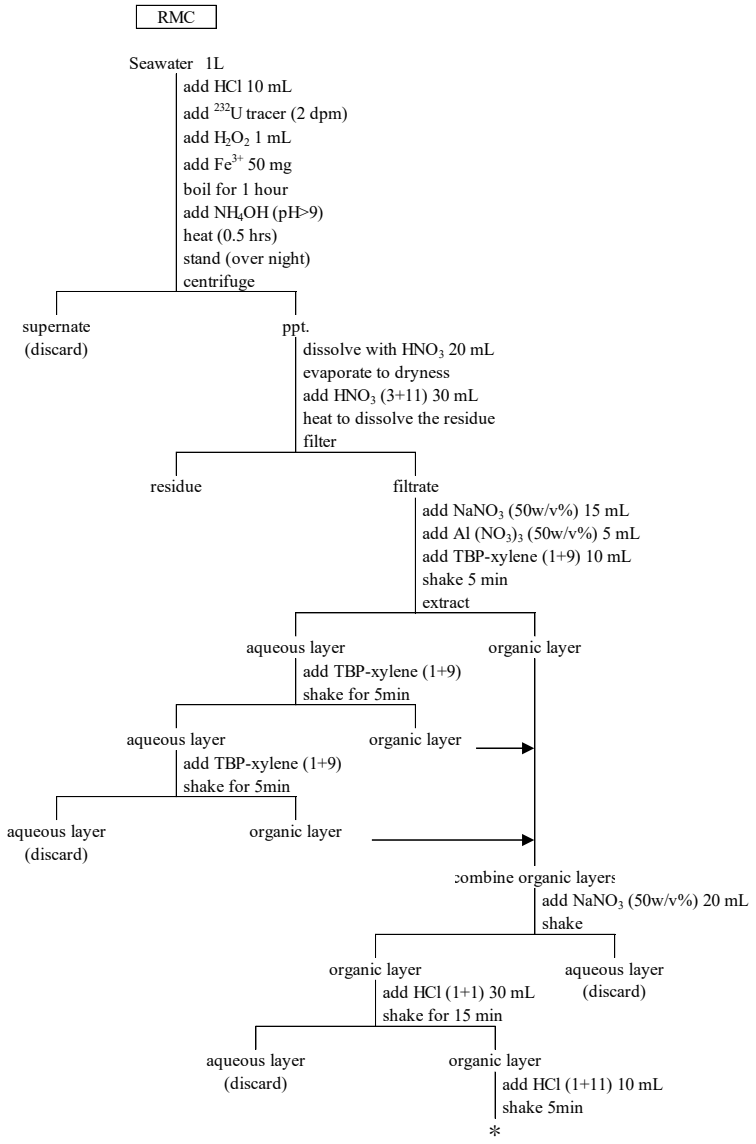
At RMC, 1 L of the seawater sample was used for uranium analysis. Uranium was chemically separated by using solvent extraction (TBP-xylene) and electrodeposited on a stainless steel disk as shown in Fig. 5. The disk was used for α-ray spectrometry.

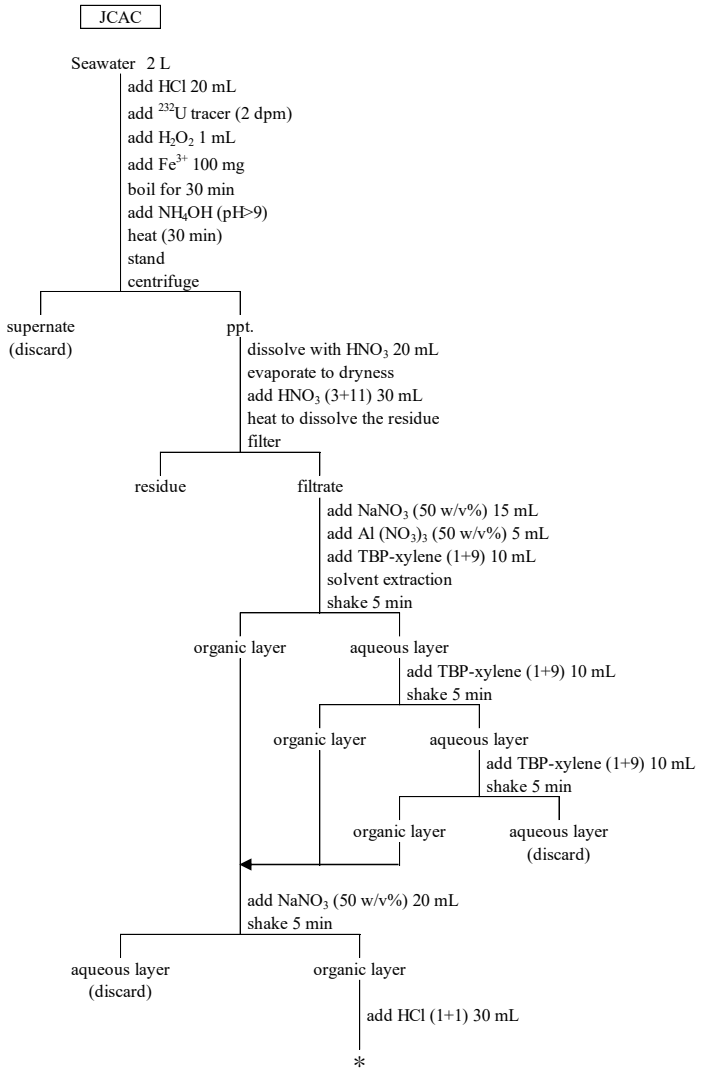
At JCAC, 2 L of the seawater sample was used for uranium analysis. Uranium was chemically separated using solvent extraction (TBP-xylene) and electrodeposited on a stainless steel disk as shown in Fig. 5. The disk was used for α-ray spectrometry.

(3) Measurement

RMC and JCAC carried out α-ray spectrometry using silicon semiconductor detectors. The instruments and operating conditions are shown in Table 4.

Ⅰ. Seawater


RMC
Seawater 1L
add HCl 10 mL
add ^{232}U tracer (2 dpm)
add H_2O_2 1 mL
add Fe^{3+} 50 mg
boil for 1 hour
add NH_4OH (pH>9)
heat (0.5 hrs)
stand (over night)
centrifuge
supernate
(discard)
ppt.
dissolve with HNO_3 20 mL
evaporate to dryness
add HNO_3 (3+11) 30 mL
heat to dissolve the residue
filter
residue
filtrate
add $NaNO_3$ (50w/v%) 15 mL
add $Al(NO_3)_3$ (50w/v%) 5 mL
add TBP-xylene (1+9) 10 mL
shake 5 min
extract
aqueous layer
organic layer
add TBP-xylene (1+9)
shake for 5min
aqueous layer
organic layer
add TBP-xylene (1+9)
shake for 5min
aqueous layer
(discard)
organic layer
combine organic layers
add $NaNO_3$ (50w/v%) 20 mL
shake
organic layer
aqueous layer
(discard)
add HCl (1+1) 30 mL
shake for 15 min
aqueous layer
(discard)
organic layer
add HCl (1+11) 10 mL
shake 5min
*


