The Series of Environmental Radioactivity Measuring Methods

AS-E
(No.35)

Generic Procedures for Environmental Sampling in Emergencies

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Chapter 1 Introduction

In case of an abnormal or possible release of radioactive materials or radiation at a nuclear facility, the emergency environmental radiation monitoring (hereinafter referred to as “emergency monitoring”) will be conducted under the following guidelines: the “Nuclear Emergency Preparedness and Response Guidelines (partially amended on October 28, 2020)” and the “Emergency Monitoring Guidelines (Supplementary Reference Materials for Nuclear Emergency Preparedness and Response Guidelines), revised on July 5, 2019, Radiation Monitoring Division, Radiation Protection Department, Nuclear Regulation Authority,” which were established by the Nuclear Regulation Authority.

Emergency monitoring can be divided into three phases: initial monitoring, mid-term monitoring, and recovery phase monitoring. During initial monitoring, it is essential to collect samples promptly because the results will be used to make decisions on protective measures. This manual describes the sampling procedures for environmental samples during initial monitoring, from sampling preparedness to sample acceptance.

Significant differences between normal monitoring and emergency monitoring are as follows: First, the person in charge of sampling must be protected from radiation. Second, the collected samples must be protected from cross-contamination because they may be contaminated with radioactive materials. Third, personnel who have not previously engaged in monitoring work may have to conduct emergency monitoring in the situation. Considering these situations in emergencies, this manual has been prepared to facilitate prompt and easy sampling in emergencies.

This manual consists of five chapters. Following the introduction in Chapter 1, Chapter 2 describes the basics of sampling in emergencies. Chapters 3 to 5 describe the procedures required at actual sampling locations. (Chapter 3 includes contamination prevention of equipment common to each sampling, protection of monitoring personnel, and measurement of dose rates. Chapter 4 describes the sampling procedures for the sample types to be collected with priority in the initial monitoring, and Chapter 5 describes the sampling procedures for the sample types to be collected as needed).

Checklists of equipment required for sampling and sampling record forms are shown as examples. In addition, the format of the external exposure dose and surface contamination measurement records for monitoring personnel is also shown in the examples. The effects of non-uniform distribution of radioactive materials in the measuring container in γ-ray spectrometry and other effects are described as explanations, and additives for preserving water samples are described as references. The appendices include an overview of emergency monitoring and definitions of terms that are desirable to understand when conducting emergency monitoring. For more information about the pretreatment of collected samples, refer to the series of environmental radioactivity measuring methods No. 24, “Preparation of Samples for Gamma-ray Spectrometry in Emergencies.” For the measurement, refer to the corresponding reports in the series of environmental radioactivity measuring methods.

As for mid-term and recovery phase monitoring, the Nuclear Emergency Preparedness and Response Guidelines state that “further consideration should be given to the nature of mid-term monitoring and recovery monitoring in the future.” Although further consideration is needed, the sampling method should be viewed and implemented as being at the stage of transitioning from initial monitoring to regular monitoring. While promptness is considered to be the most critical aspect of initial monitoring, the transition to the mid-term and recovery phase monitoring requires more reliability. For more information about sampling with more reliability, it is advisable to refer to the series of environmental radioactivity measuring methods No. 16, “Generic Procedures for Environmental Sampling,” and use the appropriate method for each period in conjunction with this manual.

Note that this manual can be used if emergency monitoring efforts are undertaken before the Emergency Radiological Monitoring Center (EMC) is set up.

Chapter 2 Fundamentals of environmental sampling in emergencies

In emergency monitoring, when environmental samples (precipitation, soil, food, drink, and others) are collected, one of the significant differences from normal monitoring is the need for radiation protection for the person in charge of sampling. In addition, since the sampling area may be contaminated, one must always be careful to avoid contamination while transporting and storing the samples.

2.1 Workflow of sampling

In emergency monitoring, the Emergency Response Center (ERC) of the Nuclear Regulation Authority (NRA) formulates an emergency monitoring implementation plan, and the EMC conducts emergency monitoring. In case of an emergency, the EMC measurement and analysis staff will collect environmental samples in accordance with the instructions from the EMC Planning and Coordination Group.

[Formulating an emergency monitoring implementation plan and instructions]

	Workflow
1	ERC formulates the emergency monitoring implementation plan
2	EMC prepares emergency monitoring instructions based on the implementation plan Note: The instructions are prepared by the EMC Planning and Coordination Group and sent to the person in charge of measurement and analysis after approval by the EMC Director.
3	EMC conducts emergency monitoring

[Sampling in emergency monitoring]

	Workflow *Reference chapters are indicated in parentheses [ ].
1	Review the contents of the emergency monitoring instructions.
2	Confirm necessary equipment.
3	Confirm operation of equipment.
4	Cover equipment (including monitoring vehicles) (prevention of contamination) [3.1].
5	Radiation protection measures for persons in charge of sampling (selecting protective equipment and wearing electronic personal dosimeters) [3.2].
6	Move to the sampling location indicated in the instructions.
7	Measurement of dose rate in the vicinity of the sampling location (to confirm safety and to grasp the situation of the sampling location) [3.3].
8	Sampling (in parallel, filling out sampling record forms and assigning identification codes)
9	Pack samples
10	Checking for omissions in the sampling record forms
11	Cleanup of sampling locations (clearing away equipment used)
12	Move to the analytical laboratory, activity site, and the like. [3.4].
13	Dose inspection of collected samples (screening inspection) [3.5].
14	Sample delivery
15	Record radiation exposure and contamination measurements of monitoring personnel [3.6].

[Contents of the instructions]

Items that EMCs should consider when preparing instructions for environmental sampling include followings:

・Protective equipment required for monitoring personnel
・Dose control standards for monitoring personnel (exposure dose limits, withdrawal dose rates, and other standards)
・Sample name
・Date of sampling (including information on sampling period, sampling frequency, and other information)
・Sampling location (latitude and longitude)
 Note: Desirable to describe in units of 0.1 seconds (approximately 3 m).
・Sampling method (for soil: sampling area, number of sampling points, sampling depth, and the like)
・Sampling amount (for air: sampling flow rate, integrated flow volume, and other amounts)
・Measures in stormy weather (e.g., amount of rainfall to halt sampling in the field)
・Special notes (items that require special attention from the sampling time for proper measurements, such as separate sampling for radioactive iodine)
・Guideline for determining "highly concentrated sample" in screening inspections of samples
 Note: If it is difficult to indicate numerically, use a guideline such as "when the alarm sound of the measuring instrument changes from an intermittent sound to a continuous sound."
・Guideline for contamination during surface contamination inspection of monitoring personnel

2.2 Required amounts of environmental samples

When collecting environmental samples for radioactivity analysis, the critical factor is the amount of sample to be collected. In the initial monitoring, it is desirable to minimize the sampling amount (e.g., approximately one measuring container for soil) in order to reduce sampling time and handling of the samples. The minimum amount of sampling required should be determined by considering information such as the concentration of radioactive materials, radionuclides to be analyzed, and analysis methods. If conditions at the sampling location permit, 1.5 to 2 times the minimum amount may be collected, including reserves.

Table 2-1 shows the relationship between measurement time, sample amount, and quantifiable levels of iodine-131, cesium-137, and cesium-134 using a germanium semiconductor detector.

Table 2-1 Relationship between measurement time, sample amount, and minimum detectable activity by germanium semiconductor detector in samples collected after the accident at TEPCO's Fukushima Daiichi Nuclear Power Station

sample	sample amount	I-131 Quantifiable Level				unit
		Measurement Time				
		10 min.	30 min.	1 hour	10 hours (Ref.)	
air	1 m^3	6	4	3	0.8	Bq/m^3
soil	140 g	240	140	100	30	Bq/kg
drinking water	89 g	350	200	150	50	Bq/L
drinking water	2000 g	110	70	50	20	Bq/L

sample	sample amount	Cs-137 Quantifiable level				Cs-134 Quantifiable level				unit
		Measurement Time				Measurement Time				
		10 min.	30 min.	1 hour	10 hours (Ref.)	10 min.	30 min.	1 hour	10 hours (Ref.)	
air	1 m^3	6	3	2	0.7	8	5	3	1	Bq/m^3
soil	140 g	190	110	80	30	200	120	90	30	Bq/kg
drinking water	89 g	280	170	120	40	310	180	130	40	Bq/L
drinking water	2000 g	90	60	40	20	100	60	50	20	Bq/L

(Note) Amount of air sample: the amount of air sucked through materials such as filter paper
(Note) Relative efficiency of germanium semiconductor detector: approximately 30% to 40%
* Refer to the series of environmental radioactivity measuring methods No. 24, "Preparation of Samples for Gamma-ray Spectrometry in Emergencies."

2.3 Equipment

Equipment needed to collect environmental samples in an emergency include followings:

(a) Radiation protection equipment
(b) Equipment for location confirmation and communication
(c) Equipment for measuring dose rate
(d) Equipment for sampling
(e) Equipment for management records

Equipment should be ready for operation at all times. Periodic inspection of equipment should be made to check operation and replenish items such as consumables and spare parts. Examples of necessary equipment are shown below. See the [Checklist] in this manual for details.

(a) Radiation protection equipment

- Electronic personal dosimeter (measurable range: 0.01 mSv to 100 mSv, preferably with an alarm)
- Survey meter for surface contamination inspection
  * GM Counting Tube Survey Meter (for β- and α-ray measurement)
  * ZnS(Ag) scintillation survey meter (for α-ray measurement)
- Protective equipment for workers (protective clothing, dust-proof masks, half-face masks,

gloves, protective shoes, and the like)

・Medical kit (adhesive plasters, gauze, bandages, scissors, gloves, bags, anti-diarrhea medicine, and the like)

(b) Equipment for location confirmation and communication

・GPS (It is desirable to select a GPS capable of measuring up to 0.1 seconds (approximately 3 m).

・Map

・Flag or tape to mark the site (to indicate that samples are being collected)

・Telecommunication equipment (diversify as much as possible, such as mobile phones, satellite mobiles, wireless equipment, and tablet devices)

Note: It is advisable to check the radio wave conditions of communication devices during normal situations.

(c) Equipment for measuring dose rate

・Survey meter for γ-ray (for low dose rate, the unit is dose rate)

* NaI(Tl) scintillation survey meter

Note: CsI(Tl) scintillation survey meters are also available for low dose rates.

・Survey meter for γ-ray (for high dose rates, the unit is dose rate)

* Ionization chamber survey meter

Note: For high dose rates, silicon semiconductor survey meters are also available.

(d) Equipment for sampling

・Sampling equipment (air samplers, other samplers, knives, sickles, and the like)

・Sample storage containers (such as polyethylene bags and polyethylene bottles)

・Wiping paper (for wiping sample storage containers, sampling equipment, and the like)

(e) Equipment for management records

・Equipment operation manual

・Procedure manual

・Sampling record form

・Camera

2.4 Containers for samples

When selecting sample storage containers, consider the material, size, structure, and whether the container is appropriately sealed, and minimize the number of containers and instruments to prevent cross-contamination. When samples are collected, the container (or polyethylene bag) containing samples should be taped with a sample identification code written on it using a permanent marker (or a QR code may be printed on it using a label maker). Writing the identification code directly on the container and the like, is a good temporary measure, but care must be taken to ensure that the identification code does not disappear due to things like friction.

Container material properties	・The sample storage container must not break or leak during use or transportation, and the material of the container must not chemically react with the sample.
Opening and sealing containers	・Consider whether the sample can be easily inserted and whether there are any sealing issues.
Pre-cleaning of containers	・Do not reuse sample storage containers, and always use new containers. ・New plastic containers, including extra containers, should be cleaned and prepared in advance. ・Storing extra sample storage containers is useful. Empty containers can assure the quality of measurements and analyses.

2.5 Identification of the collected samples

The importance of properly identifying the collected samples throughout the survey process makes assigning a unique identification code useful. An identification code with information such as sample type and sampling location distinguishes the sample from samples collected at other locations. Samples repeatedly collected at the same location can be distinguished by the sampling date. Further, assigning an identification code to samples collected in addition to the target sample for reference data together at the same location facilitates linking to the target sample. The identification code should be set appropriately according to the actual sampling conditions at the EMC. Examples of information for identification codes are shown below.

[Examples of information for identification codes]

Information for identification	Code
Number of Sampling team (Institution)	Number (symbol) assigned to the sampling team, institution or organization
Sampling date	The sampling date is attached. (Example) January 11, 2021: 20210111
Sampling location	Number (symbol) assigned to each sampling location
Number of times	Consecutive numbers to be assigned when collecting the same sample type multiple times on the same date, at the same location, by the same sampling team, separated by a time interval (Example) If a sample is collected in the morning and the same sample type is collected again in the afternoon at the same location, the sample collected in the morning is numbered “1,” and the sample collected in the afternoon is numbered “2”. The default value is “1”.
Sample type	Number (symbol) assigned to each sample type
Sample No. (or applications)	A series of numbers assigned when collecting multiple samples of the same sample type on the same date, at the same location, and by the same sampling team at the same time. Multiple samples may be also identified by the use. (Example) A sample for radioactive iodine collected separately from a water sample should be marked with “-I,” and the other samples should be left blank.

Information for identification	Code
(a) Group No.	The following two methods are examples of identification when multiple samples are measured and analyzed together. (a) A serial number to be assigned to each group when collecting multiple samples on the same date, at the same location, at the same time, and by the same sampling team is measured and analyzed as a group. (Example) If there are groups A, B, and C for soil, snow, or other items that need to be analyzed in conjunction with each other, the samples belonging to A should be numbered "1", those belonging to B should be numbered "2," and those belonging to C should be numbered "3." A sample is left blank if no sample is to be analyzed together.
(b) Supplementary samples	(b) Number (symbol) to be attached when sampling together at the same location, in addition to the target sample, to be used as reference data. (Example) An identification code can be assigned to the soil sample with plants and snow present in the following method, but it should be noted that even plants and snow are managed in the database as soil for the sample type. Plant: "soil identification code" + "-P" Snow: "soil identification code" + "-S"

It is essential to identify and store samples properly during initial monitoring since it will help identify them in case of re-analyses. The remarks column should note when multiple samples are linked together or there are supplementary samples. In addition, spreadsheet software or database management system software should be used to create a database so that identification codes allow for managing the data from the point of sample collection to the data evaluation at the EMC.

The use of QR codes may help manage identification codes. Label makers, for example, facilitate creating QR codes. QR codes should be readable by smartphones and tablet devices.

[Example of QR code]

Note: This QR code contains “sample type, sampling location, sampling date, sampling team, number of samples collected, sample number, and branch number.”

Multiple samples or samples collected together at the same sampling location in addition to the target sample should be stored together in a sealable container for convenience. Samples already measured and residual one may be stored together.

[Example of sample management]

2.6 Record of sampling

Information on environmental sampling should be recorded on the sampling record form. Correct any writing errors by striking them out with a single line. In order to facilitate photocopying, do not use color ink. Take pictures to document the sampling locations and work conditions. Take pictures of sampling locations from multiple directions with landmark objects.

The sampling record includes the following information for example.

・Name of the person who made the record
・Sampling date and time
・Weather conditions at the sampling time
・Names of persons responsible for and in charge of sampling
・Sampling location information (e.g., latitude and longitude, map, pictures)
・The dose rate at the sampling time
・Type of sample (e.g., soil, drinking water)
・Status of sampling (e.g., composite, a handful, separate samples for radioactive iodine)
・Preparation work performed (e.g., removing foreign materials)
・Unique identification code for the sample

2.7 Packing and shipping

(1) Packing and shipping of samples

Seal the sample storage container with tape, write the sample identification code on the tape with a permanent marker (or print out the QR code using, e.g., a label maker), and place the samples in individual polyethylene bags. Further, pack them in polyethylene bags, and be sure to double up the bags. Pack samples in cardboard boxes or some boxes to prevent individual samples from bumping into each other, rotating or falling. See [3.4] of this manual for specific procedures for transporting samples.

When requesting a carrier to transport samples, place the sample in a transportation container and pack it securely. When placing a sample in a transportation container, place a cushioning material (urethane foam, rubber, or similar elastic material) at least 2.5 cm thick between the sample container and the walls of the transportation container, and pack the bottom of the transportation container with cushioning material to a minimum thickness of 5 cm. When multiple samples are placed in a transportation container, cushioning material should be placed between each sample container or between the sample container and the divider to prevent damage to the sample containers. Affix a label with the sender's and recipient's information (e.g., contact name and phone number) legibly on the outer surface of each transportation container. Write handling instructions on the transportation container if necessary. When a carrier transports a sample, send the sampling record to the recipient by e-mail or other means.

(2) Delivery and acceptance of samples

When receiving samples to a delivery destination (analytical laboratory, activity site, and the like.), cover the delivery entrance with a sheet or something similar, and conduct a screening inspection of the delivered samples on the sheet. When placing the NaI(Tl) scintillation survey meter or similar instrument close to the delivered sample, if “the alarm sound of the measuring instrument changes from an intermittent sound to a continuous sound,” or a guideline event occurs, treat the sample as a “highly concentrated sample.”

Personnel conducting contamination inspections must wear protective equipment (e.g., protective clothing, safety glasses, gloves, shoe covers) as instructed. In addition, preparation for receiving samples should include setting up a sample storage area, a place for pretreatment, and other facilities. Refer to [3.5] of this manual for instructions on receiving samples.

