

FY2023 Radioactive Material Monitoring in the Water Environment in and Around Fukushima Prefecture

1. Survey Overview

In FY2023, the survey was conducted on the concentrations of radioactive cesium and radioactive strontium in water, sediment, and the surrounding environment (soil on river terraces and the shores of lakes) in public water areas (rivers, lakes and reservoirs and coastal areas). Areas for survey were Iwate, Miyagi, Fukushima, Ibaraki, Tochigi, Gunma, Chiba, and Saitama Prefectures, and Tokyo Metropolis. The ambient dose rate in surrounding environment was also measured for reference.

The number of measurement points and surveys are shown in Table 1, and survey locations are shown in Figure 1.

Table 1. Number of survey measurement points

Prefecture	Area	Number of measurement points	Number of surveys	Number of Samples					
				Water		Sediment		Surrounding environment* (Soil)	
				Able to collect	Unable to collect	Able to collect	Unable to collect	Able to collect	Unable to collect
Iwate	Rivers	22	80	80	0	80	0	156	4
	Coastal areas	2	4	8	0	4	0	—	—
Miyagi	Rivers	43	196	196	0	196	0	359	33
	Lakes and reservoirs	21	76	112	40	76	0	76	0
	Coastal areas	12	52	104	0	52	0	—	—
Fukushima	Rivers	123	818	812	6	812	6	1,602	34
	Lakes and reservoirs	84	551	835	267	527	24	515	36
	Coastal areas	15	150	300	0	150	0	—	—
Ibaraki	Rivers	53	212	212	0	212	0	400	24
	Lakes and reservoirs	19	76	147	5	76	0	68	8
	Coastal areas	5	20	40	0	20	0	—	—
Tochigi	Rivers	56	278	278	0	278	0	542	14
	Lakes and reservoirs	8	32	60	4	31	1	31	1
Gunma	Rivers	48	214	213	1	213	1	425	3
	Lakes and reservoirs	24	96	184	8	96	0	96	0
Chiba, Saitama, Tokyo	Rivers	51	216	216	0	216	0	374	58
	Lakes and reservoirs	8	32	39	25	32	0	16	16
	Coastal areas	8	41	82	0	41	0	—	—
Total	Rivers	396	2,014	2,007	7	2,007	7	3,858	170
	Lakes and reservoirs	164	863	1,377	349	838	25	802	61
	Coastal areas	42	267	534	0	267	0	—	—
	Overall total	602	3,144	3,918	356	3,112	32	4,660	231
				Able to collect: 11,690			Unable to collect: 619		

* In the environmental area surrounding the Rivers surveyed, there are two sampling points; one on the left bank and one on the right bank.