JCAC
Seawater 2 L
add HCl 20 mL
add ^{232}U tracer (2 dpm)
add H_2O_2 1 mL
add Fe^{3+} 100 mg
boil for 30 min
add NH_4OH (pH>9)
heat (30 min)
stand
centrifuge
supernate
(discard)
ppt.
dissolve with HNO_3 20 mL
evaporate to dryness
add HNO_3 (3+11) 30 mL
heat to dissolve the residue
filter
residue
filtrate
add $NaNO_3$ (50 w/v%) 15 mL
add $Al(NO_3)_3$ (50 w/v%) 5 mL
add TBP-xylene (1+9) 10 mL
solvent extraction
shake 5 min
organic layer
aqueous layer
add TBP-xylene (1+9) 10 mL
shake 5 min
organic layer
aqueous layer
add TBP-xylene (1+9) 10 mL
shake 5 min
organic layer
aqueous layer
(discard)
add $NaNO_3$ (50 w/v%) 20 mL
shake 5 min
aqueous layer
(discard)
organic layer
add HCl (1+1) 30 mL
*

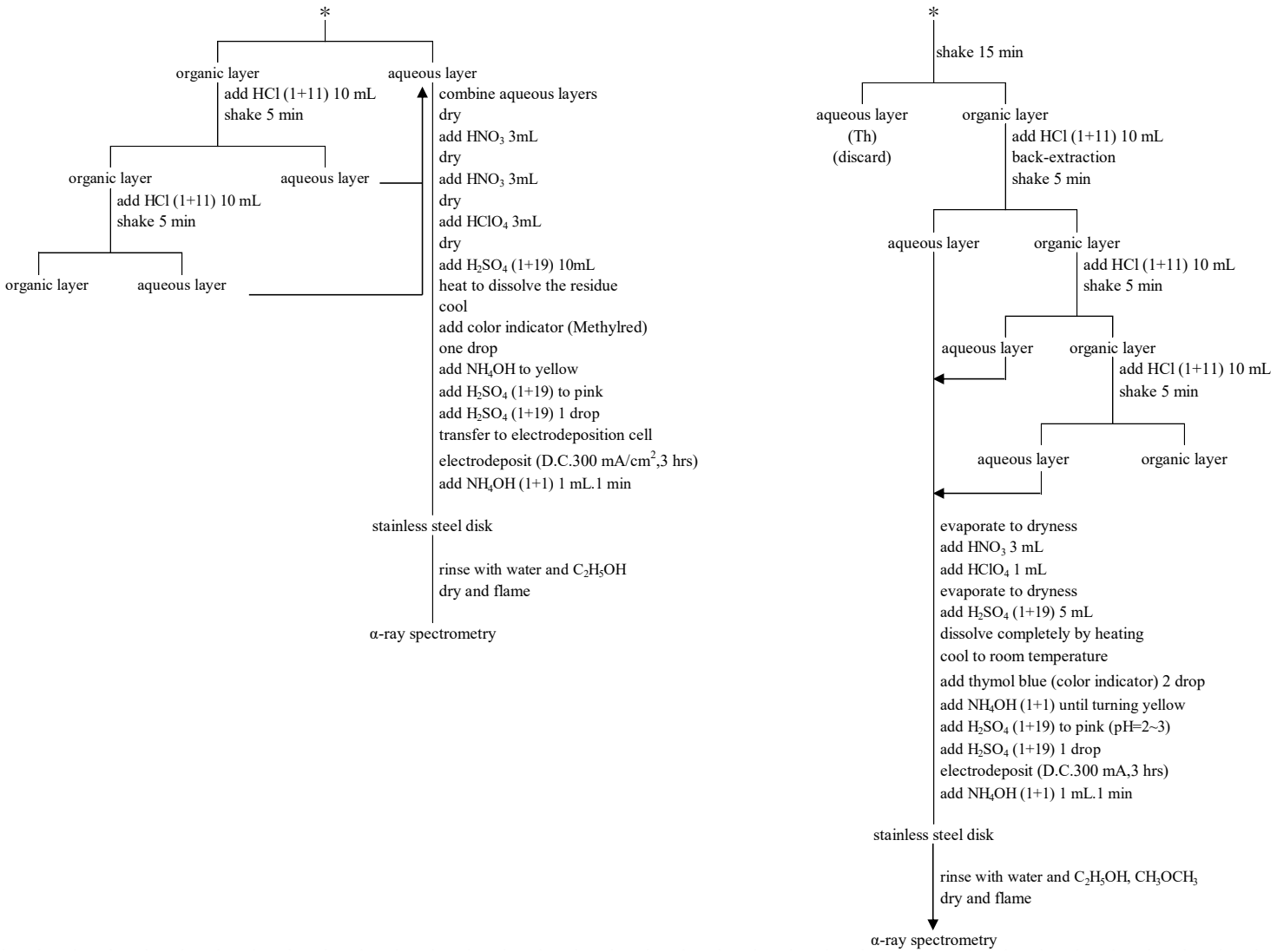


Fig.5 Flowchart for chemical separation of uranium

Table 4 Instruments and operating conditions for uranium analysis

Items		RMC	JCAC
Sample		Seawater	Seawater
Detector	Model	CANBERRA Alpha Analyst Silicon Semiconductor Detector	ORTEC 576A Silicon Semiconductor Detector
	Active area	24 mm φ	24 mm ϕ
	Resolution (FWHM)	18 keV	33 keV
	Efficiency	19 % , 27 %	32 %
Background		0 cpm	0 cpm
Calibration standard		^{241}Am	U_3O_8, ^{241}Am
Counting time		200,040 seconds	80,073-160,073 seconds

1.2.4 Determination of Tritium

(1) Pretreatment

Fresh water and seawater

At RMC, 300 mL of the water sample was distilled after adding approximately 0.2 g of potassium permanganate and 0.1 g of sodium peroxide. 10 mL of liquid scintillator (Ultima Gold LLT) was added to 10 mL of distilled sample in a plastic vial, mixed thoroughly and cooled before β-ray activity measurement.

At JCAC, 60 mL of the water sample was distilled after adding approximately 0.1 g of potassium permanganate and 0.1 g of sodium peroxide. 50 mL of liquid scintillator (Ultima Gold LLT) was added to 50 mL of distilled sample in a teflon vial, mixed thoroughly and cooled before β-ray activity measurement.

(2) Measurement

β-ray activity measurement was carried out by using liquid scintillation counter at RMC and JCAC. The instruments and operating conditions are shown in Table 5.

Table 5 Instruments and operating conditions for tritium analysis

Items	RMC	JCAC
Counter	Revvity Quantulus GCT 6220	Aloka LSC-LB5
Counting vial	Plastic vial 20 mL	Teflon vial 100 mL
Liquid scintillator	Ultima Gold LLT 10 mL	Ultima Gold LLT 50 mL
Distilled sample volume	10 mL	50 mL
Efficiency	22.1 %	26.4- 30.9 %
Calibration standard	transformed spectral index of external standard	External standard channel ratio method
Counting time	50 min. × 10 times	50 min. × 10 times
Background	0.31 cpm	2.54- 3.38 cpm
FOM (EV/√B)	397.1	764.9- 858.9

1.2.5 Measurement of gross β activity

(1) Pretreatment

1) Fresh water

At RMC, 1 L of the fresh water sample was evaporated to near dryness. All the residue was put in a dish of 1 inch in diameter, with dilute nitric acid used for washing the beaker. After drying, flame to convert the nitrate salt to oxides, the dish was used for gross β activity measurement.

At JCAC, 1 L of the fresh water sample was added nitric acid, and the sample was evaporated to near dryness. All the residue was put in a dish of 1 inch in diameter, with dilute nitric acid used for washing the beaker, and completely evaporated by using an infrared lamp. The dish was used for gross β activity measurement.

The pretreatment procedure used for fresh water sample is shown in Fig. 6.