2.8 Radiation protection of monitoring personnel

When sampling in an emergency, monitoring personnel must take protective measures to avoid external exposure to radiation and internal exposure through inhalation of radioactive materials as much as possible. Monitoring personnel must wear protective equipment as instructed, such as protective clothing, protective caps, gloves, safety glasses, respiratory protection (dust-proof mask, half-face mask), and safety shoes. Some respiratory protection is fitted with activated carbon filters as a measure against radioactive iodine. In addition, take stable iodine tablets when instructed. Prepare disposable rain gear in case it rains or snows during work. Since rain and snow may contain radioactive materials from the air, wearing rain gear over protective clothing can reduce the amount of rain and snow adhering to the protective clothing. In addition, disposable rain gear would be useful if radiation protection measures are needed in a hurry.

The longer the on-site sampling time, the greater the exposure dose. Confirm the workflow in advance to complete the work as quickly as possible. In addition, during sampling in summer, take periodic breaks and hydrate appropriately. As a rule, do not drink water in contaminated outdoors, except in cases of sudden illness. If no suitable indoor area is available, rehydrate in a car. When rehydrating, be careful of contaminated hands and protective equipment, and avoid inhaling particles such as dust.

Wear an electronic personal dosimeter or similar device to measure individual exposure doses. In an accident involving the release of radioactive materials, such as an accident at a nuclear reactor facility, measure the dose rate at the sampling location with, e.g., a NaI(Tl) scintillation survey meter. In addition, measure and grasp the dose rate at all times, even while on the move.

In accidents involving neutron emission, such as at nuclear fuel fabrication facilities, measure the dose rate with equipment such as a survey meter for neutron radiation.

The Guidelines for Establishment of the Emergency Monitoring Center Version 3 (June 25, 2019, Radiation Monitoring Division, Radiation Protection Department, Nuclear Regulation Authority) specifies that "The center director should comply with the regulations on safety management such as individual exposure limits of each member institution." From the viewpoint of efficient and appropriate management, grasp the dose control standards at the organizations to which monitoring personnel belong, and establish the management methods in advance. Monitoring personnel must understand and comply with the management methods.

For the protection of monitoring personnel, refer to [3.2] and [External exposure dose and surface contamination measurement records C1] in this manual.

2.9 Attentions

Take the following precautions when sampling.

(1) When sampling, select a team leader within the sampling team. In addition, clearly define the division of roles by assigning a "Driver," "Hot staff," and "Cold staff" (see the tables below). The driver acts as the Cold staff if the sampling team consists of two persons. If there are more than three members in the sampling team, assign additional Cold staff to the team. Avoid contact between the Hot and Cold staff in a car whenever possible. Because radioactive contamination is invisible, contamination can spread unnoticed through staff. For this reason, divide the role of Hot and Cold staff to prevent the spread of contamination by limiting the number of staff who have direct contact with the samples.

Role Name	Main Role
Driver	· Driving a car (avoid working outside the car.)
Hot staff: Personnel to actually collect samples	· Measurement of dose rate · Sampling · Clean up equipment used Note: If there are more than three members in a team, the Cold staff measures the dose rate.

Role Name	Main Role
Cold Staff: Personnel not to actually collect samples(Excluding a driver in principle).	· Recording · Packing samples · Loading samples into vehicles Note: The Cold staff assigns an identification code to the sample container.

(2) To avoid cross-contamination between samples, the person in charge of sampling should always use gloves (e.g., rubber gloves) and dispose of them after each sampling.

(3) During sampling, pay attention to airborne dust and other materials that were re-suspended from the ground surface, as inhaling them may cause internal exposure.

(4) Use sampling equipment (e.g., shovels) only once and dispose of them to avoid cross-

contamination. When reusing sampling equipment, wash it with deionized water, wipe it with paper towels, dry it, and then use a survey meter to confirm that the equipment is free of contamination.

(5) Since moisture may evaporate during transportation and the weight of the sample may change, weigh the sample promptly after sampling. However, in the initial monitoring, the promptness of sampling is a priority, so do not measure the sample weight at the sampling location unless instructed in advance.

(6) Conduct screening inspections of samples when delivering the samples. Screening inspection of samples when they are loaded into vehicles should not be mandatory but should be conducted if possible depending on the situation, since it may not be possible to conduct such inspection due to the influence of the dose rate at the sampling location and from the viewpoint of prioritizing promptness.

(7) Cover the interior of the monitoring vehicle with plastic sheets and the like. For prevention of equipment contamination, refer to [3.1] of this manual.

(8) Handle soil samples with care since they are considered to have higher radioactivity concentrations than other samples (e.g., load soil samples in the rear of the vehicle, away from vehicle seats).

(9) The highest priority in sampling is the life or health of the monitoring personnel. Never take a risk to collect a sample. Always be aware of possible accidents at the site and take necessary preventive measures. Always use appropriate protective equipment for monitoring activities. Be familiar with the use of protective equipment.

(10) If it is difficult to collect the samples according to the instructions, inform the EMC measurement and analysis staff, and ask for instructions. If communication is difficult, the sampling team leader will decide to make changes.

(11) Suspend work and turn back if the instructed dose control standards are exceeded or are likely to be exceeded during monitoring activities.

Chapter 3 Environmental sampling procedures (issues common to every sampling)

This chapter describes the procedures required at sampling locations, which are common to each sampling process: prevention of equipment contamination, protection of monitoring personnel, measurement of dose rate, transportation of samples, delivery and acceptance of samples, and contamination inspection of monitoring personnel.

3.1 Prevention of equipment contamination

Objective

It is assumed that the emergency monitoring area will be highly contaminated in emergency monitoring. Therefore, the collected samples must always be considered potentially contaminated. Care must be taken to prevent cross-contamination, and the necessary contamination prevention measures must be taken to protect the equipment used.

Contamination prevention of radiation measuring instrument

❏ NaI(Tl) scintillation survey meter: Cover with a polyethylene bag.

[Example of covering NaI(Tl) scintillation survey meter]

Note: When covering survey meters and the like, make adjustments so that the readings do not become difficult to read or the power supply does not become difficult to turn on and off.

Note: When transporting measuring instruments such as survey meters, be sure to load them in a designated place inside the vehicle. Do not place them on the floor where they can be easily contaminated.

Note: When there is a possibility of neutron emission due to a criticality accident and the like, the detector may be activated by neutron radiation, be sure to note the effect on the indicated value of the detector.

Note: Inspect equipment used for contamination measurement to confirm that the equipment is not contaminated (i.e., that it does not affect measurement). If contamination affects the measurement, consider decontamination, replacement of contaminated parts, and the like, depending on the situation.

Contamination prevention of monitoring vehicles

❏Cover seats and floor surfaces in the vehicle to the extent that they do not interfere with driving.

❑Take the following measures to prevent bringing contamination from outside into the vehicle.

a) The driver should concentrate on driving and refrain from working outside the vehicle.

b) Wear shoe covers when exiting the vehicle, and replace shoe covers before getting into the vehicle after activities outside the vehicle, or cover the shoe covers with a plastic bag before getting into the vehicle to prevent contamination inside the vehicle.

c) If possible, have a different pair of shoes for inside and outside the vehicle.

d) In principle, circulate the air inside the vehicle internally.

[Example of covering inside a vehicle]

Note: Cover the driver's seat to the extent that it does not interfere with driving.

Handling of equipment at sampling location

❑To facilitate smooth operations at the sampling location, organize equipment used at the site in containers.

❑Keep “hot” and “cold” equipment in separate containers.

[Example of equipment organization]

Environmental sampling procedures

3.2	Protection of monitoring personnel

Objective

Monitoring personnel should engage in monitoring only after taking adequate protective measures to protect themselves from external exposure due to high dose rate radiation from outside and internal exposure due to inhalation of radioactive materials and to prevent contamination of their bodies.

Protective equipment

❑Protective equipment

Protective clothing, protective caps, gloves, safety glasses, respiratory protection (dust-proof mask, half-face mask, activated carbon filter fitted), and safety shoes (boots are preferable.)

*Colored protective clothing is used in the photos for clarity.

[Dust-proof mask]

[Protective clothing]

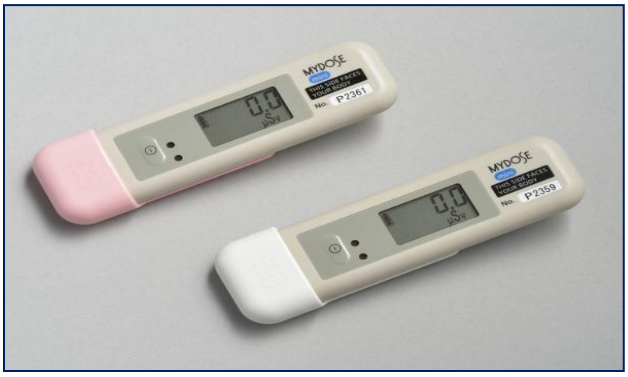
[Rubber gloves]

[Safety shoes (boots type)]

[Shoe covers]

Exposure dose control

❏Electronic personal dosimeter (example)



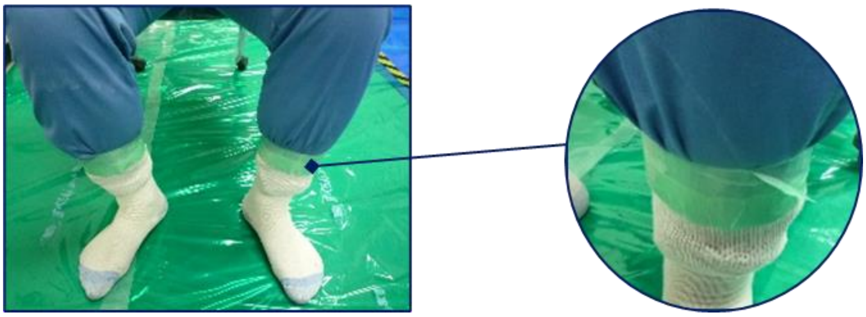
(Usage notes)

❏Electronic personal dosimeters may be affected by radio waves from cellular phones and other devices and may perform false counts. Keep the electronic personal dosimeters at least 30 cm away from any device, emitting radio waves. Direct-reading electronic personal dosimeters with countermeasures against electromagnetic radiation are also commercially available.

Protective equipment wearing procedure

❏Wear protective equipment before departure.

Procedure *Colored protective clothing and adhesive tape are used in the photos for clarity.	
1	Review instructions regarding protective equipment.
2	Inspect protective equipment, other equipment, and materials. [Checklist] ・Check for holes in the inner gloves (check by blowing air into the gloves). ・Check for tears in protective clothing. ・Check the operation of the electronic personal dosimeter (confirm that the indicated value has been reset). Note: Inner clothing should be made of cotton or other sweat-absorbent material to facilitate wearing protective clothing over it. ・Note: Inner clothing should have pockets for electronic personal dosimeters.

	Procedure *Colored protective clothing and adhesive tape are used in the photos for clarity.
3	Take off shoes and place the hems of trousers into socks (cotton work socks). 
4	Fasten the border between the hem of the pants and the socks with adhesive tape.  Note: Slightly fold back the edges of the tape to make it easier to remove. Note: Make sure that there is room for the ankles, knees, lower back and hip joint to bend freely before fasting with adhesive tape.
5	Turn on the electronic personal dosimeter and attach it (ensure it is properly oriented).  For males: chest For females: abdomen

Procedure *Colored protective clothing and adhesive tape are used in the photos for clarity.	
6	Put on inner gloves.  Note: Put on the inner gloves to cover the cuffs of the clothing worn under the protective clothing. Note: Cotton gloves may be worn under the inner gloves.
7	Wear protective clothing.   
8	Fasten the border between the cuffs of the protective clothing and the inner gloves with adhesive tape.  Note: Make sure that there is room for shoulders and elbows to bend freely before fasting with adhesive tape. Note: Slightly fold back the edges of the tape to make it easier to remove.
9	Put on outer gloves.  Note: Outer gloves do not need to be fastened with adhesive tape. Note: Change outer gloves, if necessary, e.g., after taking a sample. Make sure not to contaminate the inner gloves when doing so.

	Procedure *Colored protective clothing and adhesive tape are used in the photos for clarity.
10	Wear a mask. 
11	Wear a hat or protective clothing hood. 
12	Put on shoes and shoe covers. (1)  (2)  (3)  Note: Make sure that there is room for ankles, knees, lower back and hip joints before fasting show covers with adhesive tape. Note: Slightly fold back the edges of the tape to make it easier to remove. Note: When working outdoors, wear shoe covers and replace them as needed. Alternatively, cover the shoe covers with a plastic bag when entering a vehicle to prevent contamination of the vehicle interior.

<table>
<tr><td></td><td>Note: During snow and freezing weather, consider safety using covers with a non-slip surface.

Note: Shoes may be disposed of upon return.</td></tr>
<tr><td>13</td><td>Indicate sampling personnel name and the name of the sampling team on the front and back of the protective clothing.



Note: The worker's name can be written directly on the protective clothing with an oil-based marker or with adhesive tape with the name written on it.

Note: Marking the height of 1 m above the ground on the protective clothing with oil-based magic marker can be used as a guide to adjust the height from the ground when measuring dose rates at the sampling location.</td></tr>
</table>

Notes on work

❏The longer the sampling time at the site, the greater the exposure dose, so confirm the workflow in advance so that the work can be completed in a short time.

❏Particularly during sampling in summer, take regular breaks and rehydrate appropriately. As a rule, do not rehydrate in contaminated outdoors, except in cases of sudden illness. If there is no suitable indoor location, rehydrate inside the vehicle. When rehydrating, avoid contaminating hands and protective equipment and inhaling dust.

❏Monitoring activities in protective clothing in an area where residents live would give a misleading impression that the area is dangerous. To prevent such misunderstanding, instead of protective clothing, wear general anoraks, and the like, which have a certain degree of function to protect monitoring personnel from surface contamination.

3.3	Measurement of dose rate

Objectives

Recording the sampling conditions is important for analyzing the measurement results of the collected samples. In particular, the dose rate around the sampling location is highly important because it may be related to the radioactivity concentration of the sample. It is also useful for determining individual exposure doses and is therefore important information from the viewpoint of radiation protection.

Measuring instrument

❑**NaI(Tl) scintillation survey meter (example)**

❑**Ionization chamber survey meter (example)**

Selection of detector

・In general, NaI(Tl) scintillation survey meters, which can accurately measure radiation at background levels (low dose rates), are used.

・Ionization chamber survey meters are suitable when measuring high dose rates where NaI(Tl) scintillation survey meters cannot be used.

Dose rate	Equipment used
<10μSv/h	・NaI(Tl) scintillation survey meter
≧10μSv/h	・Ionization chamber survey meter

・Clarify the unit of the measured value since some doses are expressed in Gy or Sv.

・Avoid contaminating measuring instruments when handling survey meters in an emergency [see 3.1].

Measurement procedure

1. Confirmation before measurement

	Procedure
1	Turn on the survey meter.
2	Check the remaining battery level and HV (displayed automatically). Example: BATT. = ■■■■ → HV=OK and the like. Note: Replace the batteries when the remaining battery indication falls below 1/2. Note: Ensure that the units of measurement are appropriate.
3	Set the measurement range (some models set it automatically.) Note: Set the value so as not to exceed the range when measuring.
4	Set the "time constant" to 10 seconds. Note: Some models reset the "time constant" to 3 seconds each time the power is turned on. Note: In locations with high dose rates, the "time constant" may be set to 3 seconds for measurement. Record the set "time constant".

2. Measurement

	Procedure
1	Determine the measurement point (or the center of the sampling area in the case of soil sampling and the like, where the sampling area is defined). Note: When measuring the dose rate, measure the dose rate at an open area with no obstacles like buildings. If obstructions are present, record them on the sampling record form.

	Procedure
2	Hold the detector of the survey meter horizontally at the height of 1 m above the ground.  Note: Keep people away from the measuring location, in particular from the forward direction while measuring. Note: The person performing the measurement should keep the device as far away from the body as possible. Note: As a guide to 1 m above the ground, a 1 m long stick may be used.)
3	Move the survey meter slowly within an area of approximately 1 m square (or within the sampling area if a sampling area has been defined) centered on the position where the dose rate was measured, and confirm that the dose rate does not change. Note: If there is no change in the values in the dose rate in all directions, measure with the detector of the survey meter pointed to the direction of the nuclear facility and record the direction on the sampling record form. Note: When checking the dose rate in all directions, if there is a direction where the value is high, measure with the detector of the survey meter pointed toward the high direction and record the direction on the sampling record form. Note: If the dose rate changes rapidly over a short distance of travel, avoid taking measurements at that location as much as possible and look for a location where the dose rate fluctuates as little as possible and make measurements there.
4	After approximately 30 seconds (three times the “time constant”), read the indicated value three to five times at approximately 10-second intervals, calculate the average value, and enter the indicated value and the average value on the sampling record form (the recorder controls the time using a stopwatch). Note: Depending on the situation, it is possible to take about five measurements as in normal monitoring. Note: After three times the “time constant”, approximately 95% of the original dose value at the location is displayed as the indicated value, and after five times the “time constant”, approximately 99% of the original dose value at the location is displayed as the indicated value. Note: If the dose rate is higher than the set measurement range, switch the measurement range to a higher range. Note: The dose rate may temporarily increase by 0.01 to 0.10 μSv/h due to rainfall or snowfall caused by radioactive nuclides of radon and thoron and gradually returns to the original level about 2 hours after the rain stops. When the moisture content in the soil increases significantly, the radiation shielding effect increases, and the dose rate decrease but gradually returns to the original level as the ground dries out. This phenomenon is observed in areas where the dose rate is approximately 0.3 μGy/h or higher. Record the weather in the sampling record form. Take photographs.

Note: Do not place the survey meter on the ground because contaminating the survey meter would disable the correct measurement of the dose rate.

Note: Keep the survey meter turned on from the time of departure to the time of return to the activity site and check the fluctuation of the indicated value in a timely manner (including during movement by vehicle).