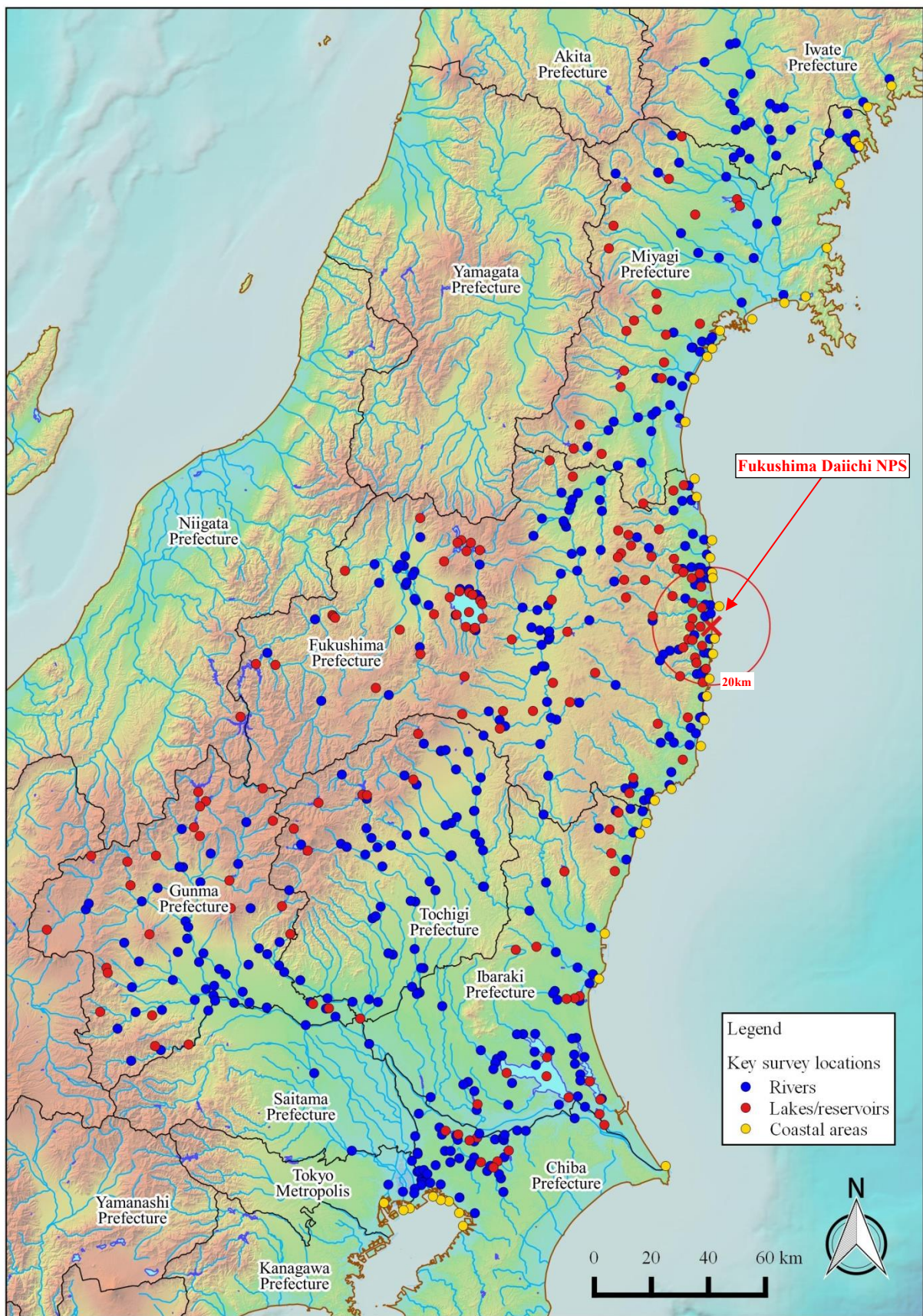


Figure 1. Survey Locations (All)

2. Outline of Results

(1) The situation of radioactive cesium concentrations in FY 2023 was as follows.

1) Water

The values of radioactive cesium were below the less than detection limits (1Bq/L) at more than 90% of locations but were detected at some locations (up to a maximum of 3.8Bq/L). At these detected locations, relatively high values were also detected on suspended solid (SS) and turbidity.

2) Sediments

① Rivers

Among approximately 400 measurement points conducted the survey, the results below the detection limit accounted for approximately 20%, the results from 10 to 100 Bq/kg accounted for approximately 60%, and the results from 100 to 1,000 Bq/kg accounted for approximately 20%. Approximately 80% of the total were below 100 Bq/kg.

In regard to an increase and decrease tendency, decreasing trend was observed at more than 90% of the measurement points.

② Lakes and Reservoirs

Among approximately 160 measurement points conducted the survey, the results from 10 to 100 Bq/kg accounted for approximately 30%, the results from 100 to 1,000 Bq/kg accounted for approximately 50%, and the results from 1,000 to 10,000 Bq/kg accounted for approximately 20%. Approximately 80% of the total were below 1,000 Bq/kg. In regard to an increase and decrease tendency, decreasing trend was observed at about 80% of the measurement points.

③ Coastal areas

Among approximately 40 measurement points conducted the survey, the results below the detection limit accounted for approximately 30%, the results from 10 to 100 Bq/kg accounted for approximately 50%. Approximately 80% of the total were below 100 Bq/kg. In regard to an increase and decrease tendency, decreasing trend was observed at about 80% of the measurement points.

*The status of bottom sediment concentrations in rivers, lakes and water sources, and coastal areas were calculated based on annual average values by each measurement point.