2) Tea leaves and soil

Each portion of the ashed tea leaves and dried soil samples in the pretreatment procedure for γ-ray spectrometry or radiochemical analysis was also used for the measurement of gross β activity.

At RMC, 0.5 g of tea leaves and 0.2 g of soil were separately placed in dishes of 2 inches in diameter. A small quantity of alcohol was poured into the samples and the surface of each sample was flattened while it was wet. After drying, each dish was used for gross β activity measurement.

At JCAC, 0.5 g of the ashed tea leaves and the dried soil were taken and placed separately in dishes of 1 inch in diameter. A small quantity of ethanol was poured into the samples and the surface of each sample was flattened while it was wet. After each sample was dried by an infrared lamp, a few drop of collodion was added. After drying, each dish was used for gross β activity measurement.

The pretreatment procedures for the tea leaves and soil samples are shown in Fig. 7.

(2) Measurement

Gross β activity measurement was carried out using low background gas-flow type proportional counter at RMC and low background gas-flow type GM counter at JCAC. The instruments and operating conditions are shown in Table 3.

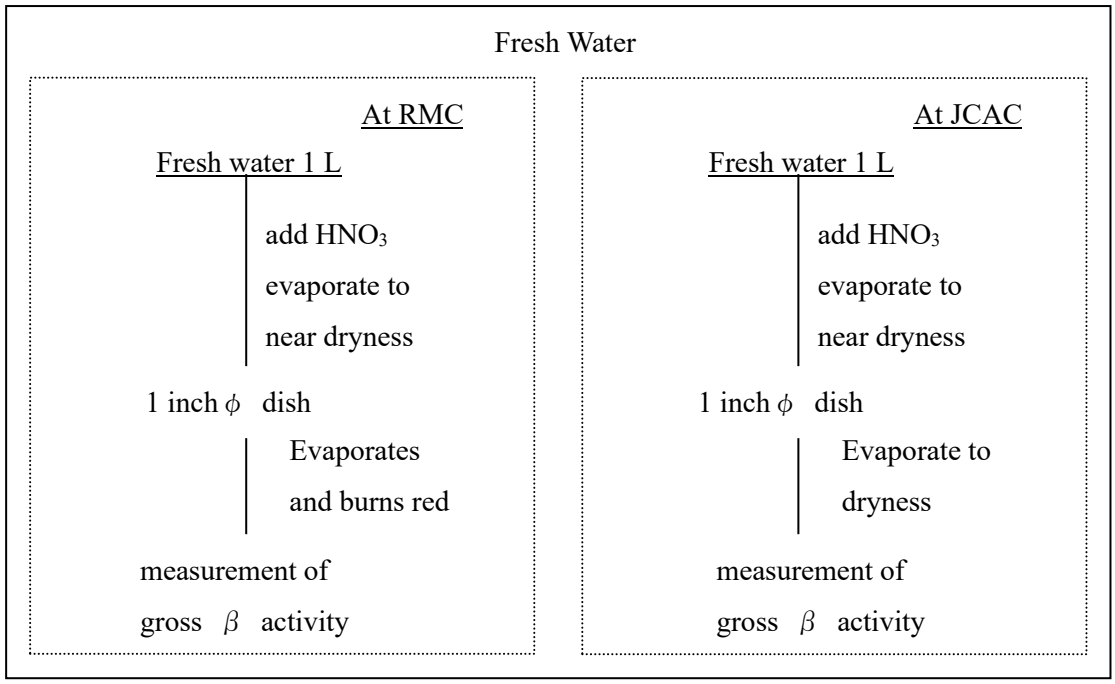


Fig. 6 Pretreatment method for gross β activity measurement

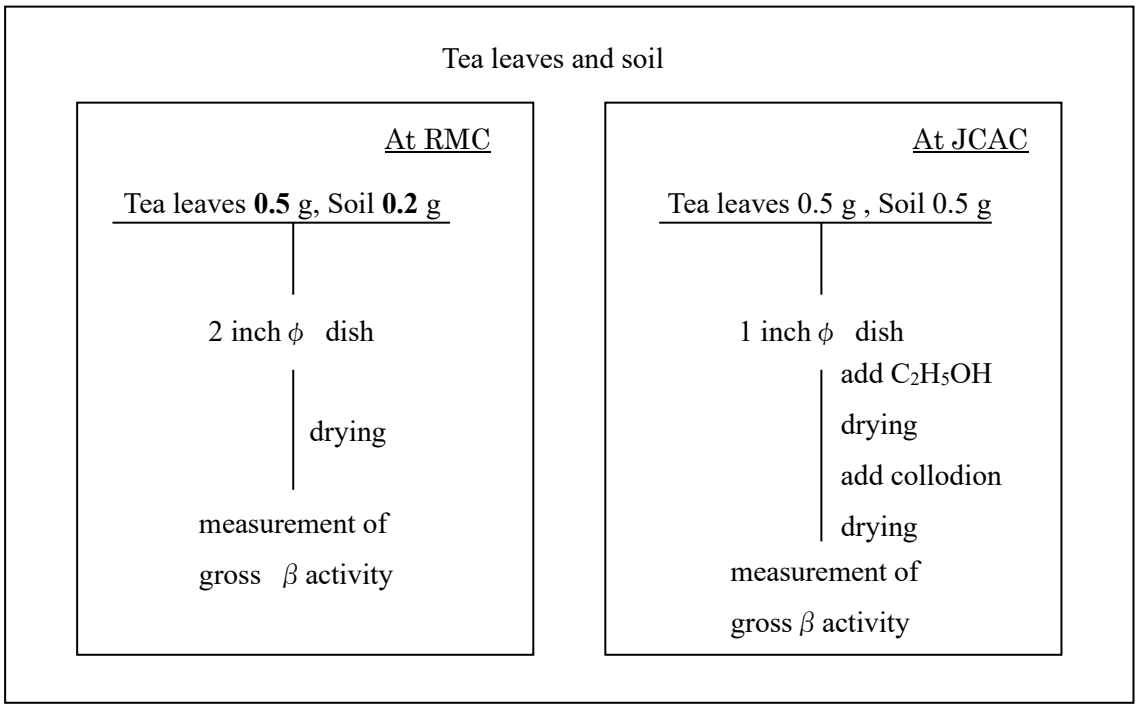


Fig. 7 Pretreatment method for gross β activity measurement

1.2.6 Determination of Plutonium

(1) Pretreatment

Soil (Taipei)

At RMC, 5g of ashed soil was taken for analysis. The sample was spiked with ^{242}Pu tracer and leached with 50 mL of hot 3:2 HNO_3 for 2 hours. During the leaching step, the soil was boiled and stirred under reflux. The mixture was then filtered and then 1 mL of 30% H_2O_2 and 0.2 g of $NaNO_2$ were used for the valence adjustment of Pu.