Reference: Variation of measured values in dose rate by the "time constant"

Dose rate (nGy/h)	Coefficient of variation (%)		
	"Time constant" 3 sec.	"Time constant" 10 sec.	"Time constant" 30 sec.
10	77	42	24
20	54	30	17
50	34	19	11
100	24	13	8
200	17	9	5
500	11	6	3
1 000	8	4	2
2 000	5	3	2
5 000	3	2	1
10 000	2	1	1
20 000	2	1	1

Note: Equipment: 1 in φ × 1 in cylindrical NaI (Tl) scintillation survey meter

*From Explanation G of the series of environmental radioactivity measuring methods No. 17, "Method for Measurement of Environmental Gamma-rays with a Continuous Monitor"

3.4	Transportation of collected samples

Objective

To ensure the safe delivery of the collected samples, the samples should be transported with contamination prevention measures in place.

	Procedure
1	Perform final confirmation of the collected samples. [Checklist] ・Confirm collected samples (prevention of forgetting to collect samples) ・Confirm that the collected samples are double bagged (to prevent contamination between samples)
2	Packing of the sample. [Packing Method] ・Place the sample in a container or cardboard box. ・Pack cushioning materials if tipping prevention measures are required, such as for water samples.    [Example of sample packing]

	Procedure
3	Load the sample into the vehicle. Note: Perform dose inspection (screening inspection) of samples when loading collected samples into a vehicle if possible, depending on the situation. If a guideline event occurs, such as “when the alarm sound of the measuring instrument changes from intermittent to continuous sound” when a survey meter is brought close to the sample, treat such a sample as a “highly concentrated sample.” Note: Even if a screening inspection cannot be performed, when loading samples that are expected to be highly concentrated into a vehicle arrange the layout such that they are separated from the seats.  [Example layout inside a vehicle] Note: Allow a distance between the seat and the collected samples. Note: Placing a water sample between the lowly and highly concentrated samples to protect from radiation against the highly concentrated sample. Note: Isolate the contaminants (trash and used equipment) from the sample. Note: Remove mud and dirt from items before loading them into the vehicle.

3.5 Acceptance of collected samples

Objective

To properly analyze the collected samples, take contamination prevention measures when delivering the samples.

Preparation on the receiver side

The sample receiver should prepare for acceptance. Even if the receiver cannot provide sufficient space for receiving the sample, handle highly concentrated samples separately from other samples. Use the following examples to devise the best way to handle the samples.

❏Determine in advance the parking position of the monitoring vehicle.

❏If the outdoor area is unusable due to rainfall, provide a tent or similar equipment or use a portion of the facility as a roofed area.

❏Separate the areas for highly concentrated samples (**high concentration zones**) and areas for other samples (referred to here as "**low concentration zones**" for convenience).

❏Receiving personnel will be divided into the team that screens samples outdoors (**outdoor team**) and the team that works indoors only (**indoor team**). The division of roles for each team is shown below.

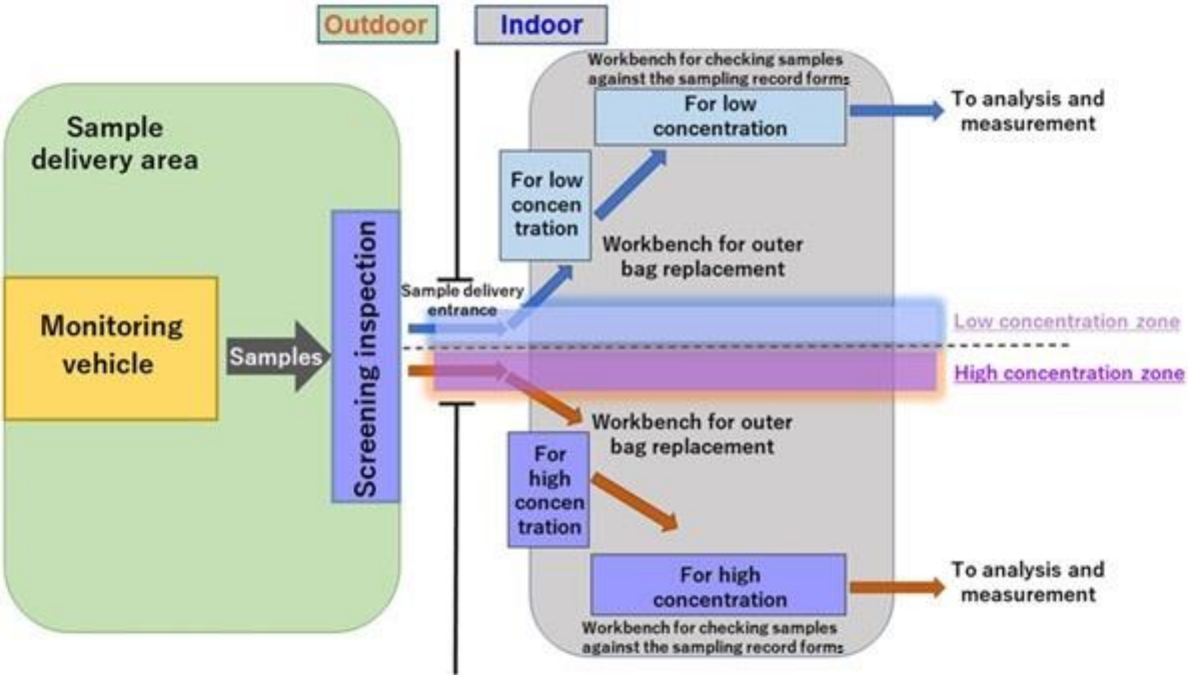
● : in charge

Work contents	Sampling team	Outdoor Team	Indoor Team
Decontamination of the vehicle body	●		
Loading and unloading samples from the vehicle	●		
Re-covering of the interior of the vehicle (if necessary)	●		
Screening inspection before carrying in samples indoors		●	
Carrying samples indoors		●	●
Checking samples against sampling record forms		●	●
Reception of samples			●
If the receiver is an analytical laboratory, delivery of samples to the person in charge of measurement and analysis (If another organization measures and analyzes the sample, shipping and transportation of the sample)			●

Note: Personnel from outdoor and indoor teams should wear protective equipment as indicated, including protective clothing, gloves, and dust-proof masks.

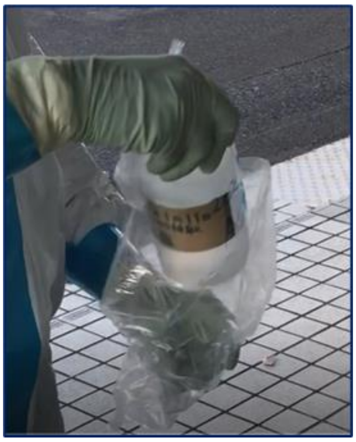
Note: If a sufficient workforce is unavailable, the "cold person" of the sampling team may also be in charge of the outdoor team.

[Example layout (when the delivery destination is an analytical laboratory)]



Procedure

	Procedure
1	Park the vehicle at the assigned location. (**Sampling team**)
2	The samples are removed from the vehicle one after another. Then, if necessary, decontaminate the vehicle body by wiping and the like, and re-cover the inside of the vehicle. (**Sampling team**) Note: Be careful not to touch the vehicle body when unloading the samples from the vehicle. Note: If the vehicle is going to another sampling location, after the sampling team has unloaded all collected samples in an assigned space, the outdoor team will transport the samples one at a time to the inspection site for screening inspections. Note: If all sampling has been completed and the vehicle will not be used that day, the sampling team will unload the samples from the vehicle one at a time, and the outdoor team will transport the samples to the inspection site one at a time for screening inspection. Note: In case of rainfall, take care not to get the sample wet.

	Procedure
3	Perform screening inspection of samples before carrying them in. (**Outdoor Team**) Note: If a guideline event occurs, such as “when the alarm sound of the measuring instrument changes from intermittent to continuous sound” when a survey meter is brought close to the sample. Treat such a sample as a “highly concentrated sample”. Note: After sampling, sampling team personnel must remove protective equipment and undergo a surface contamination inspection before entering the building.  [Screening inspection]
4	Remove the outer bag of the sample indoors near the delivery entrance and carry the sample indoors. (**Outdoor team**)  [Remove outer bag and hand over] Note: Highly concentrated samples are carried in last. Note: Highly concentrated samples are handled in the “high concentration zone”. Other samples are handled in the “low concentration zone”. Note: Do not directly hand-deliver samples between the “high concentration zone” and the “low concentration zone”.

	Procedure
5	The receiver unrolls the new outer bag, receives the sample, and seals it. (**Indoor team**)  [Receiving a new outer bag unfolded]
6	The person in charge of receiving the sample signs the receipt after checking the sample against the sampling record form. (**Indoor team**)
7	Receive the samples carried in (again, check the samples against the sampling record forms). (**Indoor team**) [Examples of contamination measures for sampling record form] a) Take photographs of the sampling record forms and convert them into data. b) Place the sampling record form in a polyethylene bag and laminate it. c) Place the sampling record form in a polyethylene bag and scan it using a multifunction printer to create a PDF file.
8	If the delivery destination is an analytical laboratory, hand the sample to the person in charge of measurement and analysis. (**Indoor team**) Note: If necessary, open the sampling container (e.g., to reduce the soil sample amount, move water into a measuring container) in a draft chamber (local exhaust ventilation). Note: When handling highly concentrated samples, take protective measures by stacking lead blocks between the analyst and the sample. Note: A draft chamber dedicated to high concentration is recommendable. If the delivery destination is not an analytical laboratory, ship and transport the sample to the analytical laboratory after completing the sample reception procedures.

3.6	Contamination inspection of monitoring personnel

Objective

When monitoring personnel return to the site after completing the sampling, they must remove their protective equipment and conduct a contamination inspection to prevent contaminating indoors. The results of external exposure doses from electronic personal dosimeters and surface contamination inspections for each person should be recorded and managed.

Preparation of inspection space

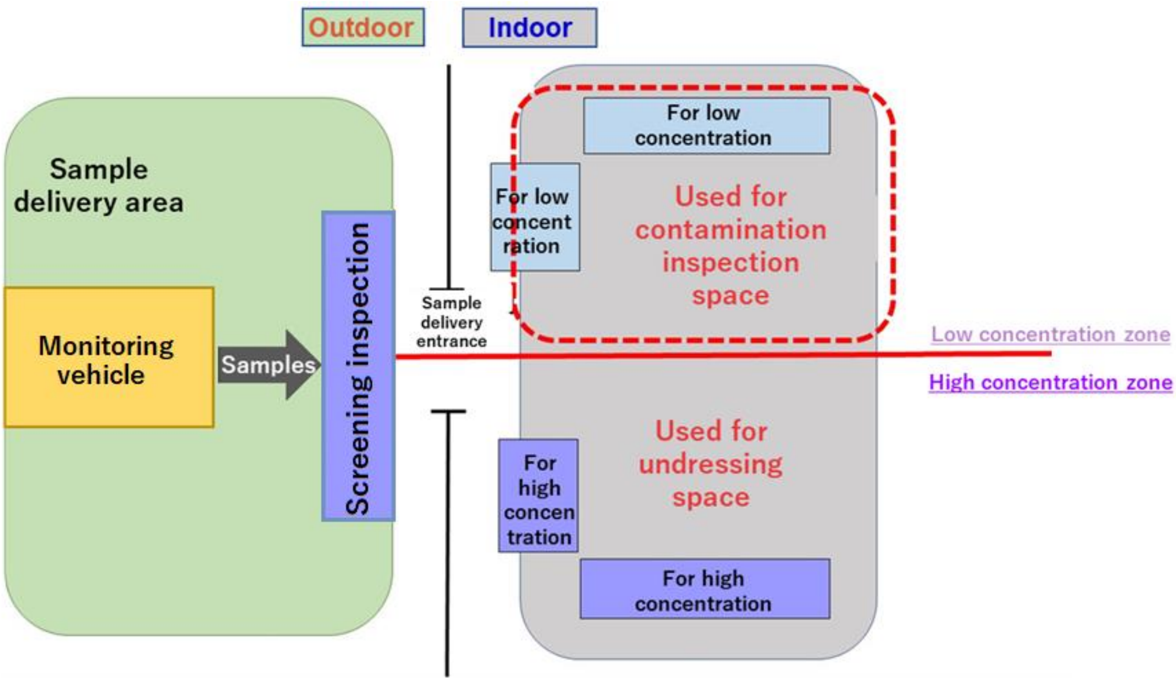
❏Provide space for contamination inspection of monitoring personnel.

Use gummed tape or other materials to clearly delineate the boundaries between undressing and contamination inspection spaces.

Undressing space	A place to take off protective equipment Note: Prepare a trash bag (box) to dispose of the removed protective equipment. Note: A chair is helpful for undressing.
Contamination inspection space	Location for surface contamination inspection

❏If the sample and the monitoring personnel share the same entrance and exit, inspect the monitoring personnel for contamination after the sample is carried in.

[Layout example (where the sample delivery entrance and the entrance/exit for monitoring personnel share the same entrance/exit)]



Preparation for measurement

❑Cover the instrument's main body and the survey meter's detector for surface contamination measurement (GM tube survey meter and the like) with a polyethylene bag or the like.

[Example of covering a GM tube survey meter]

❑The measurer should wear protective equipment as indicated, such as protective clothing, gloves, and dust-proof masks.

Protective equipment undressing procedure

	Procedure *In the photo, “blue: undressing space” and “green: contamination inspection space”.
1	Remove the outer gloves by pinching the mouth of the gloves and turning them inside out.   Note: Chairs may be provided if necessary. Cover the chairs to prevent contamination.  Note: Gloves that have been removed should be placed in the designated trash bag (box). In the subsequent undressing procedures, place the used protective equipment in the designated trash bag.

	Procedure *In the photo, “blue: undressing space” and “green: contamination inspection space”.
2	Remove the adhesive tape that held the inner gloves in place. 
3	Take off the hood (hat) of the protective clothing.  Note: Consider the outside of the protective clothing as contaminated and undress without touching it. Note: Don’t touch skin or hair while removing a hood.

	Procedure *In the photo, “blue: undressing space” and “green: contamination inspection space”.
4	Remove the top half of protective clothing. (1)  (2)  (3)  (4)  Note: Remove the arm part from the shoulder by putting the arm behind the back and pulling the arm out of the clothing.

	Procedure *In the photo, “blue: undressing space” and “green: contamination inspection space”.
5	Pull the protective clothing down to the knees and sit in the chair.  Note: Lower the protective clothing while turning it inside out so that the outside of the protective clothing is rolled up.  Note: After removing the protective clothing, sit on a different chair from the one previously used. Also, the chairs should be covered as a measure against contamination. Note: Do not touch the clothing under the protective clothing with your hands.
6	Remove the adhesive tape holding the shoe covers and take off the protective clothing and shoe covers simultaneously.  Note: It is better to remove the shoe covers by wrapping them in protective clothing.  Note: After removing the shoe covers, lower the feet on the non-contaminated zone (floor on the side of the contamination inspection space).

	Procedure *In the photo, “blue: undressing space” and “green: contamination inspection space”.
7	Remove the safety shoes and peel off the adhesive tape that fastened the border between the hem of the pants and the socks. 
8	Remove the mask.  Note: Since the surface of the mask may be contaminated, it may be possible to remove it in the changing area depending on how the changing area and the contamination inspection area are set up (e.g., separate rooms). Follow the instructions.
9	Remove the inner gloves, turning them inside out. 

Procedure of surface contamination inspection

	Procedure
1	The measurer uses the measuring instrument to inspect the surface contamination of the monitoring personnel.  Note: Set the “time constant” to 3 seconds and place the measuring instrument approximately 1 cm away from the subject's body. Note: Move the measuring instrument at a speed of about 10 cm per second while measuring.
2	Measure the entire body, including the top of the head, face, upper body (shoulders, arms, palms, back of hands, chest, and back), lower body (abdomen, waist, buttocks, and feet), and soles of shoes to check for contamination. Note: If contamination is suspected, such as when the instrument sounds a warning tone, set the “time constant” to 10 seconds. Then hold the instrument for about 30 seconds at the position where the counting rate (CPM value) reaches its maximum and measure.
3	Record the inspection results [External exposure dose and surface contamination measurement records C1]. Note: If the results of the measurements indicate that any areas exceed the guidelines for contamination as directed by the EMC Planning and Coordination Group, carry out decontamination.
4	Check and record the values of electronic personal dosimeters [External exposure dose and surface contamination measurement records C1]. 

Decontamination procedure

1. Decontamination by undressing (if clothing is contaminated)

	Procedure
1	Move to a designated decontamination area.
2	Wear gloves and a mask. Note: Prepare a change of clothes in advance.
3	Undress while wrapping the garment inside. Note: Dispose of removed clothing.
4	After undressing, inspect the relevant area for surface contamination [Record of external exposure dose and surface contamination measurement C1]. Note: If the measurement results are not below the guidelines for contamination, decontaminate by wiping.

2. Decontamination by wiping (if head hair or skin is contaminated)

	Procedure
1	Move to a designated decontamination area.
2	Wear gloves and a mask. Note: Gloves are not required for hand decontamination.
3	Wipe the area with a wet wipe in one direction from the periphery to the center of the area where contamination was observed. Note: Do not use one wet wipe repeatedly. Note: Personnel allergic to alcohol should use gauze or other material moistened with water.
4	After wiping, inspect the surface contamination of the relevant area [external exposure dose/surface contamination measurement record C1]. Note: If the result of the measurement is not below the guidelines for contamination, take measures according to the instructions of the EMC Planning and Coordination Group.

Chapter 4 Environmental sampling procedures (first prioritized materials)

The sampling procedures for air, soil, and drinking water, which are prioritized during the initial monitoring as necessary to make decisions regarding protective measures are described below.