- (2) The situation of radioactive strontium in FY 2023 was as follows (Analysis of Sr-90 in the sediment was conducted at locations where the concentration of radioactive cesium in the sediment was relatively high).

1) Sediments

① Rivers

Radioactive strontium ranged (detection limits : 1Bq/L) from 0.63 to 0.80Bq/kg. The detected value has been gradually decreasing since FY2014, and since FY2016, the maximum has been around 1Bq/kg.

② Lakes and Reservoirs

Radioactive strontium ranged from 0.42 to 11Bq/kg. The detected value has remained at a low level since FY2017

* For more details, refer to the survey results for each prefecture.

3. Survey Methods

(1) Outline

1) Sample collection

Sample		Outline
Rivers	Water	Around 3L of water samples were collected from the surface layer (at up to 50cm below the surface), using a bucket or a dipper, from the top of a bridge or from the riverbank.
	Sediments	Sediment samples were collected from the surface layer (at up to 10cm below the surface), more than three times, using an Ekman-Birge bottom sampler or a scoop, from the top of a bridge or from the riverbank, and were mixed up.
	Surrounding environment (soil)	Soil samples were collected from the surface layer (at up to 5cm below the surface) on both riverbanks near a bridge or a levee using a soil sampler or a scoop, at five points each and mix them up.
	Ambient dose rate	At the location where soil samples were collected, the ambient dose rate was measured at a height of 1m from the ground surface using a NaI (TI) scintillation survey meter.
Lakes and reservoirs	Water	Around 3L of water samples were collected from the surface layer (at up to 0.5m below the surface) and from the bottom layer (at 1m from the bottom), using a Van Dorn sampler or a dipper, from a boat or from the lakeside.
	Sediments	Sediment samples were collected from the surface layer (at up to 10cm below the surface), more than three times, using an Ekman-Birge bottom sampler or a scoop, from a boat or from the lakeside, and were mixed up.
	Surrounding environment (soil)	Soil samples were collected from the surface layer (at up to 5cm below the surface) on lakeside or reservoir edge using a soil sampler or a scoop, at five points each and were mixed up.
	Ambient dose rate	At the location where soil samples were collected, the ambient dose rate was measured at a height of 1m from the ground surface using a NaI (TI) scintillation survey meter.
Coastal areas	Water	Around 3L of water samples were collected from a vessel from the surface layer (at up to 0.5m below the surface) and from the bottom layer (at 1m from the bottom) using a Van Dorn sampler.
	Sediments	Sediment samples were collected from the surface layer (at up to 10cm below the surface), more than three times, using an Ekman-Birge bottom sampler or a Smith-McIntyre grab sampler, from a vessel, and were mixed up.

2) Sample preparation (samples for gamma-ray spectrometry)

Sample	Outline
Water	<ul style="list-style-type: none"> Put a sample in a 2L Marinelli beaker.
Sediments	<ul style="list-style-type: none"> Put a sample in a U-8 container. At the same time, separate approx. 10g from the sample and dry it at 105°C to obtain the sediment content.
Surrounding environment (soil)	<ul style="list-style-type: none"> Put a sample in a U-8 container. At the same time, separate approx. 10g from the sample and dry it at 105°C to obtain the dry sediment content.

3) Analysis Methods

Analysis	Sample	Details
Cs-134 Cs-137 Other radionuclides	Water	<ul style="list-style-type: none"> Measure for 1,000 seconds, in principle, using a germanium semiconductor detector.*
	Sediments	<ul style="list-style-type: none"> Measure for 2,000 seconds, in principle, using a germanium semiconductor detector.*
	Soil	<ul style="list-style-type: none"> Measure for 2,000 seconds, in principle, using a germanium semiconductor detector.*
Sr-90	Sediments	<ul style="list-style-type: none"> Acid leaching – carbonate separation – oxalate separation – ion exchange separation- scavenging – leave for 2 weeks- milking – measurement of β-rays
Other	Water	<ul style="list-style-type: none"> Suspended solids (SS), turbidity
	Sediments	<ul style="list-style-type: none"> Sediment content, grain size distribution, soil particle density

* Some samples were re-measured for a long time over 1,000 or 2,000 seconds, if necessary.