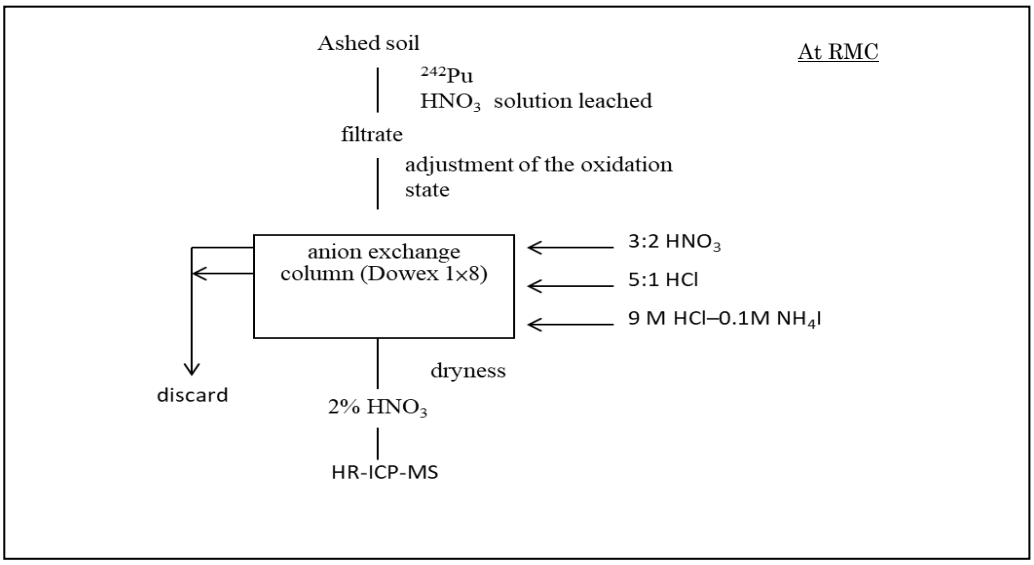
After the adjustment of the oxidation state of Pu to Pu(IV), the solution was added into a column with 3 mL preconditioned anion exchange column (Dowex 1×8, 100–200 mesh). The column was washed with 50 mL of 3:2 HNO_3 and 50 mL of 5:1 HCl to remove the interfering elements and Pu was eluted from the column by reduction with 15 mL of freshly prepared 9 M HCl–0.1M NH_4I. The eluted solution was heated to dryness, and then dissolved in 2% HNO_3 for plutonium measurement.

At JCAC, about 50 g of ashed soil was sampled and heated at 500°C for 12 hours. The sample was spiked with ^{242}Pu tracer and leached with 100 mL of 3:2 HNO_3 for 3h on a hot plate. The sample was filtered and then added 10 mL of 20% $NaNO_2$ for the valence adjustment of Pu. After the adjustment of the oxidation state of Pu (Pu(IV)), the solution was added into a column with 6 mL preconditioned anion exchange resin (Dowex 1×8, 100-200 mesh). The column was washed with 120 mL of 8 M HNO_3 and 200 mL of 10 M HCl to remove the interfering elements and Pu was eluted from the column by reduction with 100 mL of freshly prepared 10 M HCl-0.1 M NH_4I. The eluted solution was heated to dryness, and 10 mL of 4 M-CH_3COOH was added and dissolved by heating. This solution was passed through the column to remove U. The column was washed twice with 10 mL of 4 M CH_3COOH to recover remained Pu in the column. The solution was heated to dryness, and then dissolved in 1 M HNO_3 for plutonium measurement.

The pretreatment procedure used for soil sample is shown in Fig. 8.

(2) Measurement

The determination for the activities of ^{239}Pu and ^{240}Pu was carried out by using HR-ICP-MS at RMC and JCAC. The instruments and operating conditions are shown in Table 6.



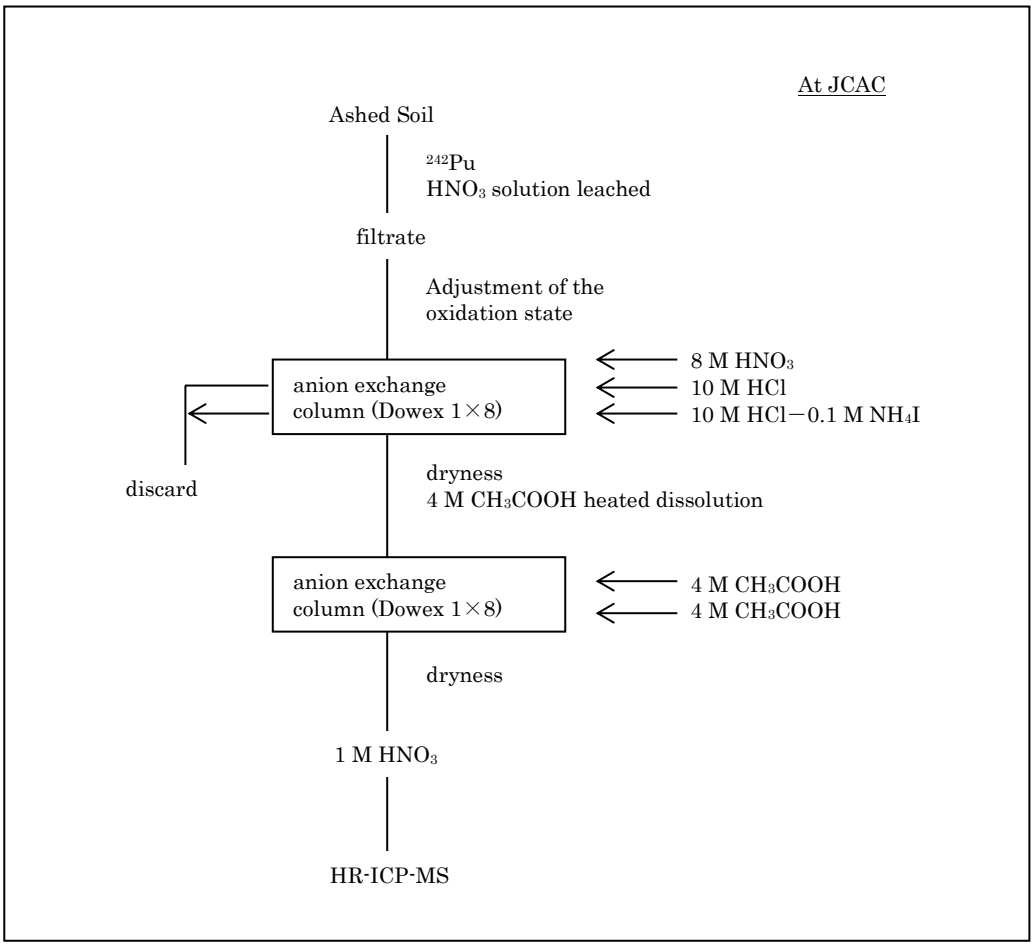


Fig. 8 Pretreatment method for plutonium activity measurement

Table 6　Instruments and operating conditions for plutonium analysis

Items	RMC	JCAC
Instrument	Element XR	Element 2
RF power	1200 W	1300W
Mass resolution	Low	Low
Nebulizer	Apex-HF desolvating nebulizer	Glass concentric nebulizer
Sampling and skimmer cones	Nickel	Nickel

1.3 Criteria for evaluation of results

In this report, E_n score applied to evaluate for each laboratory results.

The value of the E_n was calculated according to the following equation:

$$En = \frac{Value_{RMC} - Value_{JCAC}}{\sqrt{U_{RMC}^2 + U_{JCAC}^2}}$$

where

$Value_{RMC}$: RMC result

$Value_{JCAC}$: JCAC result

U_{RMC}: expanded uncertainty (k=2) of RMC

U_{JCAC}: expanded uncertainty (k=2) of JCAC

The result was assigned “acceptable” score if: En≦1

The result was assigned “not acceptable” score if: En>1

1.4 Results

The sampling and pretreatment data are shown in Table 7. The analytical results are shown in Table 8. The E_n scores are shown in Table 9. The results of ^{240}Pu /^{239}Pu atom ratio are shown in Table 10.