[Initial monitoring flow]

Information collection situation

- Continuous monitoring through normal monitoring

State of alert

● Strengthening normal monitoring

- Enhancement of measurement of dose rate at the monitoring station (data collection frequency at least once every two minutes)
- Installation of transportable monitoring posts at planned sites and measurement
- Preparation for starting air monitors
- Preparation for starting iodine samplers

Facility site emergency

● Establishment of Emergency Monitoring Center

● Formulation of the emergency monitoring implementation plan

● Implementation of emergency monitoring

- Enhanced monitoring of dose rates (review of positioning and relocation of portable monitoring posts, as necessary)
- Starting air monitors depending on the status of nuclear facilities
- Starting iodine samplers depending on the status of nuclear facilities

General emergency

● Implementation of emergency monitoring

- Enhanced monitoring of dose rate (monitoring for OIL1 and OIL2)
- Measurement and sampling by air monitors
- Sampling with iodine samplers (sampling with portable samplers as needed)
- Drinking water sampling (during and after release of radioactive materials)
- Soil sampling (after release of radioactive materials)

4.1 Air

The primary purpose of measuring the concentration of radioactive materials in the air is to collect information on the environmental radiation situation caused by a nuclear disaster and to provide materials for evaluating the radiological impact of the nuclear disaster on residents and the environment. Air sampling can be divided into two main categories: automated sampling using air monitors and iodine samplers/sampling using transportable samplers. Automatic sampling by air monitors and iodine samplers is shown in [4.1-a], and sampling by transportable samplers is shown in [4.1-b].

Environmental sampling procedure	
4.1-a	**Using air monitor/iodine sampler**

Emergency monitoring response

Establishing a measurement system based on continuous measurement is necessary to obtain information for evaluating radiological impacts on residents and the environment due to nuclear disasters. This section describes automatic air sampling by air monitors (a device for measuring the radioactivity concentration of dust collected by the suction of air through filter paper, as described in the Emergency Supplemental Reference Material) and an iodine sampler (iodine sampler with auto-sample changer).

Ⅰ. Measurements for nuclear power reactor facilities

Measurement system

	Air monitor	Iodine sampler
Objectives	・Determine temporal changes in the concentration of radioactive materials in the air. ・Collect data that contributes to determining the presence or absence of radioactive plumes near the air monitors. ・Collect samples to grasp detailed changes in radioactive material concentrations and their nuclide composition to evaluate exposure doses.	・Collect particulate and gaseous iodine samples continuously to assess the exposure dose of residents and others.
Equipment overview	・A continuous dust collection/continuous measurement type β-ray detector equipped with filter paper sucks in particles in the air using a pump, the glass fiber filter paper adsorbs the particles, and the radioactivity detector measures the gross β radioactivity. ・The difference before and after a fixed time interval (10 minutes) in the continuous measurement determines the concentration of gross β radioactivity in the air.	・An iodine sampler with an auto-sample changer equipped with an activated carbon cartridge (impregnated with approximately 10% TEDA: triethylenediamine) and glass fiber filter paper collects gaseous and particulate iodine continuously. Note: Activated carbon cartridges (impregnated with approximately 10% TEDA) collect gaseous iodine. Filter paper collects particulate iodine.
Measuring conditions	・Measurable range: 100 to 100,000 Bq/ m^3 Note: It should be possible to confirm the presence of a radioactive plume even if the concentration exceeds 100,000 Bq/ m^3. ・Height of air inlet: approx. 1 m ・Air flow rate: approx. 50 L/min ・The filter paper is automatically fed at intervals (approx. once per hour).	・Height of air inlet: approx. 1 m ・Air flow rate: approx. 50 L/min ・The air should be collected for a certain period (approx. 6 hours), and an auto-sample changer should automatically replace adsorbents (filter paper and activated carbon cartridges) at a fixed time interval. Note: The auto-sample changer should be able to change 20 or more adsorbents

	Air monitor	Iodine sampler
	Note: Example of air volume: 50 L/min x 60 min = 3,000 L = 3 m^3 ・The system should be able to operate continuously without refueling for at least 3 days after the startup of the air monitor.	automatically. Note: Example of air volume: 50 L/min × 360 min =18,000 L = 18 m^3 ・The iodine sampler should be able to operate continuously without refueling for at least 3 days after startup.

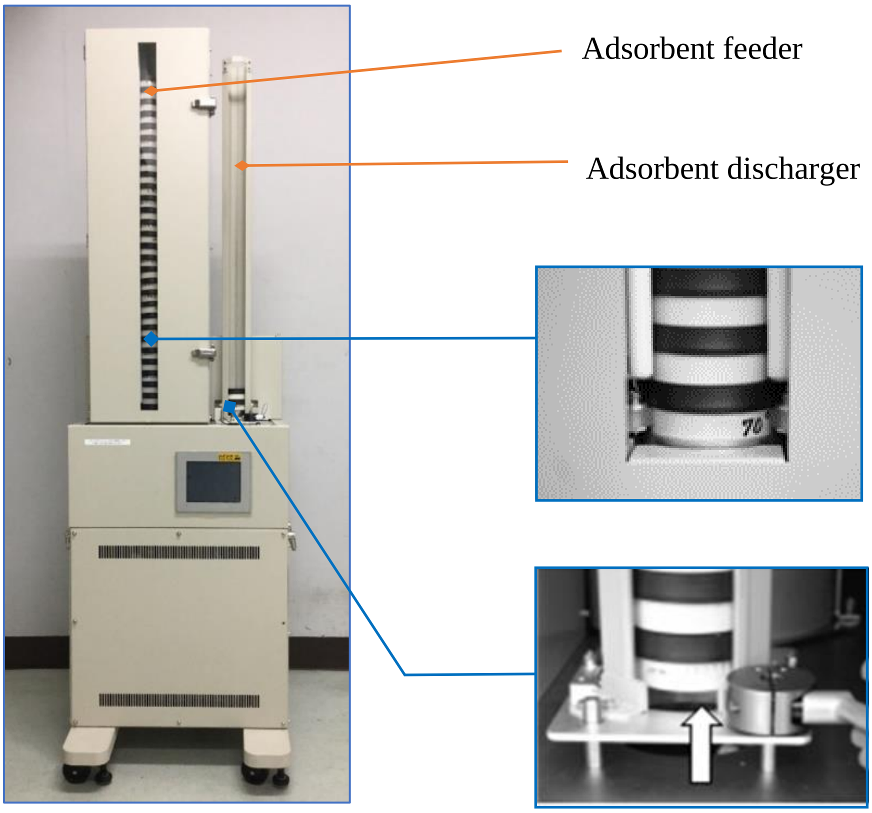
❑Air monitor (example)

[Measuring station]

[Air monitor appearance]

[Air monitor: air filter setting]

❑Iodine sampler (example)



[Iodine sampler (with the cover adsorbent discharger removed)]

❑In automated sampling using air monitors and iodine samplers, retrieving and replacing adsorbents (filter paper, cartridges, and the like) is necessary.

Preparation before departure

	Procedure	Reference/records
1	Confirm the location (measuring station) to retrieve and replace the adsorbents.	
2	Prepare necessary equipment. Note: It is good to keep adsorbents for replacement on hand at the measuring station where the air monitors are installed. The method of keeping adsorbents on hand should be in accordance with the instruction manual for the adsorbent to be used. Note: To prevent contamination of the measuring station, replace the adsorbent promptly. Confirm how to replace adsorbents in advance in the instruction manual of the equipment being used.	
3	Check the operation of equipment (especially communication device).	
4	Cover equipment, if necessary.	3.1 Prevention of equipment contamination
5	Check the operation of electronic personal dosimeters.	
6	Wear appropriate protective equipment (including protective clothing and masks) following the instructions for use. Also, if directed, take stable iodine tablets.	3.2 Protection of monitoring personnel

	Procedure	Reference/records
	Note: A dedicated air sampling team should replace the adsorbents, or if it is difficult to organize a dedicated sampling team, do it first before collecting any other environmental samples.	

Sampling procedure (retrieval of adsorbents)

	Procedure	Reference/records
1	Move to the sampling location (measuring station) where the adsorbent will be retrieved and installed.	
2	Retrieve the used adsorbents and record the date and time of retrieval, the lot number of the adsorbents, and other information. [Air monitor] ・If the adsorbent is a long filter paper, use either of these two methods: retrieve the entire roll of filter paper or cut off and retrieve the adsorbed portion. ・Retrieve absorbents according to the instructions provided. [Iodine sampler] ・Retrieve several days' worth of adsorbents. Retrieve absorbents according to the instructions provided. Note: Follow the directions in the instruction manual for the equipment used for how to retrieve and install the adsorbents.	Sampling record form B1 **d**
3	Put the used adsorbents in a polyethylene bag.	
4	Fold the bag opening, seal it with vinyl tape, and affix a label (printed or written) with the identification code.	Sampling record form B1
5	Put the sample in a second bag (i.e., an outer bag) and pack it.	
6	Set a new adsorbent and verify that the equipment is operating correctly.	
7	Check packaging, records, and photographs.	Sampling record form B1 **e**

Note: If a monitoring station is not installed at the sampling location, it is necessary to measure the dose rate around the sampling location using a survey meter or other instrument before Step 2.

Ⅱ. Measurements for nuclear fuel facilities

Measurement system

1. Air monitor

Apply the following devices depending on the type of accident at the facility. Table 4.1-1 shows the application.

(a) Able to detect α- emitting nuclides in the air (“Air monitor α”)

(b) Able to detect β-emitting nuclides in the air (“Air monitor β”)

For information on the retrieval and installation of adsorbents, see “I. Measurement for nuclear power reactor facilities.”

(a) Air monitor α

❏Measure gross α-radioactivity to continuously determine the concentration of α-emitting nuclides in the air.

❏Use filter paper like a membrane filter or similar material that does not allow particles to penetrate the interior of the filter.

❏The difference before and after a fixed time interval (10 minutes) in the continuous measurement determines the concentration of gross α radioactivity in the air.

❏The lower ldetection limit: is 10 Bq/m^3

❏The system should be able to operate continuously without refueling for at least 3 days after the startup of the air monitor.

❏Retrieve the filter paper as soon as possible in consideration of limiting the exposure of monitoring personnel and analyze the paper in detail to provide material for exposure evaluation.

(b) Air monitor β

Same as measurements for nuclear power reactor facilities.

Table 4.1-1 Application of air monitors to nuclear fuel facilities

Applicable facilities	Accident form	Type of equipment	Remarks
Uranium processing facility (Other nuclear fuel facilities)	Criticality accident	Air monitor (β)	Forming, processing, enrichment, reconversion
	UF_6 release	Air monitor (α)	Enrichment and reconversion only
Plutonium processing facility	Criticality accident	Air monitor (β)	—
	Large fire or explosion	Air monitor (α)	—
Reprocessing plant	Criticality accident	Air monitor (β)	—
	Large fire or explosion	Air monitor (β) Air monitor (α)	—
	Evaporation to dryness	Air monitor (β)	—

(Note) From the Emergency Supplemental Reference Material

Environmental sampling procedure	
4.1-b	**Using transportable sampler**

Objectives

The purposes of collecting air samples are to obtain information on the environmental radiation situation caused by a nuclear disaster and to evaluate the radiological impacts of the nuclear disaster. The analysis results of the radioactivity concentration in the air are used to estimate internal exposure caused by inhalation of radioactive materials and are also helpful in obtaining information about deposition on the ground surface. This section describes the air sampling via a transportable sampler.

Required equipment

❏Equipment common to all sampling (Checklist A1)
❏Equipment for air sampling (Checklist A2)

[Example of a low-volume air sampler]

[Example of a high-volume air sampler]

Preparation before departure

	Procedure	Reference/records
1	Receive written instructions.	
2	Prepare the necessary equipment according to checklists A1 and A2.	Checklist A1 and A2
3	Check the operation of equipment (especially communication device and GPS).	
4	Check the sampling location on the map.	
5	Cover equipment to prevent contamination. Note: Air samplers should never be wrapped in anything.	3.1 Prevention of equipment contamination
6	Check the operation of electronic personal dosimeters.	
7	Wear appropriate protective equipment (including protective clothing and masks) following the instructions for use. Also, if directed, take stable iodine tablets.	3.2 Protection of monitoring personnel

Sampling procedure (sampling via low-volume air sampler)

Low-volume air sampler: Flow rate approximately 10 to 100L/min

Note: When targeting radioactive iodine, use a low-volume air sampler.

1. Identification of sampling locations

	Procedure	Reference/records
1	Move to the sampling location indicated in the instructions.	
2	Record information (including the address) and take pictures of the sampling location.	Sampling record form B1 a
3	Record the latitude and longitude of the sampling location measured by GPS. If not available, find the location, mark it on the map, and record it.	Sampling record form B1 b

2. Sampling

	Procedure	Reference/records
1	Measure and record the dose rate near the sampling location using a NaI(Tl) scintillation survey meter or an ionization chamber survey meter.	3.3 Measurement of dose rate Sampling record form B1 c

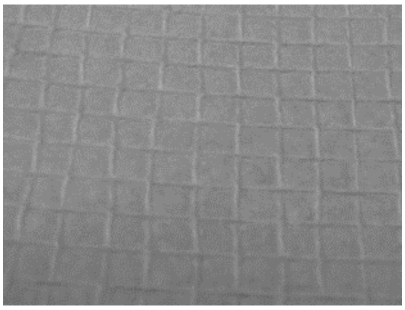
<table>
<tr><th></th><th colspan="2">Procedure</th><th>Reference/records</th></tr>
<tr><td rowspan="2">2</td><td colspan="2">Install air samplers so that they do not interfere with the airflow.
Note: To evaluate internal exposure doses, install air samplers so that their air inlets are approximately 1 m from the ground.

Note: Since the absorption of raindrops significantly degrades the collection performance of filter paper and activated carbon cartridges, install the air samplers in a roofed area to prevent the suction of raindrops when it rains. If there is no roofed area around the sampling location, hold an umbrella or something similar to avoid the suction of raindrops.

Note: If a transportable generator is used as a power source, ensure that the air sampler does not suck in its exhaust.

Note: Avoid, if possible, obtaining electric power from a vehicle used for transportation, as the measurement may be affected by exhaust gas (except in the case of vehicle-mounted air samplers).

Note: When using multiple air samplers together, ensure that their exhaust air does not affect each other.</td><td></td></tr>
<tr><td>Landscape type
Since the installation direction affects the integrated flow volume, determine the installation criteria in advance, such as in which direction to install the air sampler against the wind or whether to direct it toward the emission source regardless of the wind direction.</td><td>Vertical type
The air sampler sucks in air vertically.</td><td></td></tr>
</table>

	Procedure	Reference/records
3	Set the filter paper and activated carbon cartridge in the suction holder. The front side of filter paper has no lattice structure and collects dust. Note: To equalize the granular activated carbon in the activated carbon cartridge, gently shake it back and forth side to side before setting. Note: It is a good idea to write the airflow direction on the side of the activated carbon cartridge.   [Front side of glass fiber filter paper] [Back side: Lattice structure]  [The description of activated carbon cartridge]  Note: Use tweezers to handle the filter paper.	Sampling record form B1 **d**
4	Start sampling and record the time of sampling and volume (flow volume). Note: Set the flow rate of the air sampler at approximately 50 L/min (set to the flow rate indicated in the instructions.)	Sampling record form B1 **d**
5	Collect air until the integrated flow volume reaches the value indicated in the instructions. Note: If the flow rate is 50 L/min, the integrated flow volume is 1000 L (= 1 m^3) after 20 minutes of sampling. Note: If it rains during dust collection, stop the suction. The integrated flow volume until the rainfall is the sample's integrated flow volume. Alternatively, continue sampling while holding an umbrella or other object to prevent the air sampler from sucking in raindrops.	
6	Just before the end of sampling, read and record the sampling volume (flow volume).	Sampling record form B1 **d**

	Procedure	Reference/records
7	Stop the air sampler and record the time.	Sampling record form B1 **d**
8	Remove the filter paper and cartridge from the air sampler.	
9	Stack the filter paper and the cartridge and put them in a polyethylene bag. Note: The relation between the filter and the cartridge should be maintained in case they are packed in bags separately.	
10	Fold the bag opening, seal it with vinyl tape, and affix a label (printed or written) with the identification code.	Sampling record form B1
11	Put the sample in a second bag (i.e., an outer bag) and pack it.	
12	Check the packaging, records, and photographs.	Sampling record form B1 **e**
13	Remove the air sampler and load it into the vehicle. Note: Wipe and decontaminate the equipment used. Note: Decontaminate power and extension cords by wiping while winding them up.	

Sampling procedure (sampling via high-volume air sampler)

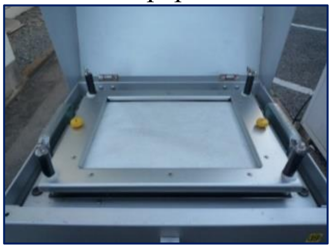
High-volume air sampler: flow rate 100 L/min. or more

1. Identification of sampling location

	Procedure	Reference/records
1	Move to the sampling location indicated in the instruction.	
2	Record information (including the address) and take pictures of the sampling location.	Sampling record form B1 **a**
3	Record the latitude and longitude of the sampling location measured by GPS. If not available, find the location, mark it on the map, and record it.	Sampling record form B1 **b**

2. Sampling

	Procedure	Reference/records
1	Measure and record the dose rate near the sampling location using a NaI(Tl) scintillation survey meter or an ionization chamber survey meter.	3.3 Measurement of dose rate Sampling record form B1 **c**
2	Install air samplers so that they do not interfere with the airflow. Note: To evaluate internal exposure doses, install air samplers with air inlets approximately 1 m from the ground. Note: Since the absorption of raindrops significantly degrades the collection performance of filter paper, install the air samplers in a roofed area to prevent the suction of raindrops when it rains. If there is no roofed area around the sampling location, hold an umbrella or something similar to avoid suction of raindrops. Note: If a transportable generator is used as a power source, ensure that the air sampler does not suck in its exhaust. Note: Avoid, if possible, obtaining electric power from a vehicle used for transportation, as the measurement may be affected by exhaust gas (except in the case of vehicle-mounted air samplers).	