4. Content of the survey

In the survey, on-site measurements (including the air dose rate of the surrounding environment) and water, sediment and soil were collected from rivers, lakes and reservoirs, and coastal areas.

Nuclide analysis by gamma-ray spectrometry was carried out using the collected samples. Details are as follows.

1) Sample Collection

(i) Rivers

① Water

Around 3L of water samples were collected from the surface layer (at up to 50cm below the surface), using a bucket or a dipper, from the top of a bridge or from the riverbank at each monitoring location.

Sampling was impossible in some cases owing to ice and snow coverage.

■ Field observation items: Water depth, sampling depth, water temperature, color, odor, transparency, electrical conductivity

② Sediments

Sediment samples (15cm×15cm) were collected at a depth of up to 10cm below the surface more than three times, using an Ekman-Birge bottom sampler (Figure 2), from the top of a bridge or from the riverbank at each monitoring location, and were mixed up.

Sampling was impossible in some cases owing to ice and snow coverage.

■ Field observation items: Sampling depth, properties, color, sediment temperature, odor

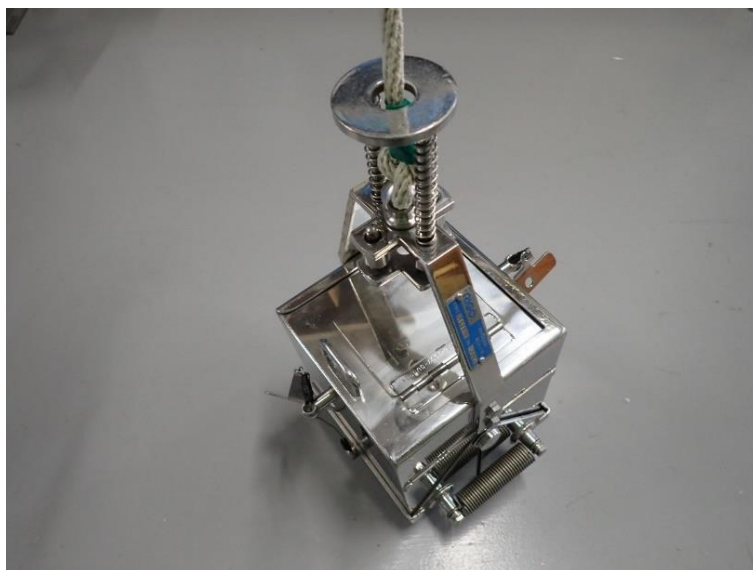


Figure 2. Ekman-Birge bottom sampler

③ Surrounding environment (soil)

In principle, on both riverbanks (at two points) outside the dike on the upstream side of each monitoring location, soil samples up to a depth of approx. 5cm below the surface were collected at five points within a 3 to 5m-sided square (basically four vertexes and the diagonal intersection point; see Figure 4) using a soil sampler which has a diameter of 5cm (Figure 3) or a scoop and were mixed up.

When collecting samples, sampling points were selected at flat, spacious places as far as possible after measuring the ambient dose rate around those points with a NaI (TI) scintillation survey meter and confirming that there were no spots where the ambient dose rate was extraordinarily high. If there was too much vegetation, surface grass was cut and removed with a sickle or other means.

When it was difficult to secure a 3 to 5m-sided square, adjustments were made depending on the circumstances at the site, such as selecting five points with 3 to 5 meter intervals along the river.

Soil samples were not collected in the following cases:

- When the sampling location was on private property (house, farmland, facility site, etc.)
- When the sampling point was concrete-covered and soil was not exposed
- When soil was not exposed owing to snow coverage

■Field observation items: Properties, color, odor



Figure 3. Soil sampler kit.

