FY2019 Radioactive Material Monitoring in the Water Environment in and Around Fukushima Prefecture

1. Survey Overview

Surveys of the concentration of radioactive materials (radioactive cesium, and radioactive strontium) in water, sediments and the surrounding environment (soil on river terraces and the shores of lakes) have been carried out in the water environment (public water areas (rivers, lakes and reservoirs, coastal areas)) in Iwate, Miyagi, Fukushima, Ibaraki, Tochigi, Gunma, Saitama, and Chiba Prefectures and Tokyo Metropolis since April 2019 (surveys of the surrounding environment also included measurements of ambient dose rates).

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

Table 1.Number of Survey Locations

Prefecture	Area	Number of Locations	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	79	1	79	1	154	6
	Coastal areas	2	4	8	0	4	0	—	—
Miyagi	Rivers	43	196	193	3	193	3	375	17
	Lakes and reservoirs	21	76	113	39	73	3	75	1
	Coastal areas	12	52	104	0	52	0	—	—
Fukushima	Rivers	123	818	812	6	812	6	1,600	36
	Lakes and reservoirs	84	552	814	290	524	28	515	37
	Coastal areas	15	150	300	0	150	0	—	—
Ibaraki	Rivers	53	212	212	0	212	0	400	24
	Lakes and reservoirs	19	76	144	8	76	0	68	8
	Coastal areas	5	20	40	0	20	0	—	—
Tochigi	Rivers	56	278	278	0	278	0	543	13
	Lakes and reservoirs	8	32	64	0	32	0	32	0
Gunma	Rivers	48	214	214	0	214	0	428	0
	Lakes and reservoirs	24	96	186	6	96	0	96	0
Chiba, Saitama, Tokyo	Rivers	51	216	216	0	216	0	376	56
	Lakes and reservoirs	8	32	37	27	32	0	16	16
	Coastal areas	8	41	82	0	41	0	—	—
Total	Rivers	396	2,014	2,004	10	2,004	10	3,876	152
	Lakes and reservoirs	164	864	1,358	370	833	31	802	62
	Coastal areas	42	267	534	0	267	0	—	—
	Overall total	602	3,145	3,896	380	3,104	41	4,678	214
				Able to collect:11,678			Unable to collect:635		