	Procedure	Reference/records
	Note: When using multiple air samplers together, ensure that their exhaust air does not affect each other.	
3	Set the filter paper in the suction holder.   [Example of filter paper set]	Sampling record form B1 **d**
4	Start sampling and record the time of sampling and volume (flow volume). Note: The time required to collect an air sample depends on the radioactivity concentration in the air.	Sampling record form B1 **d**
5	Collect air until the integrated flow volume reaches the value indicated in the instructions. Note: If the flow rate is 1000 L/min, the integrated flow volume is 1000 L (= 1 m^3) when sampled for 1 minute.	
6	Just before the end of sampling, read and record the sampling volume (flow volume).  [Example of a model with the integrated flow volume and current flow rate display] Note: Some models continue suction at a specified flow rate and automatically stop when the specified integrated flow volume is reached.	Sampling record form B1 **d**
7	Stop the air sampler and record the time.	Sampling record form B1 **d**
8	Remove the holder fixing the filter paper with the air sampler in the vertical position. Note: Remove all screws fixing holders. Keeping the removed screws in a small poly beaker or similar container effectively prevents loss.  [Example of preventing loss of screws]	

	Procedure	Reference/records
9	Remove the filter paper from the air sampler. Note: Set new filter paper promptly after removal to prevent foreign material from entering the air sampler. The suction surface from which the filter paper is removed is often netlike. Work quickly to prevent small dust and particles from passing through the net and entering the air sampler.  [Suction surface with filter paper removed] Note: An entire cartridge is retrieved in some models.	
10	Do not fold the filter paper to be measured with the α-ray spectrometer but put it in a lidded plastic container or box with the suction side up, assuring that the suction side does not touch the walls or lid of the container. Fold the filter paper used for other measurements in half, with the suction side facing inward, and put it in a polyethylene bag (i.e., inner bag).  [Example of retrieved a sample for α-ray spectrometer]	
11	Affix a label with the identification code on the container or the inner bag with the bag opening folded over and sealed with vinyl tape and affix a (printed or written) label. Seal the lid of the container with vinyl tape, and put it in a polyethylene bag (i.e., an inner bag).	Sampling record form B1
12	Put the sample in a second bag (i.e., an outer bag) and pack it.	
13	Check the packaging, records, and photographs.	Sampling record form B1 **e**
14	Remove the air sampler and load it into the vehicle. Note: Wipe and decontaminate the equipment used. Note: Decontaminate power and extension cords by wiping while winding them up.	

Reference: Sampling at the time of enhanced monitoring in the environmental radioactivity level survey (air)

If radioactive materials are released, and there is a risk of radiation exposure and radioactive contamination of the environment, monitoring may be enhanced to conduct an environmental radioactivity level survey in order to determine the radiation levels in the area. The objectives of the enhanced monitoring are to obtain information for making decisions on measures to be taken for the public and to contribute to estimating the exposure dose to the public. When instructed by the Liaison Conference on Countermeasures against Radioactivity, prefectures implement enhanced monitoring. Here is an example response procedure.

	Procedure
1	The Liaison Conference on Countermeasures against Radioactivity indicates the start time of sampling.
2	Collect samples once a day by a high-volume air sampler, continuously sucking in air for 24 hours from a designated starting time to the ending time the following day.
3	The air inlet of the high-volume air sampler should be at the height of at least 1 m above ground level and be sheltered to prevent rain from entering.
4	If significant fluctuations in radioactivity concentration are expected, change the filter paper at the indicated intervals (more frequently than usual) and collect the samples.
5	Use glass fiber filter paper as the adsorbent.
6	Pack filter paper in a measuring container and measure with a germanium semiconductor detector for approximately 6 hours.
7	Report the results of measurements once a day regularly at the time instructed by the Liaison Conference on Countermeasures against Radioactivity.

The following are points to understand and keep in mind when collecting samples.

Things to keep in mind

❏Several types of radioactive materials can be released into the air during an emergency, including (a) particulate matter, (b) noble gases, and (c) volatile halogens (especially radioactive iodine).

❏This section describes the air sampling using two types of transportable air samplers (a low-volume air sampler: flow rate of 10 to 100 L/min, high-volume air sampler: a flow rate of 100 L/min or more). Select the air sampler, ensuring that the device can achieve the necessary detection level.

❏Air samplers may be installed on monitoring vehicles.

❏To collect air samples to determine air radioactivity concentrations relative to the soil, collect soil samples at the same time and place as the air sample.

❏Radioactive iodine can exist in a chemical form that cannot be collected by filter paper. Thus, use activated carbon filters (cartridge type) also for sampling (when radioactive iodine is expected to be present, such as in accidents at nuclear reactors, in hospitals where radioactive iodine is used, or during transportation of radioactive iodine).

❏Activated carbon filters (those impregnated with approximately 10% TEDA are recommendable to improve the adsorption of organoiodine compounds) can collect radioactive iodine and noble gases.

❏Silver/zeolite filters are sometimes used when collecting air for measuring radioactive iodine, but they are costly, so activated carbon cartridges are usually used.

❏Normally, use fiberglass filter paper.

❏Determine outlets for power sources for air samplers during emergency monitoring and clearly indicate them on drawings and photographs in advance. In addition, consider measures in advance to secure a power source in the event of a power outage to assure prompt on-site response.

Environmental sampling procedures	
4.2	**Soil**

Objectives

Collect soil samples for initial monitoring to collect, and measure and analyze potentially contaminated samples to obtain information on the spread and nuclide composition of radioactive materials deposited on the ground due to the nuclear disaster.

The results of the analysis of radioactivity concentration in soil are helpful for the following items.

(a) Evaluation of the level of surface contamination by dry or wet deposits

(b) Evaluation of the level of gross deposition per unit area on the ground surface.
→When sampling soil, it is essential to record the sampling area from which the soil was collected.

(c) Prediction of dose rate and its change over time at the sampling location

(d) Rough estimation of contamination of crops by radioactive materials absorbed from the soil.

(e) Obtaining reference information when estimating internal exposure through inhalation or further spread of radioactive materials, since contamination of the ground surface can become a source of resuspended radioactive materials later.

(f) Obtaining information to determine the necessity of changing the OIL default settings by determining the ratio of radioactive materials.

Required equipment

❏Equipment common to all sampling (Checklist A1)
❏Equipment for environmental sampling (Checklist A3)

Preparation before departure

	Procedure	Reference/records
1	Receive written instructions.	
2	Prepare necessary equipment according to checklists A1 and A3. Note: When performing γ-ray measurement directly with the small container used for sampling, it is recommended to measure and record the weight of the empty container, including the lid, in advance.	Checklist A1 and A3
3	Check the operation of equipment (especially communication device and GPS).	
4	Check the sampling location on the map.	
5	Cover equipment to prevent contamination.	3.1 Prevention of equipment contamination
6	Check the operation of electronic personal dosimeters.	
7	Wear appropriate protective equipment (including protective clothing and masks) following the instructions for use. Also, if directed, take stable iodine tablets.	3.2 Protection of monitoring personnel

Sampling procedure

1. Identification of sampling location

	Procedure	Reference/records
1	Move to the sampling location indicated in the instructions. Note: Places under trees, eaves, or anything that covers the ground surface are not appropriate for a sampling location. In addition, if there are ditches, slopes, hollow basins, roads, or drainage channels, radioactive materials may flow into the ditches and the like, resulting in higher radioactivity levels. If there are ditches and the like, avoid areas where the dose rate value changes drastically within the movement of only 1 m. Note: Bare ground is ideal. Note: Sampling may be difficult in sandy areas.	
2	Record information (including the address) and take pictures of the sampling location.	Sampling record form B2 **a**
3	Record the latitude and longitude of the sampling location measured by GPS. If not available, find the location, mark it on the map, and record it.	Sampling record form B2 **b**

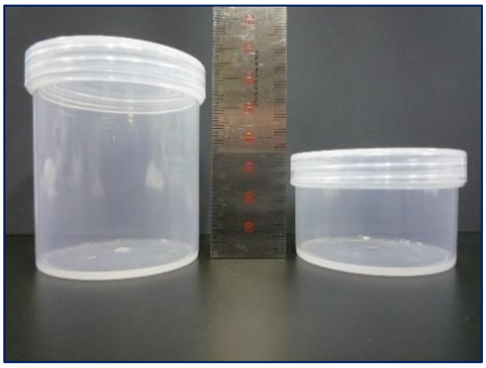
2. Sampling

	Procedure	Reference/records
1	Determine the sampling area in order to secure the specified area. Then, measure and record the dose rate in the area using a NaI(Tl) scintillation survey meter or an ionization chamber survey meter. Note: The sampling area should be at least 1 m square.	3.3Measurement of dose rate Sampling record form B2 **c** Sampling record form B2 **d**
2	Check the condition of the soil for sampling. Note: If grass or weeds cover the ground surface of the sampling area, mow and collect them separately from the soil as a plant sample. Identify the plants so they can be linked to the soil for use as reference data. In addition, record the area mowed. Collect small plants along with the soil if they are too small for separate sampling.  Note: If there is snow, collect snow separately from the soil as a sample, followed by soil sampling. Snow melts and becomes water, so collect it in a sample container suitable for liquids. Identify the snow so it can be linked to the soil for use as reference data. At this time, keep track of the area from which the snow was collected. If snow and soil cannot be collected separately, they should be collected together. Also, avoid collecting from snowdrifts.	Sampling record form B2 **d**

	Procedure	Reference/records
	 Note: If there is so much snow that soil sampling is impossible, collect snow from the surface to a certain depth (e.g., 5 cm) and use it as reference data (as with soil, record the area of snow collected) in consideration of the objective. Note: If it is difficult to collect the samples according to the instructions, inform the general and liaison team in charge of EMC measurement and analysis and ask for instructions regarding changes. If communication is difficult, the team leader of the sampling team decides on any changes.	
3	Place the sampling device (small container with the known base area) perpendicular to the ground surface and push it down with foot by approximately 5 cm (it may be also pushed it in with hand). Note: If the soil is hard, be careful not to push the container too hard and break it (especially if it is made of polystyrene, which is easily broken). (For details, see “Reference 2: Materials of small containers”.)	Sampling record form B2 **d**

	Procedure	Reference/records

Note: If the sample soil is expected to contain highly concentrated radioactive materials and the small container used for sampling is used for γ-ray measurement without modification, a target size of approx. 2 cm may be sampled. In this case, a smaller container with the same base area but an even smaller volume may be used (because a smaller sample volume is sufficient for γ-ray measurement of a highly concentrated sample and the higher a sample amount is, the more significantly non-uniform distribution of radioactive materials in the container affects the measurement results **[Explanation A]**).



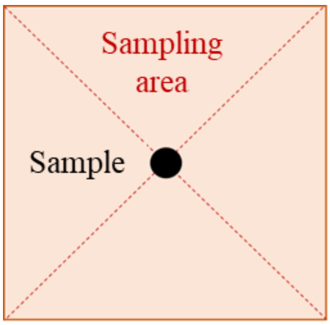
[Small container with 100 mL capacity (left) and a small container with 50 mL capacity (right)]

Note: If the soil is too hard to push down the sampling device 5 cm, collect the soil with a target of 2 cm deep and record the soil sampling condition (including the sampling depth) **[Explanation B]**.

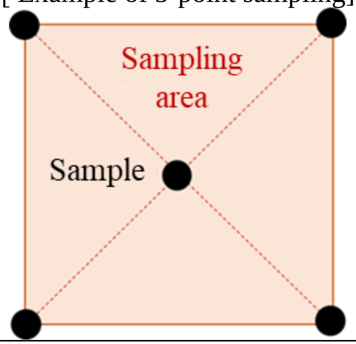
Note: Since small containers can be used quickly and conveniently as sampling devices, adopt the method of pushing a small container directly into the ground to collect a measuring sample. However, other sampling methods are not precluded.

Note: When sampling soil to quickly determine the nuclide composition of radioactive materials deposited on the ground during

<table>
<tr><th></th><th colspan="2">Procedure</th><th>Reference/records</th></tr>
<tr><td></td><td colspan="2">initial monitoring, it is acceptable to collect soil at a single point. In subsequent monitoring and monitoring in mid-term and recovery phases, increase the number of sampling points to shift to surveys aimed at a more representative determination of nuclide concentrations in the target environment. Explanation C describes the number of sampling points and reliability.</td><td></td></tr>
<tr><td></td><td>Single-point sampling
When doing single-point sampling, collect the soil at the center of the sampling area, and record the sampling point graphically.
Note: The sampling area should be at least 1 m square.

[Example of single-point sampling]

</td><td>Multiple-point sampling
Record the parts of the sampling area graphically when sampling multiple points.
Note: Collect approximately the same amount at each point.

Note: The sampling area should be at least 1 m square.

[Example of 5-point sampling]

</td><td></td></tr>
<tr><td>4</td><td colspan="2">Use a disposable spoon or similar object to scoop the soil in the container.

Note: Minimize the gaps between the samples as much as possible.</td><td></td></tr>
<tr><td>5</td><td colspan="2">Single-point sampling
Wipe off any soil adhering to the screw hole area with a paper towel, put the lid on the sampling container and wipe off the surrounding area with a paper towel.

Note: Do not put any soil adhering to the outside of the sample</td><td></td></tr>
</table>

<table>
<tr><th></th><th colspan="2">Procedure</th><th>Reference/records</th></tr>
<tr><td></td><td colspan="2">container inside the container.</td><td></td></tr>
<tr><td>6</td><td colspan="2">Record the time and the circumstances of sampling.</td><td>Sampling record form B2 d</td></tr>
<tr><td>7</td><td>Single-point sampling
Seal the lid with vinyl tape, and affix a label (printed or written) with the sample code to the surface of the container.
Then put it in a polyethylene bag (i.e., an inner bag).
Note: Tie the opening of the polyethylene bag while removing the air.
</td><td>Multiple-point sampling
Place all soil for multiple points in a polyethylene bag (i.e., inner bag), tie the bag opening, and gently crush any clumps of soil from the outside of the bag (may be lightly shaken). Then affix a label (printed or written) to the inner bag with an identification code.
</td><td>Sampling record form B2</td></tr>
<tr><td>8</td><td colspan="2">Put the sample in a second bag (i.e., an outer bag) and pack it.
Note: Avoid vibration and shock as much as possible when transporting samples, as vibration and shock may cause the water and soil portions to separate.</td><td></td></tr>
<tr><td>9</td><td colspan="2">Check the packaging, records, and photographs.</td><td>Sampling record form B2 e</td></tr>
</table>

Reference 1: About the soil sampler

A cylindrical tube can be used as a tool for soil sampling. The cylindrical tube can be used to collect hard soil, but dispose of it each time or use it with sufficient care to prevent cross-contamination if you cannot wash it with deionized water.

[Example cylindrical tube]

*From "Results of the Research on Distribution of Radioactive Substances Discharged by the Accident at TEPCO's Fukushima Daiichi NPP" (March 2012), funded by the FY 2011 Strategic Funds for the Promotion of Science and Technology

Reference 2: Material of small containers

Polypropylene (PP) and polystyrene (PS) are commonly used materials for these types of small containers. The PP material is somewhat softer and may present difficulties when driven into hard soil.

On the other hand, PS materials are sturdy enough to drive into hard soil but may break when force is applied. Both have advantages and disadvantages, so it is essential to understand their characteristics and handle them accordingly.

[Small container made of PP]

[Small container made of PS]

The following are points to understand and keep in mind when collecting samples.

Things to keep in mind

❑ Soil sampling will be conducted at the following locations.

(a) Sites where OIL2 criteria were exceeded among the sites of monitoring stations and electronic dosimeters.

(b) Sites where the concentration of radioactive materials in the air is measured, such as sites where air monitors are installed

(c) Sites of in-situ measurements (analysis of α- and β-emitting nuclides is performed if necessary).

❏If the sampling locations include private properties when developing an emergency monitoring plan, it is advisable to obtain permission from the landowner for soil sampling during a normal situation.

❏It is advisable to manage the soil sampling locations designated in the emergency monitoring plan (e.g., weeding) regularly to eliminate sampling problems.

❏Collect soil after the release of radioactive materials from the nuclear facility has stopped and the plume has passed.

❏The sampling frequency is as follows.

Conduct the first sampling promptly after the release of radioactive materials has stopped and radioactive materials are deposited on the ground.

↓

Conduct the second sampling approximately one week after the first sampling.

↓

For the third and subsequent sampling, review and implement the sampling plan based on the measurement results of the second sample.

❏If the dose rate in the sampling area is high, collect only a sufficient amount of soil for measurement.

❏The measuring container can be used as a sampling device.

❏If the container with sample is directly used for γ-ray measurement, its geometry should be the same as a container used for efficiency calibration. It is also advisable to measure and record the weight of the empty container, including the lid, beforehand.

❏Ground surface contamination can vary markedly from place to place (hot spots). When assessing the level of contamination, it is also advisable to refer the dose rate of the area.

❏In conducting continuous sampling, mark the sampling points with some kind of marker or take pictures to facilitate finding the sampling points later.