The intercomparison samples and measured radionuclides are as follows.

(1) γ-ray spectrometry

Tea leaves ash (^{40}K and ^{137}Cs)

Soil (^{40}K, ^{137}Cs, ^{208}Tl and ^{228}Ac)

The E_n scores of the tea leaves and soil samples are within 1.0.

(2) Radiochemical analysis

Fresh water (^{90}Sr,^{3}H and Gross β)

Seawater (^{137}Cs, Uranium and ^{3}H)

Tea leaves (^{90}Sr and Gross β)

Soil (^{90}Sr, Gross β, ^{239}Pu, ^{240}Pu and ^{240}Pu /^{239}Pu atom ratio)

The E_n scores are within 1.0 except for ^{239}Pu and ^{240}Pu in soil.

1.5 Remarks

The En score for Plutonium (Pu) in the soil exceeded 1. Subsequent analysis at RMC was conducted, using a newly prepared Pu-242 tracer, which yielded an En score of less than 1.0 in the measurement result.

Therefore, the initial high En score (and the associated low Pu activity reported by RMC) appears to be due to the evaporation of the existing tracer, which led to an increased concentration and consequently, artificially lower measured activity values.

Table 7 Sampling and pretreatment data

Upper line: RMC Lower line: JCAC

sample	Sampling date	Sampling location	Sampling method and amount	Nuclides	Pretreatment Method	Amount for analysis	Measurement sample mass
Fresh water	Jan. 1, 2024	Long-Tan	Underground water was collected with a plastic bucket, 30 L, and filtered. For JCAC, 25 L of the sample was acidified with 1 mL HCl per liter, and another 2 L was kept unacidified for ^{3}H measurement.	^{90}Sr	–	1.0 L	–
					–	4.0 L	–
				^{3}H	distilled with $KMnO_4$ and Na_2O_2	–	10 mL
					distilled with $KMnO_4$ and Na_2O_2	60 mL	50 mL
				Gβ	dry for Gross β	1.0 L	139.1 mg
					dry for Gross β	1.0 L	154.7 mg
Sea water-A		Kaohsiung and Hengchun	Sampling with a plastic bucket, 100 L, filtered. For JCAC, 5 L of the sample was acidified with 1 mL HCl per liter for U analysis. For Cs-137 analysis, 40 L of seawater was acidified with 1 mL HCl per liter and spiked with ^{137}Cs at about 10–20 mBq/L. Another 2 L of the sample was kept unacidified for ^{3}H measurement.	^{137}Cs	adsorption onto AMP and dissolve with NaOH	20 L	–
					adsorption onto AMP	20 L	9.15 g
				U	–	1.0 L	–
					–	2.0 L	–
				^{3}H	distilled with $KMnO_4$ and Na_2O_2	300 mL	10 mL
					distilled with $KMnO_4$ and Na_2O_2	60 mL	50 mL
Tea leave (ash)		Shin-Ban-San	Sampling from a farm. Grind, mix and ash at 450°C.	^{90}Sr, γ, Gβ	–	10.0 g/ash, –, –	–, 47.80 g/ash, 0.50 g/ash
					–	14.6 g/ash, –, –	–, 59.92 g/ash, 0.49 g/ash
Soil		Long-Tan	Samples were collected with a spade, ground, sieved, dried at 105°C, mixed, and ashed at 450 °C. In Longtan, 500 g was used for ^{90}Sr; in Taipei, 500 g was used for γ , Gβ, Pu analyses.	^{90}Sr	dry (110°C) grind, mix	100 g	–
					dry (105°C) and homogenize	99.7 g	–
		Taipei		γ, Gβ, ^{239}Pu, ^{240}Pu	dry (110°C) grind, mix.	100 g, 10 g, –	–,0.20 g, 1.5 mL
					dry (105°C) and homogenize	–, –, 50 g	78.43 g, 0.50 g, 15 mL
Sea water-B	Jan. 1, 2025	Kaohsiung and Hengchun	Sampling with a plastic bucket, 100 L, filtered. For JCAC, 5 L of the sample was acidified with 1 mL HCl per liter for U analysis. For Cs-137 analysis, 40 L of seawater was acidified with 1 mL HCl per liter and spiked with ^{137}Cs at about 10–20 mBq/L. Another 2 L of the sample was kept unacidified for ^{3}H measurement.	^{137}Cs	adsorption onto AMP and dissolve with NaOH	20 L	–
					adsorption onto AMP	20 L	9.34 g
				U	–	1.0 L	–
					–	2.0 L	–
				^{3}H	distilled with $KMnO_4$ and Na_2O_2	300 mL	10 mL
					distilled with $KMnO_4$ and Na_2O_2	60 mL	50 mL

Table 8 Analytical results

Upper line: RMC Lower line: JCAC

Sample	Sampling date	γ-ray spectrometry				Radiochemical analysis							Unit
		^{40}K	^{137}Cs	^{208}Tl	^{228}Ac	^{90}Sr	^{137}Cs	Total U	^{3}H	Gross β	^{239}Pu	^{240}Pu	
Fresh water	Jan. 1, 2024	—	—	—	—	0.720 ± 0.065 (0.02)	—	—	18.6 ± 1.60 (0.6)	1.20 ± 0.11 (0.03)	—	—	Bq/L
		—	—	—	—	0.735 ± 0.075 (0.010)	—	—	19.7 ± 1.4 (0.26)	1.15 ± 0.14 (0.034)	—	—	
Seawater-A		—	—	—	—	—	0.0178 ± 0.0028 (0.0014)	0.077 ± 0.012 (0.0021)	27.9 ± 2.2 (0.66)	—	—	—	Bq/L
		—	—	—	—	—	0.0178 ± 0.0029 (0.00065)	0.078 ± 0.0035 (0.0017)	28.5 ± 1.9 (0.27)	—	—	—	
Tea leaves ash		7152 ± 683.7 (314.7)	21.5 ± 3.3 (1.6)	—	—	59.0 ± 5.96 (1.69)	—	—	—	7276.1 ± 657.0 (78.40)	—	—	Bq/kg dry ash.
		7540 ± 1100 (40)	23.3 ± 3.7 (0.78)	—	—	56.4 ± 7.3 (2.3)	—	—	—	7730 ± 340 (150)	—	—	
Soil		457.3 ± 44.2 (21.63)	155.44 ± 19.1 (9.4)	14.2 ± 2.4 (1.2)	39.7 ± 6.1 (3.0)	23.7 ± 1.92 (0.34)	—	—	—	3188.9 ± 529.4 (83.00)	—	—	Bq/kg dry wt.
		511 ± 66 (11)	152 ± 19 (1.5)	14.2 ± 2.1 (0.58)	37.7 ± 6.2 (2.1)	24.3 ± 2.7 (0.57)	—	—	—	2790 ± 190 (89)	—	—	
		—	—	—	—	—	—	—	—	—	4.16 ± 0.19 (0.034)	2.52 ± 0.12 (0.022)	Bq/kg dry ash.
		—	—	—	—	—	—	—	—	—	6.05 ± 0.37 (0.086)	3.69 ± 0.23 (0.058)	
Seawater-B	Jan. 1, 2025	—	—	—	—	—	0.0109 ± 0.0017 (0.00077)	0.082 ± 0.035 (0.0022)	110.5 ± 7.5 (1.56)	—	—	—	Bq/L
		—	—	—	—	—	0.0108 ± 0.0019 (0.00053)	0.079 ± 0.0049 (0.0024)	112 ± 7.0 (0.54)	—	—	—	

Measured results are shown in the form of " measured results ± expanded uncertainties "(k=2) for nuclides respectively.
（counting error 1σ）
The results are decay-corrected to sampling date (except gross β, Total U, ^{239}Pu and ^{240}Pu).