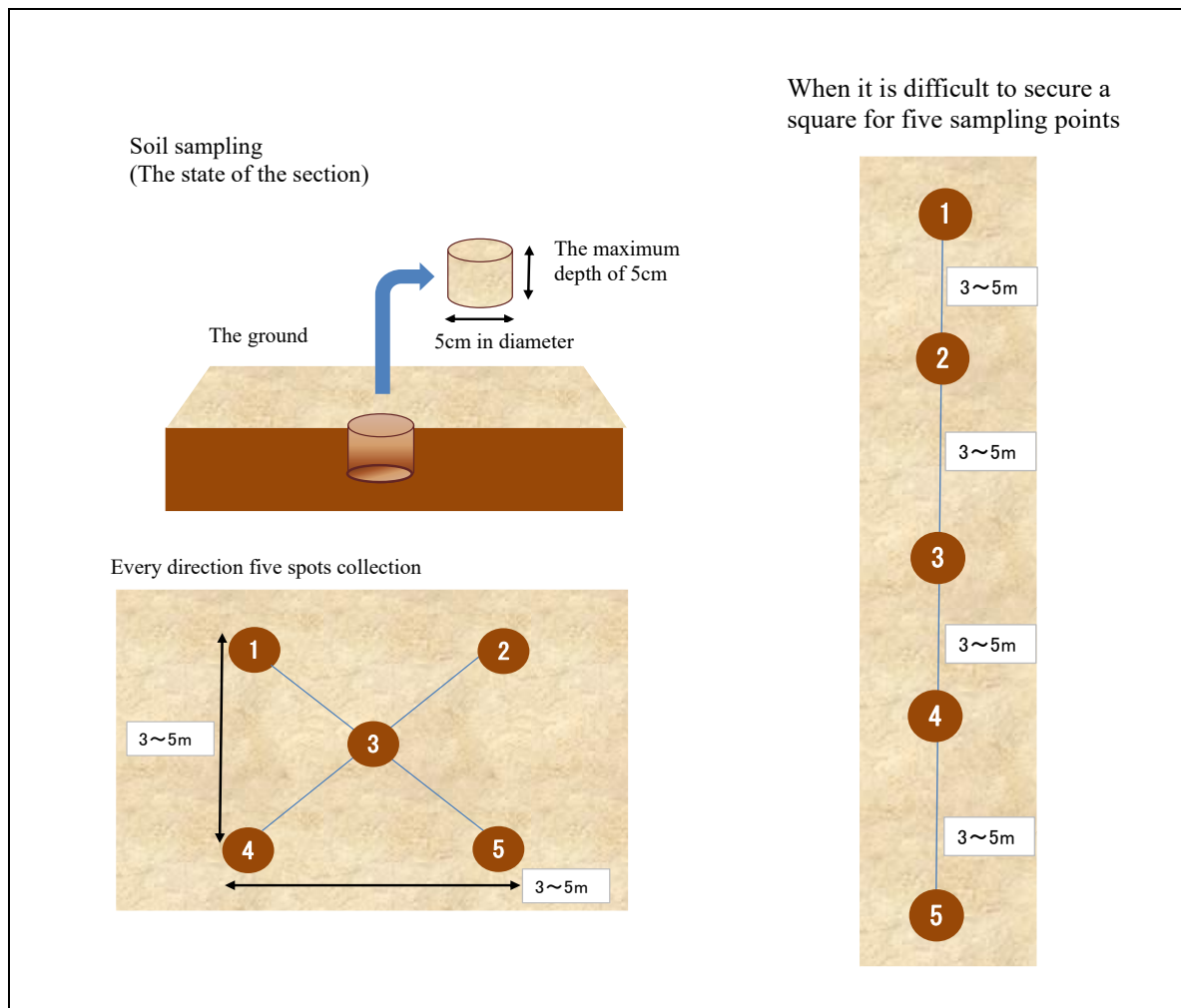


Figure 4. Examples of soil sampling

④ Measurement of ambient dose rates

At each location where soil samples were collected (at the center within a 3 to 5m-sided square), ambient dose rate was measured using a NaI (Tl) scintillation survey meter (Table 2 and Figure 5) (Figure 6).

Measurement was conducted at a height of 1m from the ground surface, while keeping the sensing station of the NaI (Tl) scintillation survey meter horizontal. The time constant was set at 30 seconds (10 seconds when the detected value was $0.1\mu\text{Sv/h}$ or above). After holding the survey meter for a duration 5 times the time constant, readings were taken 5 times with intervals equivalent to the time constant. The ambient dose rate was obtained by multiplying the average of the readings by the calibration constant.