❏When a monitoring station site is selected as a soil sampling location in an emergency monitoring plan, soil sampling may be difficult if the ground surface is graveled or paved. For initial monitoring to quickly determine the nuclide composition of radioactive materials deposited on the ground, installing containers (e.g., planters) filled with soil during a normal situation is recommendable. Soil from these containers is collected during emergency monitoring. When using this method, measure the background of the soil to be placed in the container in advance with a germanium semiconductor detector or similar device.

[Example of a planter filled with soil]

Mid-term and recovery phase monitoring

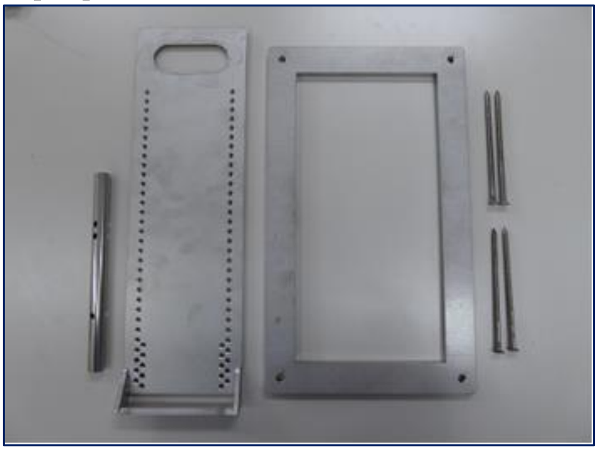
❑Monitoring in mid-term and recovery phases requires more reliable sampling, including increasing the number of sampling locations [Explanation C]. For the sampling method, it is recommended to refer to the series of environmental radioactivity measuring methods No. 16, "Generic Procedures for Environmental Sampling."

Other soil sampling procedure (scraper plate method)

❑For radionuclide distribution and depth distribution surveys in soil, the soil is collected by the scraper plate method. For details, refer to the series of environmental radioactivity measuring methods No.33, "In-situ Measurement Using Germanium Detector."

1. Preparation of sampling device

・Scraper plate



・Polyethylene bags for soil sampling (per sampling layer)
・Bats
・Hammer, pruning shears, grafting trowel, spatula, tweezers
・Disposable rubber gloves
・Deionized water (or wet wipes) for cleaning sampling equipment
・Blue sheets (when collecting at multiple locations, use disposable paper to avoid contamination)
・Weighing scale (only if soil weight is to be measured on-site)
・Small containers (per sampling layer. only if measuring samples are prepared on-site)
・Tent or parasol for shelter from rain and sun (if necessary)

2. Sampling procedure

	Procedure
1	Fix the frame to the ground using a hammer or similar tool. Note: Make sure that the frame is solidly nailed down.
2	Remove plants, stones, and the like, if present on the soil surface. If these plants or stones are to be used for measuring the radioactivity concentration, collect them separately from the soil. Note: Remove stones from the soil surface, but do not remove buried stones. Note: If the ground is frozen, wait for it to thaw or use a gas burner/similar tool to melt it before sampling. If there is snow, remove the snow carefully so as not to disturb the soil surface before sampling. (Plant removal method) Carefully remove only those parts of the plant on the ground surface, using pruning shears or similar tools.

	Procedure
	  [Plant removal (left: before removal, right: after removal)]
3	Fix the metal rod to the plate with a screw and adjust it to the desired depth for sampling.
4	Move the plate horizontally in the frame to scrape off the soil and put it in a polyethylene bag.   [Soil sampling by scraper plate] Note: The sampling operation should be conducted until all the soil has been scraped off. Note: Cut roots with pruning shears or similar tools and add them to the soil in that layer. If a stone exists through multiple layers, add it to the layer of soil in which the biggest part of the stone is located. If it is impossible to determine which layer includes the stone, add it to the upper layer. Note: Sampling with the plate at an angle to the ground makes the sampling depth deeper than the adjusted depth, so keep the plate perpendicular to the ground while sampling. Note: Use a grafting trowel or spatula to completely collect the soil from the edges and corners of the frame. Otherwise, the upper soil layer will be mixed in when collecting the lower soil layer, which causes errors when calculating the density in the soil layer.
5	After completing soil sampling in a layer, wash the plate to remove soil with deionized water and wipe dry to prevent the upper layer soil from contaminating the next layer. In addition, discard the rubber gloves used for sampling and replace them with new ones. Note: If the upper layer of soil falls and mixes with the lower layer due to the collapse of the inner wall scraped by the plate, remove it with care to avoid mixing the upper layer soil with the lower layer soil. If the inner wall is prone to collapsing, dampen it with a misting spray to protect it. Note: If deionized water cannot be prepared, wipe off the soil with wet wipes.
6	Repeat steps 3-5 for each sampling layer.
7	After sampling all layers, refill the holes created by the sampling with soil from the surrounding area. Note: Determine the refilling method in advance. Note: When refilling, in consideration of continual sampling, mark the sampling points or take photographs to identify the sampling points.

3. Sampling record

Record the following items on the sampling record form, and take photographs of the entire view of the sampling location, a close-up view, the sampling conditions, and the collected soil.

(a) Location information of the sampling location
(b) Sampling date and time
(c) Weather conditions at the sampling time
(d) Other information on the sampling location
(e) Depth and weight of soil collected (only if the soil is weighed in the field)
(f) Other special notes

Environmental sampling procedures	
4.3	**Drinking water**

Objectives

Since radioactive materials transferred to drinking water can be ingested by humans, determining their concentrations is essential to evaluate exposure doses. Collect drinking water to provide materials for making decisions on the implementation of protective measures and for evaluating the radiological impact of a nuclear disaster on residents and the environment. Sampling of drinking water is the first priority in the initial monitoring.

Required equipment

❏ Equipment common to all sampling (Checklist A1)
❏ Equipment for environmental sampling (Checklist A3)

Preparation before departure

	Procedure	Reference/records
1	Receive written instructions.	
2	Prepare the necessary equipment according to checklists A1 and A3.	Checklist A1 and A3
3	Check the operation of equipment (especially communication device and GPS).	
4	Check the sampling location on the map.	
5	Cover equipment to prevent contamination.	3.1 Prevention of equipment contamination
6	Check the operation of electronic personal dosimeters.	
7	Wear appropriate protective equipment (including protective clothing and mask) following the instructions for use. Also, if directed, take stable iodine tablets.	3.2 Protection of monitoring personnel

Sampling procedure

1. Identification of sampling locations

	Procedure	Reference/records
1	Move to the sampling location indicated in the instruction.	
2	Record information (including the address) and take pictures of the sampling location.	Sampling record form B3 a
3	Record the latitude and longitude of the sampling location measured by GPS. If not available, find the location, mark it on the map, and record it.	Sampling record form B3 b

2. Sampling

	Procedure	Reference/records
1	Measure and record the dose rate near the sampling location using a NaI(Tl) scintillation survey meter or an ionization chamber survey meter.	3.3 Measurement of dose rate Sampling record form

	Procedure	Reference/records
	Note: Since sampling during the release of radioactive materials will be conducted indoors, do not measure the dose rate.	B3 c
2	Open the faucet wide and let the water run for at least one minute. Note: Water pipe consists of the main pipe and branch pipes (side pipes) that branch off from the main pipe, and a faucet is usually attached to a branch pipe. When a faucet is turned on, water accumulated in the branch pipe is first released. However, since the water accumulated in the branch pipe is not suitable for an analysis sample, open the faucet wide and let the water run for at least one minute. Note: Water in outdoor pipes might be frozen in winter. If the pipes are frozen, cover them with a towel or cloth and slowly pour "warm water" over them to melt the ice. Sudden application of boiling water may burst pipes and faucets.	Sampling record form B3 d
3	Rinse the sample container with tap water from which the sample is to be collected. Note: Wastewater used for rinsing should be disposed of in a location that does not affect sampling.	
4	Collect approx. 2 L directly from the faucet into a container. Note: In the initial monitoring, since speed is a priority, do not use additives (e.g., hydrochloric acid). Note: Use additives only when directed to do so (e.g., if several days are required to deliver the sample to the analytical laboratory). In this case, add approximately 1 mL of hydrochloric acid (approx. 12 mol/L) per 1 L to prevent nuclides from adhering to the inner walls of the container. When radioactive iodine is the target, add 80 to 100 mg of sodium thiosulfate per liter to prevent radioactive iodine from adhering to the inner walls of the container (collect the samples for radioactive iodine and for other nuclides separately). Note: If tritium or carbon-14 is to be analyzed, do not use additives.	Sampling record form B3 d
5	Put the lid on the sampling container and wipe off the surrounding area with a paper towel.	
6	Record the time and the circumstances of sampling.	Sampling record form B3 d
7	Affix a label (printed or written) with an identification code to the container containing the sample.	Sampling record formB3
8	Seal the lid with vinyl tape and put it in a polyethylene bag (i.e., an inner bag).	
9	Put the sample in a second bag (i.e., an outer bag) and pack it.	
10	Check the packaging, records, and photographs.	Sampling record form B3 e

The following are points to understand and keep in mind when collecting samples.

Things to keep in mind

❏Drinking water sampling "during the release of radioactive materials" and "immediately after stopping the release of radioactive material" are as follows.

	During the release of radioactive materials	Immediately after stopping the release of radioactive materials
Sampling location	・Collect water samples from indoor taps in public facilities (town halls, branch offices, or others) supplied from water sources in UPZs [Urgent Protection action planning Zones] (including PAZs [Precautionary Action Zones]), such as surface water that is relatively easily contaminated by radioactive materials.	・Collect purified water (or raw water if it is difficult to collect purified water) from all water treatment plants that take water from sources such as water sources in UPZs (including PAZs), which includes surface water that is relatively easily contaminated by radioactive materials.
Frequency of sampling	At least once a day	At least once a day
Sampling amount	2 L or more	2 L or more
Remarks	・Select one water treatment plant or so per municipality before the "Heisei merging." ・If it is too difficult to collect 2 L or more, the sampling amount may be less than 2 L.	・If it is too difficult to collect at all water treatment plants, prioritize water treatment plants supplying a large population and water treatment plants that draw water from sources with high dose rates in the surrounding area. ・If it is too difficult to collect 2 L or more, the sampling amount may be less than 2 L.

❏Drinking water comes from various sources (river water, groundwater, and others). While some of these sources can be contaminated at significant levels of radioactive materials, the purification process in large water supply systems decontaminates drinking water to some degree.
❏Determine taps for sampling drinking water during emergency monitoring in advance and indicate them on drawings and photographs.

Chapter 5 Environmental sampling procedures (second prioritized materials)

The document " Emergency Supplemental Reference Material (supplementary reference material of the Nuclear Emergency Preparedness and Response Guidelines)" describes measurements of the concentration of radioactive materials in environmental samples other than air sample. Environmental samples are classified into 'precipitation', 'soil and others' (including land water, seawater, river sediment, lake sediment, sea sediment and indicator organisms) and 'foods and drink'. Plants mainly used for food as substitute for green vegetables are classified as 'food and drink' considering local food cultures. Among these environmental samples, collection of soil and drinking water (described in Chapter 4) should be given first priority to obtain information for decision making on protective measures. Other environmental samples should also be collected to evaluate radiological impacts on residents and to grasp environmental radiation situation.

This chapter describes the procedures for collecting environmental samples such as milk, vegetables, precipitation(rainwater), water samples (other than drinking water), agricultural and livestock products, seafood and algae and sediment other than environmental samples described in Chapter 4.

Environmental sampling procedures	
5.1	**Milk**

Objectives

Milk samples are well-known for their grass-cow-milk-human exposure pathway. In emergencies, radioactive iodine contamination is critical because milk is located in a food chain, grass-cow-milk-human. Milk sampling will be conducted as necessary to provide materials for making decisions on the implementation of protective measures and for evaluating the radiological impact of a nuclear disaster on residents and the environment. This section describes the procedure for monitoring personnel sampling at a farm or other locations.

Required equipment

❑Equipment common to all sampling (Checklist A1)
❑Equipment for environmental sampling (Checklist A3)

Preparations before departure

	Procedure	Reference/records
1	Receive written instructions.	
2	Prepare the necessary equipment according to checklists A1 and A3.	Checklists A1 and A3
3	Check the operation of equipment (especially communication device and GPS).	
4	Check the sampling location on the map.	
5	Cover equipment to prevent contamination.	3.1 Prevention of equipment contamination
6	Check the operation of electronic personal dosimeters.	
7	Wear appropriate protective equipment (including protective clothing and masks) following the instructions for use. Also, if directed, take stable iodine tablets.	3.2 Protection of monitoring personnel

Sampling procedure

1. Identification of sampling locations

	Procedure	Reference/records
1	Move to the sampling location indicated in the instructions.	
2	Record information (including the address) and take pictures of the sampling location.	Sampling record form B4 **a**
3	Record the latitude and longitude of the sampling location measured by GPS. If not available, find the location, mark it on the map, and record it.	Sampling record form B4 **b**

2. Sampling

	Procedure	Reference/records
1	Measure and record the dose rate near the sampling location with a NaI (Tl) scintillation survey meter or an ionization chamber survey meter.	3.3 Measurement of dose rate Sampling record form B4 **c**
2	Rinse the sample container with milk to be collected, if necessary. Note: Wastewater used for rinsing should be disposed of in a location that does not affect sampling.	
3	Collect about 2 L of milk and place it in a container. Note: In the initial monitoring, since rapidity is a priority, preservatives (e.g., methanol) should not be added. Note: For preservatives, add approximately 10 to 20 mL per liter of milk only when instructed (e.g., several days are required to deliver the sample to the analytical laboratory), and record this fact. Also, be careful to handle samples to which preservatives have been added, for example, by identifying the sample as one to which the preservative has been added. Note: Some items used as preservatives have legal restrictions on their use and disposal. Consider the usage in consideration of the handling during and after the measurement.	Sampling record form B4 **d**
4	Put the lid on the sample container and wipe off the surrounding area with a paper towel.	
5	Record the time and the circumstances of sampling. Note: If the milking date differs from the sampling date, check and record the milking date.	Sampling record form B4 **d**
6	Paste a label with the identification code (printed or written) on the container holding the sample.	Sampling record form B4
7	Seal the lid with vinyl tape and put it in a polyethylene bag (i.e., an inner bag).	
8	Put the sample in a second bag (i.e., an outer bag) and pack it. Note: Avoid vibration and shock when transporting samples since vibration and shock may separate water and fat content.	
9	Check the packaging, records, and photographs.	Sampling record form B4 **e**
10	Put the sample in a cold insulation container.	

The following are points to understand and keep in mind when collecting samples.

Things to keep in mind

❏Milk should be collected from dairy cows that have consumed grass or water in the area surrounding the sampling location, not from cows fed stored feed.

❏One method of milk sampling is from the combined milk of dairy cows (a mixture of 4-5 cows' raw milk as it is milked from the dairy cows).

❏Milk sampling requires the consent and cooperation of the producer (dairy farmer). When developing an emergency monitoring plan, it is recommended that producers selected as candidates for sampling be asked for permission and cooperation in preparation for emergency monitoring in normal situations.

5.2 Vegetables

Objectives

Green vegetable samples are collected to determine the surface contamination of green vegetables (fruits) caused by deposits containing radioactive materials. Plant uptake of radioactive materials from the soil becomes an issue only later. Green vegetables are collected as necessary to provide materials for making decisions on the implementation of protective measures and for evaluating the radiological impact of a nuclear disaster on residents and the environment.