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

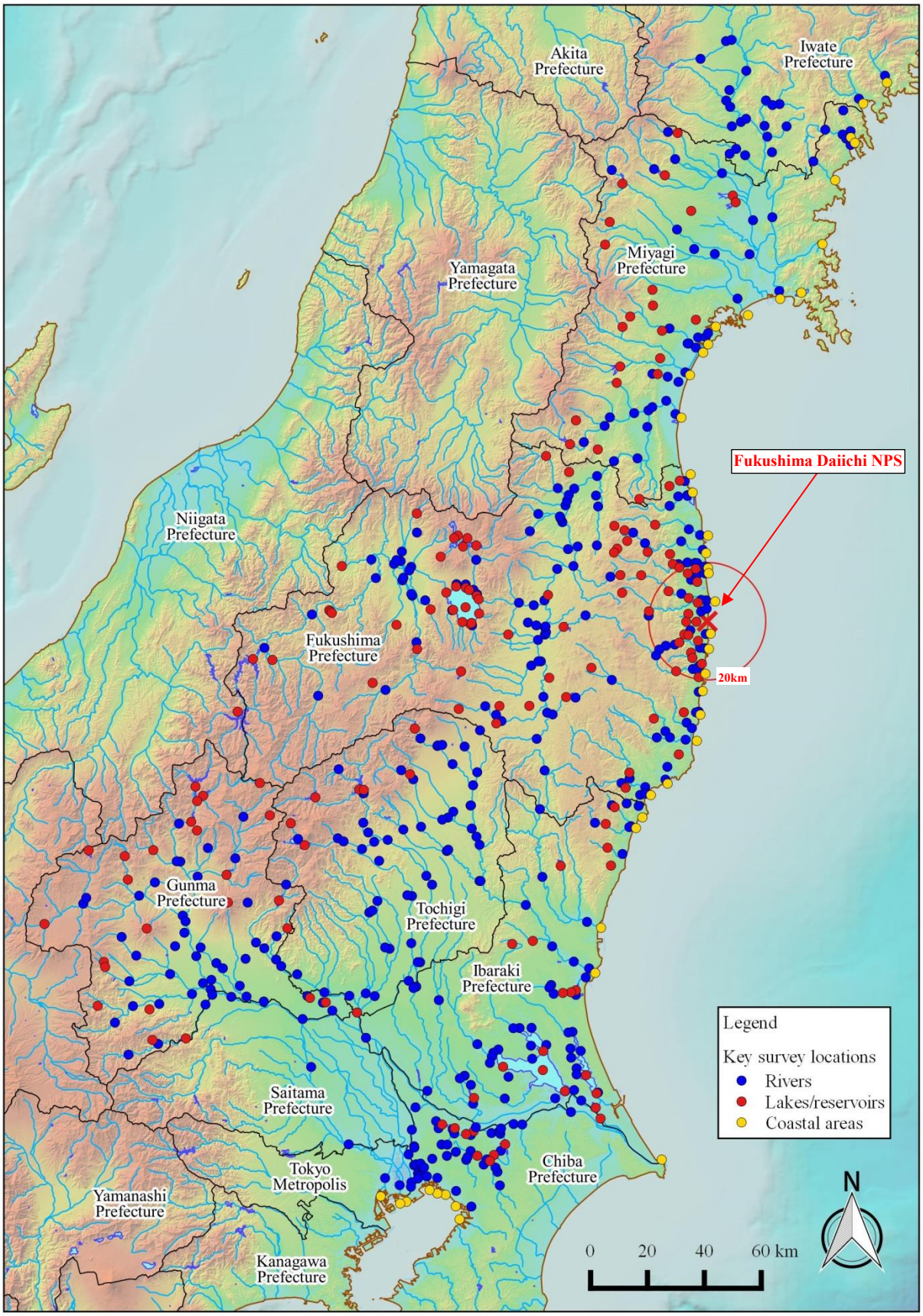

Figure 1. Survey Locations (All)

2. Outline of Results

The situation concerning radioactive cesium in FY 2019 was as follows.

(1) Water

Radioactive materials were not detectable at more than 90% of locations (lower detection limit: 1Bq/L) but were detected at some locations (up to a maximum of 8.7Bq/L). At these detected points, suspended solid(SS) and turbidity measured relatively high concentrations.

(2) Sediments

1) Rivers

High readings were seen at a limited number of locations, such as those within 20km from Tokyo Electric Power Fukushima Daiichi Nuclear Power Station (hereinafter referred to as "Within 20 km"), but at about 90% of locations, detected values were generally 200Bq/kg or lower. Concentration levels are decreasing at more than 90% of locations.

2) Lakes and Reservoirs

High readings were seen at a limited number of locations, such as those Within 20km, but at more than 80% of locations, detected values were generally 3,000Bq/kg or lower. About 80% of the concentration levels are unchanged or decreasing, with about 20% tending to fluctuate.

3) Coastal areas

Detected values were generally 150Bq/kg or lower at more than 80% of locations. Although about 10% of the locations showed some fluctuations in the concentration levels, unchanged or decreasing trends were observed in most of the other locations.

*For details, refer to the survey results by 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 (Tl) 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 (Tl) 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	・Put a sample in a 2L Marinelli beaker.
Sediments	・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)	・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	・Measure for 1,000 seconds, in principle, using a germanium semiconductor detector.*
	Sediments	・Measure for 2,000 seconds, in principle, using a germanium semiconductor detector.*
	Soil	・Measure for 2,000 seconds, in principle, using a germanium semiconductor detector.*
Sr-90	Sediments	・Acid leaching – carbonate separation – oxalate separation – ion exchange separation- scavenging – leave for 2 weeks- milking – measurement of β-rays
Other	Water	・Suspended solids (SS), turbidity
	Sediments	・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

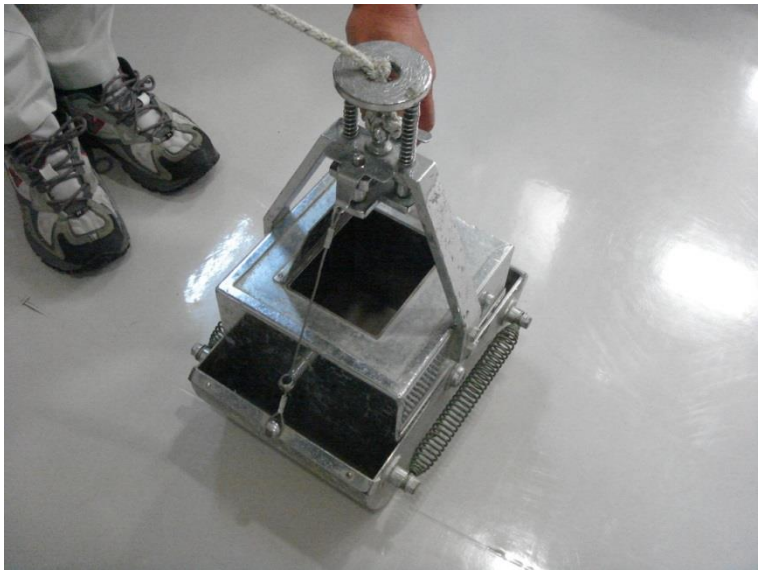

Figure 2. Ekman-Birge bottom sampler

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 (Tl) 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.