Table 9 The values of the E_n score

Sample	γ-ray spectrometry				Radiochemical analysis						
	^{40}K	^{137}Cs	^{208}Tl	^{228}Ac	^{90}Sr	^{137}Cs	Total U	^{3}H	Gross β	^{239}Pu	^{240}Pu
Fresh water	—	—	—	—	-0.15	—	—	-0.52	0.28	—	—
Seawater-A	—	—	—	—	—	0.00	-0.08	-0.21	—	—	—
Tea leaves ash	-0.30	-0.36	—	—	0.28	—	—	—	-0.61	—	—
Soil	-0.68	0.13	0.00	0.23	-0.18	—	—	—	0.71	-4.54	-4.51
Seawater-B	—	—	—	—	—	0.04	0.08	-0.15	—	—	—

Table 10 Evaluation results of intercomparison for $^{240}Pu/^{239}Pu$ atom ratio

Measure	Sample	Nuclides	Unit	Lab	Data	Evaluation criteria	Evaluation [1] value	Difference [2]	Judgment [3]
ICP-MS	Soil	^{240}Pu /^{239}Pu	atom ratio	RMC	0.170 ± 0.0025	≦7 %	0.0119	0.004	Good
				JCAC	0.166 ± 0.0025				

1) Evaluation value: The value is calculated by 7% of the higher value between RMC and JCAC.
2) Difference: Difference between the analytical values obtained by RMC and JCAC.
3) Judgment: If the difference is higher than an evaluation value, "discuss" is expressed, otherwise, "Good".

2. Intercomparison of radiation dose measurements

2.1 Instruments

RMC used thermoluminescence dosimeters (hereafter referred to as TLDs) and JCAC used radiophotoluminescence glass dosimeters (hereafter referred to as RPLDs) for radiation dose measurements. The instruments and operating conditions are shown in Table 11.

2.2 Method of the radiation dose measurements

The program of the radiation dose measurements consists of three kinds of tests. These are (1) a field-exposure test at RMC's monitoring points, (2) a standard irradiation test with RMC's irradiation equipment and (3) a standard irradiation test with JCAC's irradiation equipment.

An outline of each test is shown in Table 12.

(1) Field-exposure test at RMC's three monitoring points.

1) The five sets of JCAC's RPLDs, each set consists of 5 RPLDs were annealed at 400 ℃ for 1 hour by JCAC.
2) After JCAC's RPLDs were sent from JCAC to RMC in a container made of 2 mm thick lead, the first three sets were field-exposed by RMC at three monitoring points for 92 days. The fourth set was kept in a case of 5 cm thick lead for the control. The fifth set was for the round-trip transit-dose.
3) All JCAC's RPLDs were sent back to JCAC in a container made of 2 mm thick lead and measured by JCAC.
4) RMC independently carried out the same test using RMC's TLDs.
5) The net doses were calculated by subtracting the control dose from the total doses. [The total dose includes field-exposed dose, self dose and a round-trip transit-dose. The control dose includes self dose and a round-trip transit-dose.] Each dose is shown as an average.

(2) Standard irradiation test using RMC's irradiation equipment.

1) The three sets of RPLDs, each set consists of 5 RPLDs, were annealed at 400 ℃ for 1 hour by JCAC.
2) After JCAC's RPLDs were sent from JCAC to RMC in a container made of 2 mm thick lead, the two sets were exposed to 263 μGy and 526 μGy, respectively, using a ^{137}Cs γ-ray source at RMC.

3) The remaining set was used to evaluate the round-trip transit-dose between RMC and JCAC.
4) All RPLDs were sent back to JCAC in a container made of 2 mm thick lead.
5) After arriving at JCAC, all RPLDs were measured by JCAC immediately.
6) Net doses were calculated by subtracting the round-trip transit-dose from the total doses (The total dose includes the irradiation dose, self dose and the round-trip transit-dose). Each dose is shown as an average of 5 data.

(3) Standard irradiation test using JCAC's irradiation equipment
1) The three sets of TLDs, each set includes 5 TLDs (10 elements), were annealed at 250℃ by RMC.
2) After RMC's TLDs were sent from RMC to JCAC, the two sets were exposed to 179 μGy and 247 μGy, respectively, using a ^{137}Cs γ-ray source at JCAC.
3) The remaining set was used for evaluating the round-trip transit-dose between JCAC and RMC.
4) All TLDs were sent back to RMC in a container made of 2 mm thick lead.
5) All TLDs were measured by RMC shortly after arriving at RMC.
6) Net doses were calculated by subtracting the round-trip transit-dose from the total doses (The total dose includes the irradiation dose, self dose and the round-trip transit-dose). Each dose is shown as an average of 10 data.

Table 11 Instruments and operating conditions for radiation dose measurements

Items	RMC	JCAC
Reader Read temperature (TLD)	UD-716AGL Panasonic Apporox.250℃ Fixed	FGD-202 AGC TECHNO GLASS
Material Number for each measurement	TLD UD-814AS1 Panasonic $CaSO_4$:Tm 5 pieces (10 elements)	RPLD SC-1 AGC TECHNO GLASS 5 pieces (5 elements)
Annealing oven	UD-716AGL Panasonic 250℃ 2min.	NHK-210 NITTO KAGAKU 400 ℃ 1 h.
Method of calibration	Standard irradiation by the batch	Standard irradiation
Irradiation dose level for calibration	Field-exposure test Field-1(RMC): 140 μGy Field-2(RMC): 184 μGy Field-3(RMC): 412 μGy Control(RMC): 35.1 μGy Standard irradiation test High : 247 μGy Low : 179 μGy	Field-exposure test Level-1: 59.7 μGy Level-2: 254 μGy Level-3: 552 μGy Standard irradiation test Level-1: 105 μGy Level-2: 306 μGy Level-3: 605 μGy
Irradiation dose for test	High: 526 μGy Low: 263 μGy	High : 247 μGy Low : 179 μGy
Determination of irradiation dose	Ionization chamber (800mL) EXRADIN A6 Standard Imaging Co.	Ionization chamber (4000 mL) AE-132a OYOGIKEN
γ-ray source	^{137}Cs (370 GBq)	^{137}Cs (3.7 GBq)

Table 12 Outline of field-exposure test and standard irradiation tests

(1) Field-exposure test at RMC's monitoring points

1)RMC

Number of TLD	Monitoring point	Date of annealing	Term of environmental irradiation	Date of reading
5	RMC field-1	March 26, 2025	March 27, 2025～June 27, 2025	June 27, 2025
5	RMC field-2	March 26, 2025	March 27, 2025～June 27, 2025	June 27, 2025
5	RMC field-3	March 26, 2025	March 27, 2025～June 27, 2025	June 27, 2025
5	Control	March 26, 2025	March 27, 2025～June 27, 2025	June 27, 2025

2)JCAC

Number of RPLD	Monitoring point	Date of annealing	Term of environmental irradiation	Date of reading
5	RMC field-1	March 13, 2025	March 27, 2025～June 27, 2025	July 4, 2025
5	RMC field-2	March 13, 2025	March 27, 2025～June 27, 2025	July 4, 2025
5	RMC field-3	March 13, 2025	March 27, 2025～June 27, 2025	July 4, 2025
5	Control	March 13, 2025	March 27, 2025～June 27, 2025	July 4, 2025
5	For round-trip transit dose (from JCAC to RMC)	March 13, 2025	——	July 4, 2025

(2) Standard irradiation test using RMC's irradiation equipment

1) Annealing at JCAC

March 13, 2025 (15 RPLDs)

2) Irradiation at RMC (High and Low dose)

March 24, 2025 (10 RPLDs)

3) Reading at JCAC

April 4, 2025 (15 RPLDs)

(3) Standard irradiation test using JCAC's irradiation equipment

1) Annealing at RMC

March 03, 2025 (15 TLDs)

2) Irradiation at JCAC (High and Low dose)

March 13, 2025 (10 TLDs)

3) Reading at RMC

March 21, 2025 (15 TLDs)

2.3 Criteria for evaluation of results

In this report, E_n score applied to evaluate for each laboratory results.