The requirements to be noted when selecting the point of ambient dose rates were as follows:

- A flat, open area without any major obstacles in the vicinity
- A site with as little vegetation as possible
- A site on soil, wherever possible, not on asphalt or concrete

Table 2. Type of NaI (Tl) scintillation survey meter

Manufacturer	Model
Hitachi-Aloka Medical, Ltd.	TCS-172B
Fuji Electric Co., Ltd.	NHC7

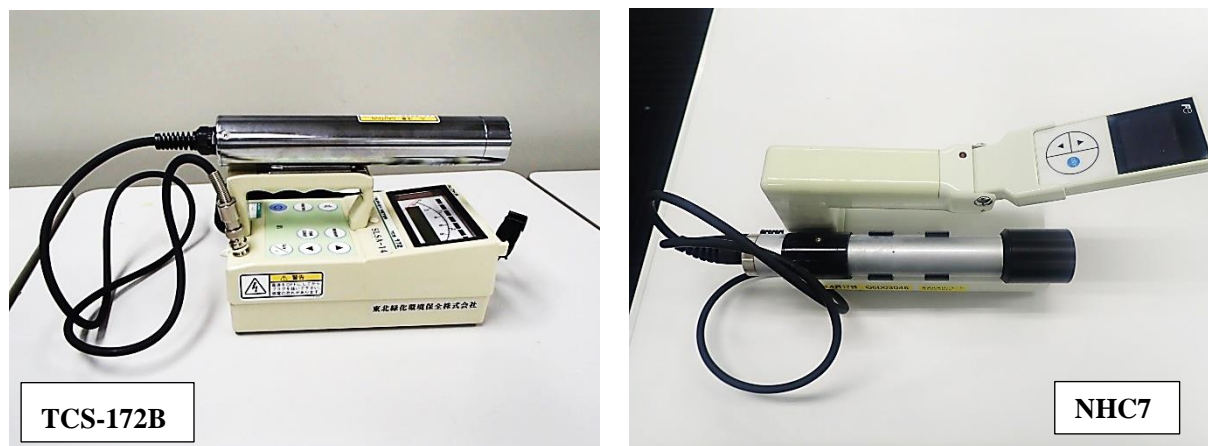


Figure 5. NaI (Tl) scintillation survey meter



Figure 6. Measurement of ambient dose rates (example)

(ii) Lakes and reservoirs

① Water

Around 3L of water samples were collected at each monitoring location, from a boat or from the lakeside, from the surface layer (at up to 0.5m below the surface) and from the bottom layer (at 1m from the bottom) using a Van Dorn sampler (Figure 7).

The bottom layer water was not collected if it was frozen, snow covered, or in the following cases:

- Difficult to use a boat
- Water depth was less than 2.0m

■Field observation items: Water depth, sampling depth, water temperature, color, odor, secchi disk depth, electrical conductivity

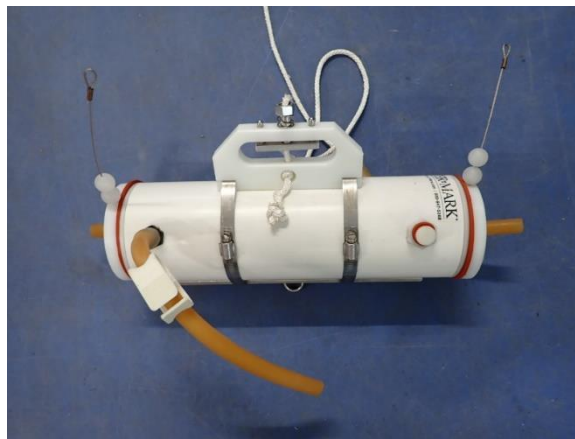


Figure 7. Van Dorn sampler

② Sediments

Sediment samples (15cm×15cm) were collected at each monitoring location, from a shipboard or from the lakeside, from the surface layer (at up to 10cm below the surface) using an Ekman-Birge bottom sampler (Figure 2). Sampling was conducted three times and the samples were mixed up.

Sampling was impossible in some cases owing to ice and snow coverage.