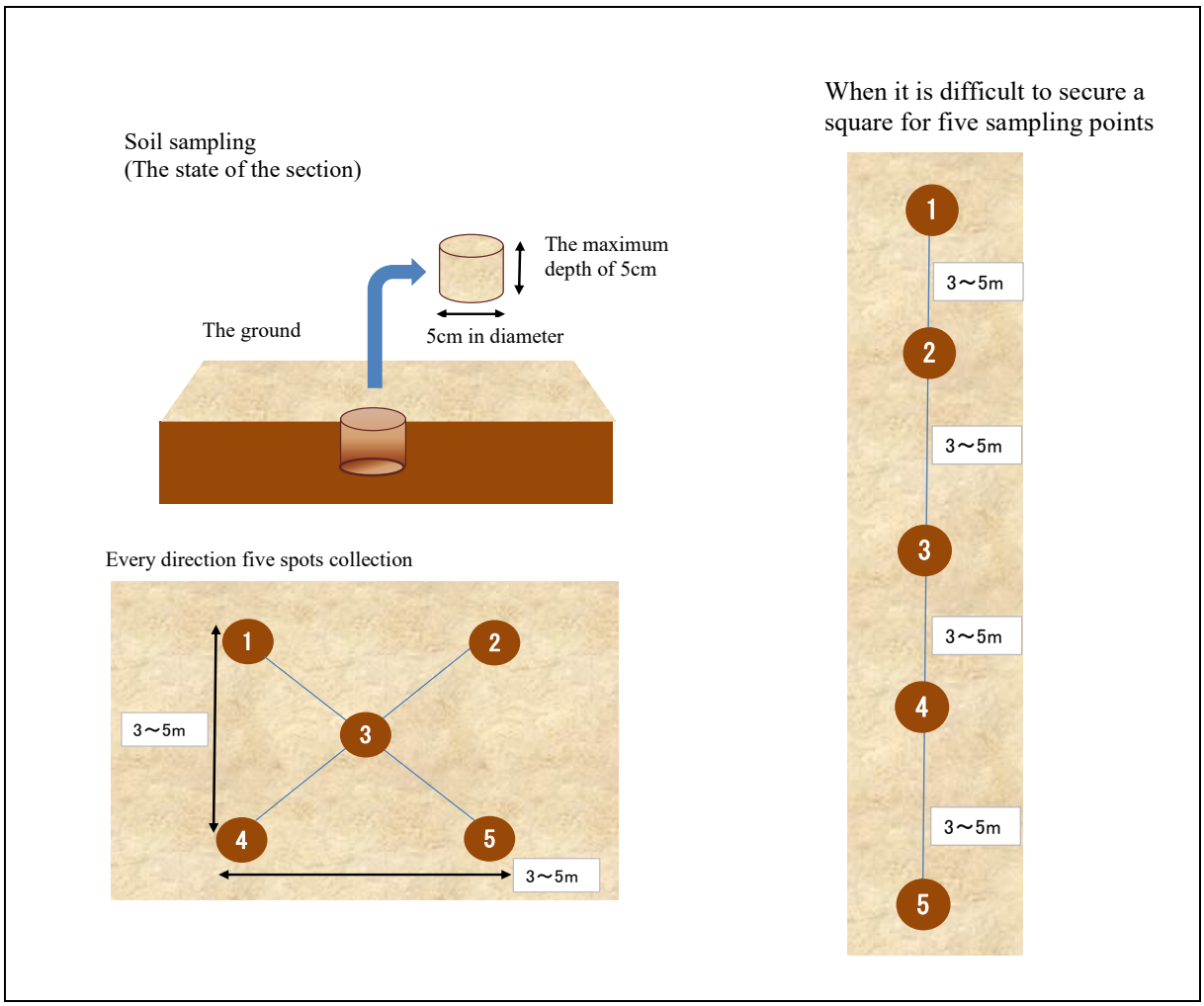

Figure 4. Examples of soil sampling

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 0.1μSv/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-1172, TCS-172B, TCS-161