The value of the E_n was calculated according to the following equation:

$$En = \frac{Value_{RMC} - Value_{JCAC}}{\sqrt{U_{RMC}^2 + U_{JCAC}^2}}$$

where

$Value_{RMC}$: RMC result

$Value_{JCAC}$: JCAC result

U_{RMC}: expanded uncertainty (k=2) of RMC

U_{JCAC}: expanded uncertainty (k=2) of JCAC

The result was assigned “acceptable” score if: En≦1

The result was assigned “not acceptable” score if: En>1

2.4 Results

The results are shown in Table13. The E_n scores are shown in Table 14. The E_n scores are within 1.0, except for the field-exposure test at the RMC Field-3 point.

2.5 Remarks

The En value for Field 3 was calculated to be 1.05, which is slightly above the acceptance criteria (|En|≤1). The potential causes are discussed in the Technical information exchange section.

Table 13 Results of field-exposure test and standard irradiation tests

(1) Field-exposure test at RMC's monitoring points　March 27, 2025～June 27, 2025　　Unit:μGy

Item / Organization	Total dose			Control (BKG)	Round-trip transit-dose (reference)	Net dose		
	Field-1	Field-2	Field-3			Field-1	Field-2	Field-3
RMC	149±3	193±3	412±8	36±1	——	113±3	157±4	376±8
JCAC	173±1	205±1	473±6	58±0	——	115±1	147±1	415±6

＊：These data include a round-trip transit-dose.　　Net dose= Total dose－Control

(2)Standard irradiation tests using RMC's irradiation equipment　　Unit:μGy

Item / Organization	Total dose*		Round-trip transit-dose (to JCAC)	Net dose		Irradiation dose	
	Low	High		Low	High	Low	High
RMC	——	——	——	——	——	263	526
JCAC	279±1	536±5	26±1	253±2	511±5	——	——

＊：These data include a round-trip transit-dose.　Net dose= Total dose－Round-trip transit dose

(3)Standard irradiation tests using JCAC's irradiation equipment　　Unit:μGy

Item / Organization	Total dose*		Round-trip transit-dose (to RMC)	Net dose		Irradiation dose	
	Low	High		Low	High	Low	High
RMC	201±4	272±5	21±0.4	180±4	251±5	——	——
JCAC	——	——	——	——	——	179	247

＊：These data include a round-trip transit-dose.　　Net dose= Total dose－Round-trip transit dose

Measured results are shown in the form of "average ± standard deviation of 10 data (RMC) or 5 data (JCAC)".

RMC's expanded uncertainties (k=2) are 6.1% for measurement and 3.0% for irradiation respectively.

JCAC's expanded uncertainties (k=2) are 6.6 % for measurement and 2.6 % for irradiation respectively.

Table14 The values of the E_n score

(1)Field-exposure test at RMC's monitoring points

Field-1	0.19
Field -2	0.76
Field -3	1.05

(2)Standard irradiation tests using RMC's irradiation equipment

Low	0.52
High	0.39

(3)Standard irradiation tests using JCAC's irradiation equipment

Low	0.08
High	0.24

3. Technical information exchange

(1) Both parties discussed following items.

1) Re-analyze of ^{239}Pu and ^{240}Pu for soil sample at RMC

RMC re-examined the entire process to identify the cause of the low Pu activity observed in the prior measurement, including the heat extraction temperature, duration, and number of extractions. However, the analytical results remained consistent with the original data, as shown in Table 15.

Simultaneously, a new Pu-242 tracer was prepared and compared with the currently used tracer. The test results, based on the intensity shown in the ICP-MS analysis (Table 16), indicated that the activity of the current tracer was approximately 1.8 times higher than the newly prepared one. This strongly suggests that evaporation in the existing tracer solution led to an increased concentration, consequently resulting in lower measured activity values.

RMC then re-analyzed the samples using the newly prepared Pu-242 tracer. The measured Pu activity in the soil and the evaluated En score of the two institutions are now less than 1, as shown in Table 17.

Table 15. Analysis results of Pu in Soil samples by different conditions of extraction

No.	Sample	Temp. of acid extraction	Extraction Time	Numbers of extraction	Pu result (Bq/kg dry ash)	
					Pu-239	Pu-240
1	Soil	400℃	2~3h	3	3.48	2.09
2		380℃ H_2O_2 was added simultaneously	5h	1	3.57	2.16

Table16. Comparison of the Intensity of the Current and the New Pu Tracer

No.	Analysis Intensity of Pu Tracer by ICP-MS	
	Current Pu Tracer	New Pu Tracer
1	9967.6	5002.5
2	9672.7	5205.6
3	10209.8	4996.8
4	9856.3	5670
5	9709	5272.3
Average	9883.08	5229.44

Table 17.Analysis of Pu and En evaluation results for Soil samples.

Sample	Lab.	Pu result（Bq/kg dry ash)		En score	
		Pu-239	Pu-240	Pu-239	Pu-240
Soil	RMC	6.11±0.27	3.62±0.16	0.16	-0.30
	JCAC	6.05±0.37	3.69±0.23		

The number to the right of ± indicates the expanded uncertainty (k=2).

2) Evaluation of uncertainty in Total U for Seawater A and B

The RMC re-evaluated the expanded uncertainties for total uranium in Seawater-A and Seawater-B and identified several issues in the original assessment, particularly those associated with the certified reference material (CRM) and the micropipette calibration data.

In the first evaluation, the reported uncertainties for Seawater-A and Seawater-B were 0.012 and 0.035, respectively. After re-evaluation, the updated results became 0.0075 for Seawater-A and 0.033 for Seawater-B.

The CRM certificate was found to specify an expanded uncertainty with a coverage factor of k = 3, which substantially increased its weighting in the combined uncertainty during the original evaluation. The micropipette uncertainty was also updated using its latest calibration data; however, its influence on the total combined uncertainty remained relatively small.

Overall, the higher combined uncertainty reported by RMC is primarily influenced by the larger uncertainty contribution associated with the reference material certificate. This contribution may be further refined in future assessments.

However, RMC's revised uncertainty values were much larger than JCAC's. The results of total U in Seawater-A and Seawater-B by both RMC and JCAC were in good agreement, which means that the analytical processes were valid. Since there seems to be some possible overestimation in evaluation of the uncertainty by RMC, it is recommended to review the uncertainty budget.

3) The field-exposure test at the RMC Field-3 point

Regarding the discrepancy observed in Field 3 (En=1.05), RMC has conducted a review of the environmental conditions. It is hypothesized that the reorganization of indoor sources (specifically the closer proximity

of Ra-226 sources) altered the radiation field geometry, increasing the component of low-energy scattered radiation.