■Field observation items: Sampling depth, properties, color, sediment temperature, odor

③ Surrounding environment (soil)

At lakes and reservoirs, soil samples were collected only at one location at the lakeside or reservoir edge where soil was exposed. Sampling was not conducted when the whole circumference was concrete-covered.

The survey method was the same as that employed for “4. Content of the survey

1) Sample collection (i) Rivers ③ Surrounding environment (soil)”.

Sampling was impossible in some cases owing to ice and snow coverage.

④ Measurement of ambient dose rates

At each location (center) where soil samples were collected, the ambient dose rate was measured using a NaI (Tl) scintillation survey meter (Figure 5).

Ambient dose rates were not measured at points where soil was not exposed owing to snow coverage.

The survey method was the same as that employed for “4. Content of the survey

1) Sample Collection, (i) Rivers ④ Measurement of ambient dose rates”.

(iii) Coastal areas

① Water

Around 3L of water samples were collected at each monitoring location, from a vessel, from the surface layer (at up to 0.5m below the surface) and from the bottom layer (at 1m from the sea bottom) using a Van Dorn sampler (Figure 7).

■Field observation items: Water depth, sampling depth, water temperature, color, odor, secchi disk depth, salinity

② Sediments

Sediment samples (15cm×15cm or 20cm×20cm) were collected at a depth of up to 10cm below the surface layer more than three times, using an Ekman-Birge bottom sampler (Figure 2) or a Smith-McIntyre grab sampler, from a vessel at a monitoring location, and were mixed up.

■Field observation items: Sampling depth, properties, color, sediment temperature, odor

2) Field Survey

Table 3 to Table 6 show the field survey methods used.

Table 3. Field survey methods (common)

Item	Survey Method	Survey Subject *		
		Rivers	Lakes and Reservoirs	Coastal Areas
Survey • Sampling Date	(Recording to a survey field book)	○	○	○
Survey • Sampling Time	(Recording to a survey field book)	○	○	○
Weather	Visual evaluation	○	○	○
Air temperature	Electronic thermometer (resolution 0.1°C)	○	○	○

*○ : Survey subject

Table 4. Field survey methods (water)

Item	Survey Method	Survey Subject *		
		Rivers	Lakes and Reservoirs	Coastal Areas
Water depth	Hydro barometer	○	○	○
Sampling depth	Hydro barometer	○	○	○
Water temperature	Electronic thermometer (resolution 0.1°C)	○	○	○
Color	Evaluation using JIS Names of Colours	○	○	○
Odor	Olfactory evaluation	○	○	○
Transparency	Transparency meter	○	—	—
Secchi disk depth	30cm white Secchi disk	—	○	○
Electrical conductivity	Electrical conductivity meter	○	○	—
Salinity	Electrical conductivity meter	—	—	○

*○ : Survey subject — : outside the scope of the survey

Table 5. Field survey methods (sediments)

Item	Survey Method	Survey Subject *		
		Rivers	Lakes and Reservoirs	Coastal Areas
Sampling depth	Visual evaluation	○	○	○
Properties	Visual evaluation	○	○	○
Color	Evaluation using Standard soil color charts	○	○	○
Sediment temperature	Electronic thermometer (resolution 0.1°C)	○	○	○
Odor	Olfactory evaluation	○	○	○

*○ : Survey subject

Table 6. Field survey methods (surrounding environment (soil))

Item	Survey Method	Survey Subject *		
		Rivers	Lakes and Reservoirs	Coastal Areas
Properties	Visual evaluation	○	○	—
Color	Evaluation using Standard soil color charts	○	○	—
Odor	Olfactory evaluation	○	○	—

*○ : Survey subject — : outside the scope of the survey

5. Analysis Methods

(1) Sample preparation

Sample preparations were carried out in accordance with Radioactivity Measurement Method Series No. 24 “Sample Pretreatment for Gamma-ray Spectrometry in a Radiological Emergency” (revised in March 2019,NRA JAPAN) and No. 29 “Gamma-ray Spectrum Analysis in a Radiological Emergency” (revised in March 2018,NRA JAPAN). The outline of the procedures is as follows.

Water samples were put in 2L Marinelli beakers and soil and sediment samples were put in U-8 containers for gamma-ray spectrometry.