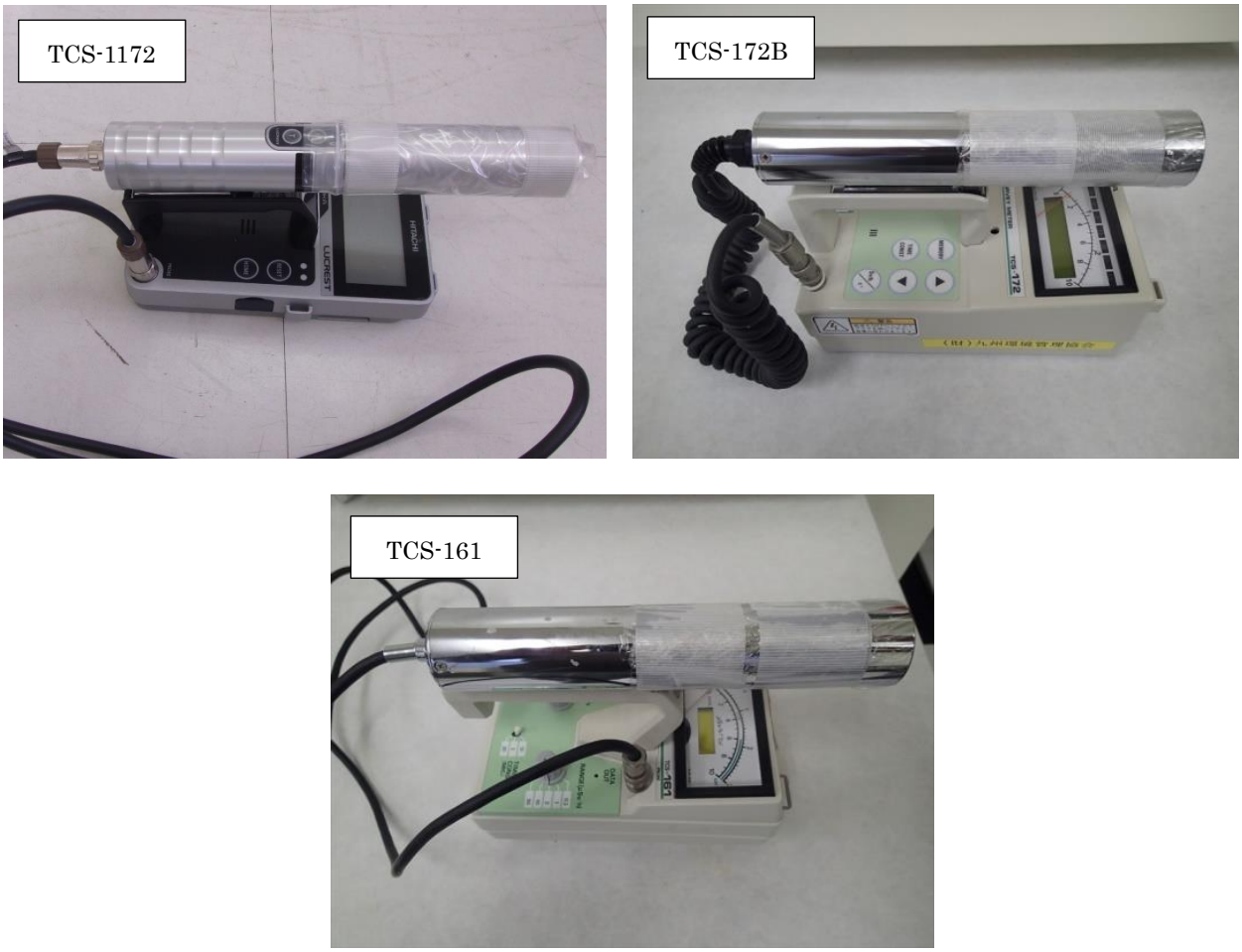

Figure 5. NaI (Tl) scintillation survey meter

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 in the following cases in addition to reasons such as freezing and snow cover:

・The boat could not be used

・Water depth was less than 2m

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

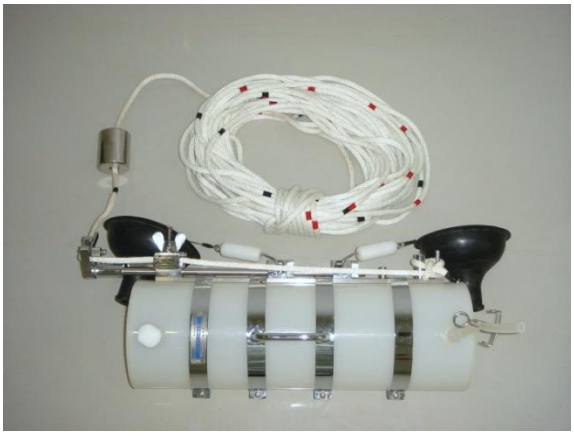

Figure 7. Van Dorn sampler

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 August 1992,MEXT,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 1,000 seconds (water samples) and 2,000 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

= Result of analysis × 100 / Sediment content(%)

2) Measuring equipment

Germanium semiconductor detectors

GMX 30P (1 unit) (SEIKO EG&G, Co., Ltd.)

GEM-C8065 (1 unit) (SEIKO EG&G, Co., Ltd.)

GX 4018 (2 units) (CANBERRA, 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-4311, LBC-4301 (Hitachi-Aloka Medical, Ltd.)

LBC-4200 (CANBERRA, 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	g/cm^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.