Due to the different physical characteristics of the detectors, the TLD (using a Lead filter) has a stronger shielding effect against low-energy photons compared to the RPLD. This difference in energy response is considered the estimated cause for the lower readings obtained by RMC. This is a technical interpretation based on physical principles rather than a systematic calibration error."

To verify the hypothesis regarding the energy response difference in Field 3, RMC will continue to investigate by conducting in-situ gamma spectrometry using an HPGe detector. The verification data will be shared as a technical reference once the analysis is complete.

4. Technical support

JCAC provided the training courses to RMC as follow.

Date	Place	Item
Mar. 24~ Mar.28, 2025	RMC	1. Introduction of Carbon-14 Analysis in fish sample.
		2. Introduction of Tritium Enrichment Analysis.
		3. Introduction of Iodine-129 Analysis in environmental samples.
Dec. 15~Dec. 18, 2025	JCAC	Technical Support for Kr-85 and Xe-133 Analysis

Appendix 1

Minutes of the 32th Annual Meeting

Minutes of the 32nd Meeting

on the Memorandum for Technical Cooperation

between Radiation Monitoring Center(RMC)

and Japan Chemical Analysis Center(JCAC)

Date : June 15-16, 2023
Place: Japan Chemical Analysis Center (JCAC)
295-3, Sanno-cho, Inage-ku, Chiba-shi, Chiba, Japan

Attendants:

From RMC

Dr. Tsai Wen -Hsien
Dr. Chen Wan-Ling
Dr. Fang Chin-Yi

From JCAC

Mr. Isogai Keisuke
Mr. Ohta Yuji
Ms. Ohta Tomoko
Dr. Wang Xiaoshui
Dr. Ohtsuki Takayuki
Mr. Abe Goh
Mr. Shinohara Hirofumi
Mr. Sano Yuichi
Mr. Sato Syoji
Ms. Kashiwara Yoko
Mr. Toyooka Shinsuke
Ms. Sakuma Tsugumi
Mr. Tan Satoshi
Dr. Shen Haifeng
Ms. Abe Minami
Ms. Koh Ikue

Agenda

1. Opening addresses by representatives of both parties
2. Discussion on the results of the 2019 cooperation program
 (1) Intercomparison study program
 (2) Technical information exchange program
 (3) Technical support program
3. Discussion on the 2023 cooperation program
 (1) Intercomparison study program
 (2) Technical support program
 (3) Annual meeting in 2025
4. Presentations

SUMMARY

1. Opening addresses by representatives of both parties
   RMC : Dr. Tsai Wen -Hsien
   JCAC : Mr. Isogai Keisuke

2. Discussion on the results of the 2019 cooperation program

(1) Intercomparison study program (Report 2019E02)

RMC and JCAC confirmed the description of the analytical methods for γ-ray spectrometry, radiochemical analysis (^{90}Sr, ^{137}Cs, Uranium, ^{3}H, and Plutonium) , gross β activity and radiation dose measurement in accordance with the report.

1) γ-ray spectrometry
   All analytical results are in good agreement between RMC and JCAC.
2) Radiochemical analysis
   All analytical results are in good agreement between RMC and JCAC except for ^{90}Sr in fresh water and soil , Uranium in soil, gross β activity in fresh water, Plutonium in soil.
3) Radiation dose measurement
   Both parties agreed that the values determined by the parties for the field-exposure tests and standard irradiation tests were in good agreement.

(2) Technical information exchange

Both parties discussed following item.

1) the results of ^{90}Sr in fresh water samples
2) the results of gross β in fresh water samples
3) the results of Uranium in soil samples
4) the results of Plutonium in soil samples
5) the results of ^{90}Sr in soil samples

(3) Technical support program

Technical support was not provided.

3. Discussion on the 2023 cooperation program

(1) Intercomparison study program (Appendix I)

1) Radioactivity analysis for environmental samples
   The intercomparison program of 2023 will essentially follow the same program as that of 2019.
   The samples and items of analysis are listed in Appendix I.

2) Radiation dose measurement
   The intercomparison program of 2023 will essentially follow the same

program as that of 2019.
The items of tests are also listed in Appendix I

3) Evaluation method
Analytical results will be evaluated with En score based on uncertainties.

(2) Technical support program
Both parties will conduct analytical support, if RMC or JCAC need.

(3) Interim meeting in 2024
The meeting will be held to evaluate the interim report for Seawater-A.

(4) Biannual meeting in 2025
The 33rd meeting is scheduled to be held at RMC in November 2025.

4. Presentations

(1) Radiation Monitoring of Sea area around Taiwan (RMC : Dr. Chen Wan-Ling)

Signatures

For RMC	For JCAC
蔡文賢	磯貝啓介
Dr. Tsai Wen -Hsien	Mr. Isogai Keisuke
Title : Deputy Director	Title : Executive Director
Date : June 16, 2023	Date : June 16, 2023

Appendix I

List of intercomparative subjects and samples (2023 Cooperation Program)

1. Radioactivity analysis

Sample	γ	^{90}Sr	^{137}Cs	U	^{3}H	Gross β	Pu
Fresh water		○			○	○	
Seawater-A			○	○	○		
Seawater-B			○	○	○		
Tea leaves	○	○				○	
Soil	○	○				○	○

γ : Determination of γ-ray emitting nuclides with Ge semiconductor detector
^{90}Sr : Determination of ^{90}Sr by radiochemical analysis
^{137}Cs : Determination of γ-ray emitting nuclides with Ge semiconductor detector
U : Determination of total U with Si semiconductor detector
^{3}H : Determination of ^{3}H with liquid scintillation counter
β : Measurement of gross β activity with low-background gas-flow counter
Pu : Determination of ^{239}Pu, ^{240}Pu and ^{240}Pu/^{239}Pu atom ratio with ICP-MS

(1) Seawater-B will be collected by RMC and will be sent to JCAC by Mar. 2025.
Other samples will be collected by RMC and will be sent to JCAC by Mar. 2024.

(2) The analytical results about Seawater-A obtained by RMC will be sent to JCAC by the end of August 2024.
JCAC will evaluate the results and issue an interim report for Seawater-A.
The analytical results except Seawater-A obtained by JCAC will be sent to RMC by the end of August 2025.
RMC will evaluate all results and make the final report.

(3) Frequency
Fresh water, tea leaves, soil : every 2 years
Seawater : every year

(4) Sampling amount for JCAC
Fresh water : 20L(HCl added), 10L(HCl not added)
Seawater : 40L(HCl added), 2L (HCl not added)

(5) Pretreatment
1) Fresh water and Seawater will be sent to JCAC without any pretreatment.
2) Tea leaves will be dried, ashed and homogenized then sent to JCAC.
3) Soil will be dried and homogenized then sent to JCAC.

2. Dosimetry

(1) Field-exposure test at RMC's monitoring points

1) Tests using RMC's TLD

Number of TLD	Monitoring Point
5	RMC-1
5	RMC-2
5	RMC-3
5	For self dose

2) Tests using JCAC's TLDs

Number of TLD	Monitoring Point
5	RMC-1
5	RMC-2
5	RMC-3
5	For self dose
5	For transit dose (between JCAC and RMC)

(2) Reference irradiation test at RMC (use 15 TLDs each)

1) Irradiation at RMC
2) Reading at JCAC

(3) Reference irradiation test at JCAC (use 15 TLDs each)

1) Irradiation at JCAC
2) Reading at RMC

Schedule for irradiation and measurement will be proposed by JCAC.

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