(2) Gamma-ray spectrometry

Gamma-ray spectrometry was carried out in accordance with Radioactivity Measurement Method Series No. 7 “Gamma-ray Spectrometry using Germanium Semiconductor Detectors” (revised in September 2020,NRA JAPAN) and No. 29 “Gamma-ray Spectrum Analysis in a Radiological Emergency” (revised in March 2018,NRA JAPAN). The outline of the procedures is as follows.

1) Measurement

Activity concentrations were calculated based on measurements conducted using a germanium semiconductor detector for around 1,500 seconds (water samples) and 1,000 - 100,000 seconds (soil and sediment samples). The lower detection limit for water quality was set to 1Bq/L. The lower detection limit for sediment and soil was set to 10Bq/kg. After analyzing the sample, the results for sediment and soil were corrected for sediment content*. Especially for sediment samples, even when Cs-137 was detected at a level below the set lower detection limit, sometimes the detection limit exceeded 10Bq/kg (dry) after correction. In such cases, another measurement was conducted under conditions to ensure the lower detection limit of 1Bq/kg (dry).

*Radioactive cesium concentration (dry) in sediment and soil

$$= \text{Result of analysis} \times 100 / \text{Sediment content}(\%)$$

2) Measuring equipment

Germanium semiconductor detectors

GEM 25P4-70 (1 unit) (SEIKO EG&G, Co., Ltd.)

GEM 30-70 (5 unit) (SEIKO EG&G, Co., Ltd.)

(3) Analysis of radioactive strontium

The analysis of radioactive strontium was carried out in accordance with Radioactivity Measurement Method Series No. 2 “Radioactive Strontium Analysis” (revised in July 2003, MEXT, JAPAN). The outline of the procedures is as follows.

1) Chemical separation

A strontium carrier was added to a sample, then hydrochloric acid was added and thermal extraction was carried out. Radioactive yttrium (Y-90) was removed (scavenging) from the strontium separated and refined via the iron exchange method, then the sample was left for two weeks and the newly-formed Y-90 was precipitated along with iron hydroxide (III) precipitation (milking). The remaining substance was used for the measurement.

2) Measurement

Concentrations of radioactive strontium (Sr-90) were calculated based on measurement conducted using a low background beta counter for 3,600 seconds, in principle. The lower detection limit for Sr-90 was set to 1Bq/kg.

3) Measuring equipment

Low background beta counter

LBC-4302B (Hitachi-Aloka Medical, Ltd.)

LBC-4502 (Hitachi, Ltd.)

(4) Other items analyzed

Table 7 shows the methods used to analyze other items.

Table 7. Methods of analyzing other items

Item		Analysis methods	Unit	Lower detection limit
Water	Suspended solids (SS)	Method indicated in Annex Table 9 of Environment Agency Notice No.59 of December1971 (Environmental Quality Standards for Water Pollution)	mg/L	1
	Turbidity	Japanese Industrial Standard K 0101 9.4	FNU	0.1
Sediments	Sediment content	2 of Remarks 5 of Environment Agency Notice No. 3 of 1976	%	0.1
	Grain size distribution	Japanese Industrial Standard A 1204	%	0.1
	Soil particle density	Japanese Industrial Standard A 1202	Mg/m ³	—

6. Survey Result

The survey results are summarized for each surveyed prefecture.

View of the results

- (1) In principle, sampling locations are listed from north to south, and for different points along the river, from upstream to downstream.
- (2) Notes to the measurement results of nuclides by gamma-ray spectrometry include:
 - The detection limits have been rounded to two significant digits by round off.
 - Measured values of radioactive cesium, if equal to or higher than the detection limits, are expressed in two significant digits by round off. If lower than the detection limits, they are expressed as “<”, followed by the detection limits. Measured values have been corrected for decay to represent the value as of the time when the sample was taken.
- (3) Notes to the analysis results of Sr-90 include:
 - The detection limits have been rounded to two significant digits by round off.
 - Measured values, if equal to or higher than the detection limits, are expressed in two significant digits by round off. If lower than the detection limits, they are expressed as “<”, followed by the detection limits. Measured values have been corrected for decay to represent the value as of the time when the sample was taken.