Required equipment

❑Equipment common to all sampling (Checklist A1)
❑Equipment for environmental sampling (Checklist A3)

Preparations before departure

	Procedure	Reference/records
1	Receive written instructions.	
2	Prepare the necessary equipment according to checklists A1 and A3.	Checklists A1 and A3
3	Check the operation of equipment (especially communication device and GPS).	
4	Check the sampling location on the map.	
5	Cover equipment to prevent contamination.	3.1 Prevention of equipment contamination
6	Check the operation of electronic personal dosimeters.	
7	Wear appropriate protective equipment (including protective clothing and masks) following the instructions for use. Also, if directed, take stable iodine tablets.	3.2 Protection of monitoring personnel

Sampling procedure

1. Identification of sampling locations

	Procedure	Reference/records
1	Move to the sampling location indicated in the instructions. Note: Collect samples in the center of the field. Sampling under an object covering the ground surface, such as trees or eaves, is inappropriate.	
2	Record information (including the address) and take pictures of the sampling location.	Sampling record form B5 **a**
3	Record the latitude and longitude of the sampling location measured by GPS. If not available, find the location, mark it on the map, and record it.	Sampling record form B5 **b**

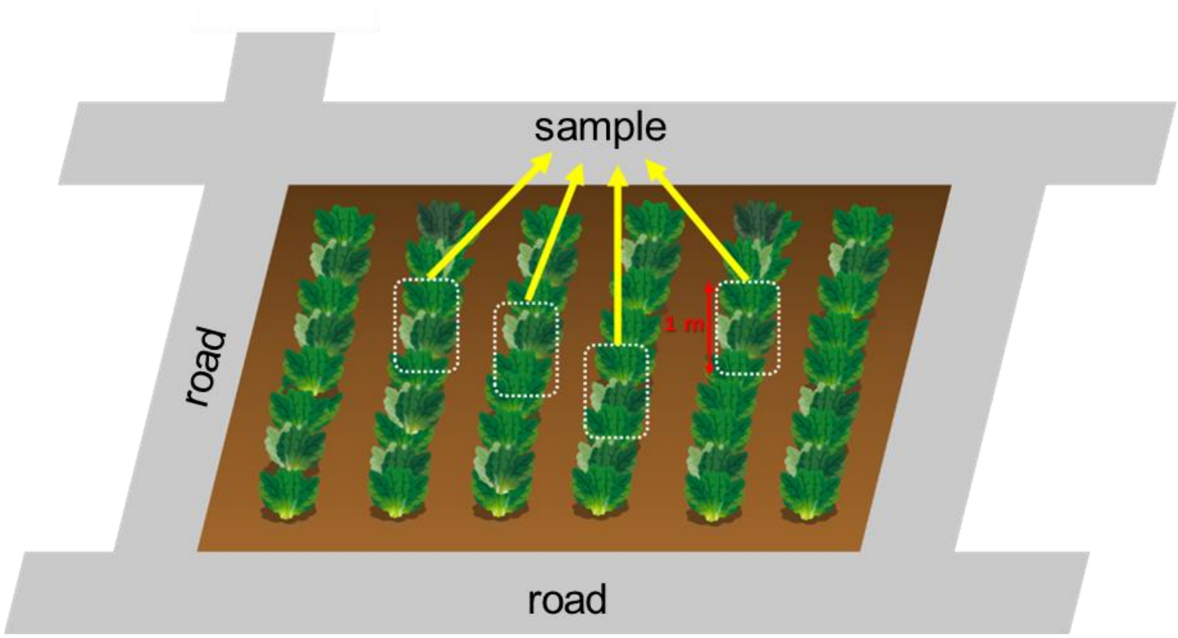
2. Sampling

	Procedure	Reference/records
1	Measure and record the dose rate near the sampling location with a NaI (Tl) scintillation survey meter or an ionization chamber survey meter.	3.3 Measurement of dose rate Sampling record form B5 **c**
2	Using a sickle or similar tool, harvest the above-ground portion of green vegetables and put them in a polyethylene bag. Note: The edible portion of the sample should weigh 1 kg (approximate). For specific examples of edible portions, refer to the series of environmental radioactivity measuring methods No. 24, "Preparation of Samples for Gamma-ray Spectrometry in Emergencies." Note: If green vegetables are covered with water (even if frozen), collect that water together. (do not wipe them off.) Note: Green vegetables are not rinsed in water. Note: For globular vegetables (Chinese cabbage and cabbage), collect the whole vegetable, not just the outer leaves. In measuring and analyzing, since the outer leaves are considered to be contaminated, the handling of the collected samples should be determined according to the purpose of the investigation.	Sampling record form B5 **d**
3	Attach (or write) a label with an identification code to the polyethylene bag (i.e., an inner bag) holding the sample, binding the mouth of the bag.	Sampling record form B5
4	Record the circumstances of the sampling.	Sampling record form B5 **d**
5	Put the sample in a second bag (i.e., an outer bag) and pack it.	
6	Check the packaging, records, and photographs.	Sampling record form B5 **e**

The following are points to understand and keep in mind when collecting samples.

Things to keep in mind

❏Samples should be collected from potentially contaminated fields and the like.
❏If private property is included in the sampling location when developing an emergency monitoring plan, it is advisable to obtain permission from the landowner and producer for emergency monitoring in normal situations.
❏Crops that can be harvested at the time of sampling should be selected as samples.
❏Samples should be taken from open field crops, not greenhouse crops.
❏Preparing a list showing when, where, and what samples can be collected is advisable. Weeds may be collected instead of green vegetables. Mugworts and other indicator organisms may also be collected. For the sampling method, refer to the series of environmental radioactivity measuring methods No. 16, "Generic Procedures for Environmental Sampling".
❏Continued sampling under the same conditions is desirable.
❏Select several locations as sampling locations where growth in the center of the field appeared to be average and collect crops growing within a certain distance (e.g., 1 m) of the ridges.



Environmental sampling procedures	
5.3	**Precipitation (rainwater)**

Objectives

Precipitation (including rainwater) is essential to determine the deposition of radioactive materials released from nuclear facilities on the ground surface in emergencies.

Required equipment

❏Equipment common to all sampling (Checklist A1)
❏Equipment for environmental sampling (Checklist A3)

[Example of the precipitation sampling device]

Preparations before departure

	Procedure	Reference/records
1	Receive written instructions.	
2	Prepare the necessary equipment according to checklists A1 and A3.	Checklists A1 and A3
3	Check the operation of equipment (especially communication device and GPS).	
4	Check the sampling location on the map.	
5	Cover equipment to prevent contamination.	3.1 Prevention of equipment contamination
6	Check the operation of electronic personal dosimeters.	
7	Wear appropriate protective equipment (including protective clothing and masks) following the instructions for use. Also, if directed, take stable iodine tablets.	3.2 Protection of monitoring personnel

Sampling procedure

1. Identification of sampling locations

	Procedure	Reference/records
1	Move to the sampling location indicated in the instructions.	
2	Record information (including the address) and take pictures of the sampling location.	Sampling record form B3**a**
3	Record the latitude and longitude of the sampling location measured by GPS. If not available, find the location, mark it on the map, and record it.	Sampling record form B3 **b**

2. Sampling

	Procedure	Reference/records
1	Measure and record the dose rate near the sampling location with a NaI (Tl) scintillation survey meter or an ionization chamber survey meter.	3.3 Measurement of dose rate Sampling record form B3 **c**
2	Place the sample container at the sampling location, and record the date and time of the start of sampling and the sampling area of the sampling device. Note: The location of the sampling device should be in a flat area unaffected by trees or buildings. However, if there is no suitable location on the ground surface, such as in urban areas, it may be installed on a flat rooftop on the first or second floor.  [Example of rooftop installation] Note: The height of the sampling device should be at least 1 m above the ground surface to prevent precipitation from bouncing off the ground and the like, and mixing with soaring soil. Note: When installed on a rooftop, it should not be affected by chimneys or other obstacles.	Sampling record form B3 **d**
3	After the prescribed time has elapsed, transfer the total amount of the sample to a polyethylene container. Note: If there was no precipitation, wash the inside of the sample container with deionized water and collect it as a dry fallout sample.	Sampling record form B3 **d**

	Procedure	Reference/records
	 [Example of sampling] Note: If the sampling device is covered with snow, collect that snow along with the water. If snow was collected or water was frozen, the total volume of the sample should be measured after it has been transported indoors and completely melted at room temperature.	
4	Put a lid on the polyethylene container and seal it with vinyl tape. Wipe off the surrounding area with paper towels and the like.	
5	Paste a label with the identification code (printed or written) on the container holding the sample.	Sampling record form B3
6	Put the container in a polyethylene bag (i.e., an inner bag).	
7	Record the end time of sampling, and the like.	Sampling record form B3 **d**
8	Put the sample in a second bag (i.e., an outer bag) and pack it.	
9	Check the packaging, records, and photographs.	Sampling record form B3 **e**

Reference: Sampling at the time of enhanced monitoring in the environmental radioactivity level survey (precipitation)

Once an event occurs releasing radioactive materials into the environment that may result in radiation exposure and radioactive contamination of the environment, monitoring for the environmental radioactivity level survey may be strengthened in order to determine the radiation levels in the local environment and obtain information for making decisions on measures for the public and to contribute to estimating the exposure dose to the public. When instructed by the Liaison Conference on Countermeasures against Radioactivity, prefectures implement enhanced monitoring. An example of the response procedure is shown below.

	Procedure
1	The Liaison Conference on Countermeasures against Radioactivity indicates the start time of sampling against radioactivity.
2	Using the prescribed sampling device (Model 70A-H precipitation sampler), collect the precipitation for 24 hours from a designated starting time to the ending time.
3	Even in the absence of precipitation, rinse the inside of the funnel of the 70A-H precipitation sampler with deionized water and collect dry fallout.
4	If there is a risk that the sample may overflow from the storage bin before the end time of sampling due to heavy rain and the like, the storage bin should be replaced as needed.
5	If the precipitation sample volume is less than 80 mL, use the entire volume; if 80 mL or more, record the sampling volume, stir it well, homogenize it, and transfer 80 mL to a measuring container and measure for approximately 6 hours with a germanium semiconductor detector.
6	Report the results of measurements once a day regularly at the reporting time instructed by the Liaison Conference on Countermeasures against Radioactivity and the like.

The following are points to understand and keep in mind when collecting samples.

Things to keep in mind

❏A temporary sampling of fixed-point samples may be conducted to enhance monitoring of environmental radioactivity level surveys.

❏Radioactive precipitation sampling device (70A-H type) or a funnel for receiving water (about 25 cm in diameter) combined with a water storage bin (about 20 cm in diameter and 10 cm depth). If a sampling device is unavailable, a vessel with a known opening area, such as a bat, tub, and the like, may be substituted.

❏When removing the equipment, it is necessary to decontaminate the equipment used by wiping and the like.

5.4 Water samples (other than drinking water)

Objectives

It is essential to determine the radioactivity concentration in water (river water, groundwater, seawater, and the like) because it will be a factor in determining the implementation of monitoring of seafood and algae when the discharge of radioactive materials into river systems, sea areas, and the like, is confirmed. During the initial monitoring, priority will be given to collecting drinking water samples among water samples, but water other than drinking water will also be collected as needed.

Required equipment

❏Equipment common to all sampling (Checklist A1)
❏Equipment for environmental sampling (Checklist A3)

Preparations before departure

	Procedure	Reference/records
1	Receive written instructions.	
2	Prepare the necessary equipment according to checklists A1 and A3.	Checklists A1 and A3
3	Check the operation of equipment (especially communication device and GPS).	
4	Check the sampling location on the map.	
5	Cover equipment to prevent contamination.	3.1 Prevention of equipment contamination
6	Check the operation of electronic personal dosimeters.	
7	Wear appropriate protective equipment (including protective clothing and masks) following the instructions for use. Also, if directed, take stable iodine tablets.	3.2 Protection of monitoring personnel

Sampling procedure

1. Identification of sampling locations

	Procedure	Reference/records
1	Move to the sampling location indicated in the instructions.	
2	Record information (including the address) and take pictures of the sampling location.	Sampling record form B3**a**
3	Record the latitude and longitude of the sampling location measured by GPS. If not available, find the location, mark it on the map, and record it.	Sampling record form B3 **b**

2. Sampling

	Procedure	Reference/records
1	Measure and record the dose rate near the sampling location with a NaI (Tl) scintillation survey meter or an ionization chamber survey meter.	3.3 Measurement of dose rate Sampling record form

	Procedure	Reference/records
		B3 **c**
2	Rinse the sample container with water sample to be collected. Note: Wastewater used for rinsing should be disposed of in a location that does not affect sampling.	
3	Throw in a bucket with a string or use a water dipper to collect about 2 L of water sample and put it in a container. Note: When throwing a bucket from a bridge into a river or other flowing area, throw it from the downstream side of the bridge to prevent damage from contact with the bridge girders. Note: When collecting surface water (lake, pond, or seawater surface), use a bucket or water dipper to collect the water and place it in a sample storage container. Avoid areas where the water is muddy or where there is a lot of sediment buildup. Avoid stirring up sediment and introducing them into the sample. Note: In the initial monitoring, since speed is a priority, do not use any additives (e.g., hydrochloric acid). Note: Use additives only when indicated (e.g., several days are required to deliver the sample to the analytical laboratory). In this case, add about 1 mL of hydrochloric acid (about 12 mol/L) per 1 L to prevent the adhesion of nuclides to the inner walls of the container. If radioactive iodine is the target, add 80-100 mg of sodium thiosulfate per liter to prevent radioactive iodine from adhering to the inner walls of the container (separate sampling for radioactive iodine and other nuclides is recommended). Note: If tritium or carbon-14 is to be analyzed, do not use additives.	Sampling record form B3 **d**
4	Put the lid on the sample container and wipe off the surrounding area with a paper towel.	
5	Record the time and the circumstances of sampling.	Sampling record form B3 **d**
6	Paste a label with the identification code (printed or written) on the container holding the sample.	Sampling record form B3
7	Seal the lid with vinyl tape and put it in a polyethylene bag (i.e., an inner bag).	
8	Put the sample in a second bag (i.e., an outer bag) and pack it.	
9	Check the packaging, records, and photographs.	Sampling record form B3 **e**

Reference 1: About water sampling equipment

Water sampling may be difficult with a bucket with a string or water dipper. Water sampling equipment, such as a water sampler with a long handle, is also available.

[Water sampler with a long handle]

The following are points to understand and keep in mind when collecting samples.

Things to keep in mind

❑Avoid entering rivers, lakes, or other bodies of water for sampling whenever possible. Consider the possibility of collecting from bridges or the shore. If it is necessary to enter the water, it is strongly recommended to know the radioactivity level of the water near the sampling location in advance, even if it is only approximate. Pay particular attention to the contamination of other samples after sampling, as cross-contamination is likely to occur through wet equipment or body part.

❑When developing an emergency monitoring plan, select a site facilitating quick sampling, considering the access to the sampling location and ease of sampling.

5.5 Agricultural and livestock products

Objectives

To assess the exposure doses of residents in the vicinity, and the like and accumulate a wide range of information necessary to determine the status of radioactive materials or radiation released into the environment, agricultural and livestock products (grains, beans, mushrooms, meat, eggs, dairy products, and the like) will be collected as necessary. The sampling may be conducted to provide a basis for making decisions on implementing protective measures.

Samples can be collected in the field, requested from producers, or purchased at the market. For the sampling method that the monitoring personnel conduct in fields, basically follow the method for sampling green vegetables or refer to the series of environmental radioactivity measuring methods No. 16 “Generic Procedures for Environmental Sampling”. This section shows how to purchase the product at a market and the like.

Required equipment

・Sample containers
・Polyethylene bag
・Vinyl tape
・Rubber gloves
・Paper towels
・Writing utensils

Sampling procedure

1. Sampling

	Procedure	Reference/records
1	Obtain samples of the specified type, quantity, and sampling location, and put them in containers. Note: Obtain samples so that the edible portion is 1 kg (approximate). For specific examples of edible portions, refer to the series of environmental radioactivity measuring methods No. 24, “Preparation of Samples for Gamma-ray Spectrometry in Emergencies.”	Sampling record form B6 **a**
2	Record information about the sample (sample name, sampling location, sampling date, and the like).	Sampling record form B6 **b**
3	Paste a label with the identification code (printed or written) on the container holding the sample.	Sampling record form B6
4	Seal the lid with vinyl tape and put it in a polyethylene bag (i.e., an inner bag).	
5	Put the sample in a second bag (i.e., an outer bag) and pack it.	
6	Check the packaging, records, and transportation conditions.	Sampling record form B6 **c**
7	Samples requiring refrigeration (meat, dairy products, and the like) should be put in cold insulation containers.	

The following are points to understand and keep in mind when obtaining samples.

Things to keep in mind

❑When purchasing samples in the market, indicate the sample type, quantity, sampling location, sampling date, and the like, and make purchases satisfying the requirements.

❑It is also advisable to record the cropping and storage/shipping methods of the crops at the sampling location and the land use in the area.

❑Select crops that are in the shipping season for sampling.

❑Confirming the distribution route with the producer for meat samples is advisable (The information may be obtained at slaughterhouses and the like.).

Environmental sampling procedures	
5.6	**Seafood and algae**

Objectives

If radioactive materials are released into rivers or oceans in emergencies, seafood and algae will be collected as necessary to accumulate extensive information necessary to ascertain the status of radioactive materials or radiation in the ocean. The sampling may be conducted to provide a basis for making decisions on implementing protective measures.

When collecting seafood and algae, it is essential to compare the results with those of normal monitoring, so priority should be given to selecting samples collected in normal monitoring. It is also advisable to investigate in advance what samples can be collected and when.

Since fishing season is limited and fishing rights are often set, obtain seafood and algae by requesting them from fishery cooperatives and other fishery-related parties or by purchasing them at markets and other places.

Required equipment

・Sample containers
・Polyethylene bag
・Vinyl tape
・Rubber gloves
・Paper towels
・Writing utensils

Sampling procedure

1. Sampling

	Procedure	Reference/records
1	Obtain samples of the specified type, quantity, and sampling location, and put them in containers. Note: Obtain samples so that the edible portion is 1 kg (approximate). For specific examples of edible portions, refer to the series of environmental radioactivity measuring methods No. 24, "Preparation of Samples for Gamma-ray Spectrometry in Emergencies."	Sampling record form B7 **a**
2	Record information about the sample (sample name, sampling location, sampling date, and the like).	Sampling record form B7 **b**
3	Paste a label with the identification code (printed or written) on the container holding the sample.	Sampling record form B7
4	Seal the lid with vinyl tape and put it in a polyethylene bag (i.e., an inner bag).	
5	Put the sample in a second bag (i.e., an outer bag) and pack it.	
6	Check the packaging, records, and transportation conditions.	Sampling record form B7 **c**
7	Put the sample in a cold insulation container.	

The following are points to understand and keep in mind when obtaining samples.

Things to keep in mind

❏When requesting fishery personnel to collect samples, it is advisable to consult with them carefully regarding the type, quantity, and sampling location of the samples. In addition, it is necessary to take safety measures for sampling, such as radiation protection for fishery personnel.
❏When purchasing samples in the market, indicate the sample type, quantity, sampling location, sampling date, and the like, and make purchases satisfying the requirements.
❏Determine the obtained amount by considering the ratio of the target parts (edible parts, bones, and the like) to the whole body.
❏Note that the nuclide to be analyzed may determine the target parts.
❏For algae, clarify the condition (fresh, dried, and the like) of the samples obtained.
❏Transport the obtained samples to the analytical laboratory without rinsing.
❏Investigating ecological information (e.g., usual habitat, feeding habits, and the like) for seafood and algae in normal situations is advisable.
❏If the samples targeted for normal monitoring are unavailable, the following points should be considered in selecting samples.

(a) Priority should be given to obtaining edible seafood and algae.
(b) Obtain seafood and algae of a non-migratory species rather than a migratory one (if possible, fish should be selected from local fish. Shellfish and crabs like clams and oysters are better indicators because they are less mobile than fish).
(c) Selecting species of seafood and algae representing the region is desirable.

❏Bivalves may contain sand, so if you ask fishery personnel to obtain them, it is best to obtain them sand-drained using the water (seawater, river water, and the like) from where the shellfish were collected.

Environmental sampling procedures	
5.7	**Sediment**

Objectives

Sediment contamination does not occur immediately after a nuclear accident, so initial monitoring does not target sediment. However, sediment contamination is crucial in some radioactive accidents where radioactive materials can spread into a body of water (ponds, lakes, and the like).

Sampling sediment may reveal contamination not detected by water monitoring alone by evaluating external exposure pathways and detecting possible radionuclide deposition contamination at the shoreline, river or lake shores, river bottom, lake bottom, or sea floor.

Required equipment

❑Equipment common to all sampling (Checklist A1)
❑Equipment for environmental sampling (Checklist A3)

Preparations before departure

	Procedure	Reference/records
1	Receive written instructions.	
2	Prepare the necessary equipment according to checklists A1 and A3.	Checklists A1 and A3
3	Check the operation of equipment (especially communication device and GPS).	
4	Check the sampling location on the map.	
5	Cover equipment to prevent contamination.	3.1 Prevention of equipment contamination
6	Check the operation of electronic personal dosimeters.	
7	Wear appropriate protective equipment (including protective clothing and masks) following the instructions for use. Also, if directed, take stable iodine tablets.	3.2 Protection of monitoring personnel

Sampling procedure

1. Identification of sampling locations

	Procedure	Reference/records
1	Move to the sampling location indicated in the instructions.	
2	Record information (including the address) and take pictures of the sampling location.	Sampling record form B8 **a**
3	Record the latitude and longitude of the sampling location measured by GPS. If not available, find the location, mark it on the map, and record it.	Sampling record form B8 **b**

2. Sampling

	Procedure	Reference/records
1	Measure and record the dose rate near the sampling location with a NaI (Tl) scintillation survey meter or an ionization chamber survey meter.	3.3 Measurement of dose rate Sampling record form

	Procedure	Reference/records
		B8 **c**
2	Using a mud sampler, shovel, and the like, collect the indicated amount of sediment and place it in a container.	
3	Put the lid on the sample container and wipe off the surrounding area with a paper towel.	
4	Record the circumstances of the sampling.	Sampling record form B8 **d**
5	Paste a label with the identification code (printed or written) on the container holding the sample.	Sampling record form B8
6	Seal the lid with vinyl tape and put it in a polyethylene bag (i.e., an inner bag).	
7	Put the sample in a second bag (i.e., an outer bag) and pack it.	
8	Check the packaging, records, and photographs.	Sampling record form B8 **e**

The following are points to understand and keep in mind when collecting samples.

Things to keep in mind

❑Depending on the soil properties of the sediment to be collected and the purpose of the monitoring (to investigate sedimentation history and predict migration rates), samples may have to be collected using special sampling equipment.

❑When sampling in a river, avoid areas where there are large stones or other obstacles disturbing the flow. Select sampling areas where the flow is quiet or slow.

❑If it is necessary to enter the water, it is strongly recommended to know the radioactivity level of the water near the sampling location in advance, even if it is only approximate. Pay particular attention to the contamination of other samples after sampling, as cross-contamination is likely to occur through wet equipment or body part.

❑For details on sediment sampling, refer to the series of environmental radioactivity measuring methods No. 16, “Generic Procedures for Environmental Sampling”.

Checklist

A1 Equipment common to all sampling

Recorded by____ Date:__________

Team name ____ Time:____________

Equipment	Quantity	Yes	No	Remarks
1. For radiation protection				
Electronic personal dosimeter (Measurable range: 0.01mSv to 100mSv inclusive)		☐	☐	
Survey meter for surface contamination measurement (for β-ray and α-ray (related to nuclear fuel facilities)))		☐	☐	
Rubber gloves		☐	☐	
Cotton gloves		☐	☐	
Protective clothing (Tyvek suits and the like)		☐	☐	
Rain gear (raincoat) Disposable raincoats (3 sets per member)		☐	☐	
Warm clothing (as required)		☐	☐	
Protective cap		☐	☐	
Helmet		☐	☐	
Protective shoes (safety shoes, safety shoe-type boots)		☐	☐	
Shoe covers (3 sets per member)		☐	☐	
Socks (cotton work socks)		☐	☐	
Dust-proof mask		☐	☐	
Goggles		☐	☐	
Half-face mask		☐	☐	
Activated carbon filters for protective masks		☐	☐	
Dust filters for protective masks		☐	☐	
Adhesive tape		☐	☐	
Polyethylene bags (for waste: 90L, 20L)		☐	☐	
Scissors *Can also be used to cut tape wound for protection.		☐	☐	
Wet wipes (wipes including alcohol are recommended)		☐	☐	
Stable iodine tablets		☐	☐	
Medical kit		☐	☐	
2. For location confirmation and communication				
GPS, compass		☐	☐	
Digital camera (preferably with GPS logger)		☐	☐	

Equipment	Quantity	Yes	No	Remarks
Map showing sampling locations		☐	☐	
Lighting equipment (flashlights and the like)		☐	☐	
Communication devices (mobile phones, satellite phones, tablet devices, mobile PCs, and the like)		☐	☐	
Spare batteries (for equipment and flashlights)		☐	☐	
Vinyl tape, warning signs		☐	☐	
Flag or tape (indicating that samples are being collected)		☐	☐	
3. For measuring dose rate				
Transportable monitoring posts (as required)		☐	☐	
Car-borne survey system (as required)		☐	☐	
γ-ray survey meter (for low dose rate)		☐	☐	
γ-ray survey meter (for high dose rate)		☐	☐	
Neutron survey meter (REM counter) (as required)		☐	☐	
Spare batteries (for survey meters)		☐	☐	
Stopwatch		☐	☐	
Tool to measure the height (height from the ground to the measuring instrument)		☐	☐	
4. For management record				
Equipment operation manual		☐	☐	
Procedure manual		☐	☐	
Sampling record form		☐	☐	
Memo pad		☐	☐	
Pen (indelible)		☐	☐	
Calculator (as required)		☐	☐	
Sticker for identification code and the like		☐	☐	

Remarks:

Confirmed by______________________

A2 Equipment for air sampling

Recorded by____ Date:___________

Team name ____ Time:__________

Checklist A1: ☐ Checked

Equipment	Quantity	Yes	No	Remarks
1. sampling equipment				
Transportable low-volume air sampler (preferably with both rechargeable batteries and AC)		☐	☐	
Transportable high-volume air sampler (preferably with both rechargeable batteries and AC)		☐	☐	
Filter paper for dust collection (filter paper)		☐	☐	
Tweezers		☐	☐	
Activated carbon cartridge (impregnated with approximately 10% TEDA)		☐	☐	
Polyethylene bags		☐	☐	
Generator (portable gasoline can)		☐	☐	
Power cords		☐	☐	
Stands for transportable air sampler (as required)		☐	☐	
2. For management record				
Operation manual for sampling equipment		☐	☐	

Remarks:

Confirmed by_________________________

A3 Equipment for environmental sampling

Recorded by____ Date:_________

Team name ____ Time:___________

Checklist A1 ☐ Checked

Equipment	Quantity	Yes	No	Remarks
1. Sampling equipment				
Small containers (U-8, U-9, and the like)		☐	☐	
Soil sampler		☐	☐	
Equipment for sampling sediment (lake sediment, sea sediment)		☐	☐	
Polyethylene bottles for water sampling (2L-5L)		☐	☐	
Wooden mallet or hammer (required when using soil sampler)		☐	☐	
Sickle		☐	☐	
Wood (necessary when using soil sampler)		☐	☐	
Grafting trowel (for disposable use)		☐	☐	
Polyethylene bags (small, medium)		☐	☐	
Vinyl tape		☐	☐	
Paper towel		☐	☐	
Deionized water (for cleaning)		☐	☐	
Additives		☐	☐	
Wet wipes (alcohol, and the like)		☐	☐	
Disposable rubber gloves		☐	☐	
Scissors		☐	☐	
Knife		☐	☐	
Cold insulation containers (as required)		☐	☐	
2. For management record				
Operation manual for sampling equipment		☐	☐	

Remarks:

Confirmed by______________________

Sampling record form

Sampling record form	
B1	**Air**

Date: / /　　Start time: Hour Minute

Weather (on the day):　　Weather (on the day before):

Team leader:　　Member:

Sampling location information

a	Sampling location (Location name, address, and the like)			
b	GPS	N (latitude)	E (longitude)	
b	Fallen snow	☐ Present ☐ Absent	Depth of snow	Approx. cm

Dose rate at the sampling location

c	Type of equipment	☐ NaI(Tl) scintillation survey meter ☐ Ionization chamber survey meter ☐ Neutron survey meter ☐ Other:
c	Model name (Serial no.)	
c	Time constant	sec. *Elapsed time to measurement:
c	Detector direction	

c	Dose rate (☐μSv / h ☐μGy / h)
	1 m above the ground (at waist height)
1	
2	
3	
4	
5	
average	

Sampling

Hot staff (personnel to actually collect samples): ______________________

Cold staff (personnel not to actually collect samples): ______________________

d	Sampling equipment	☐ High-volume air sampler ☐ Low-volume air sampler ☐ Other: ______________
d	Type of adsorbent	☐ Filter paper ______ ☐ Activated carbon cartridges: ______ ☐ Other: ______________
d	Sampling start time	
d	Flow rate at the start	[L/min]
d	Sampling end time	
d	Flow rate at the end	[L/min]
d	Suction time	[min]
d	Average flow rate	[L/min] *For equipment without an integrated flow volume display, the average flow rate is the average value of the flow rate at the start and the flow rate at the end.
d	Integrated flow volume	[m^3] * For equipment without an integrated flow volume indicator, calculate by "integrated flow volume = average flow rate [L/min] x suction time [min]/1000".
d	Remarks	

Confirmation of samples and records

e	Sample packaging	☐ Inner bag OK ☐ Outer bag OK ☐ Sealing OK
e	Omission	☐ None
e	Photo	☐ Entire view ☐ Sampling location ☐ Sampling conditions, close view

Recorded by ______________ Ending time: Hour Minute

Sample identification code	
Sample classification	☐ Treat as a highly concentrated sample
Receipt	Date/time: / / Received by ______

Sampling record form	
B2	**Soil**

Date: / / Start time: Hour Minute

Weather (on the day): Weather (on the day before):

Team leader: Member:

Sampling location information

a	Location name, address, and the like	[Incidental Information] ☐ Monitoring station site ☐ Location of air monitors and the like	☐ Electronic dosimeter installation site ☐ Other:	
b	GPS	N (latitude)	E (longitude)	
b	Fallen snow	☐ Present ☐ Absent	Depth of snow	Approx. cm

Dose rate at the sampling location

c	Type of equipment	☐ NaI(Tl) scintillation survey meter ☐ Ionization chamber survey meter ☐ Neutron survey meter ☐ Other:
c	Model name (Serial no.)	
c	Time constant	sec. *Elapsed time to measurement:
c	Detector direction	

c	Dose rate (☐μSv / h ☐μGy / h)	
	1 m above the ground (at waist height)	5 cm above the ground
1		
2		
3		
4		
5		
average		

Sampling

Hot staff (personnel to actually collect samples): ______________________

Cold staff (personnel not to actually collect samples): ______________________

d	Geology and the like	☐ Bare ground ☐ Field ☐ Meadow ☐ Lawn ☐ Sandy soil ☐ Forest ☐ Mountain ☐ Peat or humus area ☐ Other:
d	Plant	☐ Absent ☐ Present (Plant type: ____________ [Plant sampling conditions (sampling area and the like)]
d	Fallen snow	☐ Absent ☐ Present [Snow sampling conditions (sampling area and the like)]
d	Sampling area (soil)	［m］ x ［m］
d	Number of sampling locations	☐ One location ☐ Multiple locations (number of locations: ________)
d	Sampling device	☐ Small container (U-8) ☐ Small container (U-9) ☐ Other container: ____________ (surface area: ____________) ☐ Soil sampler (diameter:) ☐ Other soil samplers: (surface area:)
d	Measuring container	☐ Directly measurement by container (empty container weight g)
d	Sampling depth	cm
d	Remarks	

Confirmation of samples and records

e	Sample packaging	☐ Inner bag OK ☐ Outer bag OK ☐ Sealing OK
e	Omission	☐ None
e	Photo	☐ Entire view ☐ Sampling location ☐ Sampling conditions, close view

Recorded by ______________________ Ending time: Hour Minute

Sample identification code	
	Note: If there are supplementary samples (plants, snow, and the like) linked with the soil, enter the identification code of such supplementary samples (The sampling record of ancillary samples is to be done separately.) ☐ Plants: ____________ ☐ Snow: ____________ ☐ Other (____________)
Sample classification	☐ Treat as a highly concentrated sample
Receipt	Date/time: / / Received by ____________

Sampling record form	
B3	**Drinking water** **Precipitation (rain water)・Other water sample**

Date: / /

Start time: Hour Minute

Weather (on the day):

Weather (on the day before):

Team leader:

Member:

Sampling location information

a	Location name, address, and the like	Status when water sampling: ☐ During release ☐ Not during release		
b	GPS	N (latitude)	E (longitude)	
b	Fallen snow	☐ Present ☐ Absent	Depth of snow	Approx. cm

Dose rate at the sampling location

c	Type of equipment	☐ NaI(Tl) scintillation survey meter ☐ Ionization chamber survey meter ☐ Neutron survey meter ☐ Other:
c	Model name (Serial no.)	
c	Time constant	sec. *Elapsed time to measurement:
c	Detector direction	

c	Dose rate (☐μSv / h ☐μGy / h) 1 m above the ground (at waist height)
1	
2	
3	
4	
5	
average	

Sampling

Hot staff (personnel to actually collect samples): ______________________

Cold staff (personnel not to actually collect samples): ______________________

☐ Drinking water

d	Classification	Water supply (☐indoor Faucet ☐outdoor faucet) ☐well water ☐ Other: ____________
d	Source of water	☐ River water ☐ Groundwater ☐ Well water ☐Other ____________
d	Elasped time of water discharge before sampling	[min]

☐ Precipitation (rainwater)

d	Sampling start date and time	
d	Sampling end date and time	
d	Sampling area	[m^2]

☐ Other Water Sample

d	Classification	☐ River water ☐ Lake water ☐ Pond water ☐ Swamp water ☐ Seawater ☐ Other: ____________
d	Name of the water system	

d	Additive	☐ No ☐ Yes (Additive type: ____________)
d	Dose of samples	☐ Lowly concentrated sample ☐ Highly concentrated sample

Confirmation of samples and records

e	Sample packaging	☐ Inner bag OK ☐ Outer bag OK ☐ Sealing OK
e	Omission	☐ None
e	Photo	☐ Entire view ☐ Sampling location ☐ Sampling conditions, close view

Recorded by ______________________ Ending time: ______ Hour ______ Minute

Sample identification code	
	☐ For radioactive iodine

Sample classification	☐ Treat as a highly concentrated sample
Receipt	Date/time: _______ / _______ / _______ Received by ______________

Sampling record form	
B4	**Milk**

Date: / /　　　Start time: Hour Minute
Weather (on the day):　　　Weather (on the day before):
Team leader:　　　Member:

Sampling location information

a	Location name, address , and the like	Producer's name: Producer's address:		
b	GPS	N (latitude)	E (longitude)	
b	Fallen snow	☐ Present ☐ Absent	Depth of snow	Approx. cm

Dose rate at the sampling location

c	Type of equipment	☐ NaI(Tl) scintillation survey meter ☐ Ionization chamber survey meter ☐ Neutron survey meter ☐ Other:
c	Model name (Serial no.)	
c	Time constant	sec. *Elapsed time to measurement:
c	Detector direction	

c	Dose rate (☐μSv / h ☐μGy / h)
	1 m above the ground (at waist height)
1	
2	
3	
4	
5	
average	

Sampling

Hot staff (personnel to actually collect samples): ______________________

Cold staff (personnel not to actually collect samples): ________________

d	Subject of analysis	☐ For radioactive iodine ☐ Other: ________
d	Classification	☐ Cow's milk ☐ Goat's milk ☐ Other: ____________
d	Milking date	Note: Enter if different from the sampling date.
d	Milking conditions	☐ Milk from one cow ☐ Mixed milk
d	Additive	☐ No ☐ Yes (Additive type: ____________)
d	Feed type	☐ Pasture ☐ Storage feed ☐ Other: ____________
d	Fodder spot	GPS: N (latitude) E (longitude)
d	Remarks	

Confirmation of samples and records

e	Sample packaging	☐ Inner bag OK ☐ Outer bag OK ☐ Sealing OK
e	Omission	☐ None
e	Photo	☐ Entire view ☐ Sampling location ☐ Sampling conditions, close view

Recorded by ____________________ Ending time: Hour Minute

Sample identification code	
Sample classification	☐ Treat as a highly concentrated sample
Receipt	Date/time: / / Received by

Sampling record form	
B5	**Vegetables**

Date: / /　　Start time: Hour Minute
Weather (on the day):　　Weather (on the day before):
Team leader:　　Member:

Sampling location information

a	Location name, address, and the like	Producer's name: Producer's address:		
b	GPS	N (latitude) E (longitude)		
b	Fallen snow	☐ Present ☐ Absent	Depth of snow	Approx. cm

Dose rate at the sampling location

c	Type of equipment	☐ NaI (Tl) scintillation survey meter ☐ Ionization chamber survey meter ☐ Neutron survey meter ☐ Other:
c	Model name (Serial no.)	
c	Time constant	sec. *Elapsed time to measurement:
c	Detector direction	

c	Dose rate (☐μSv / h ☐μGy / h)
	1 m above the ground (at waist height)
1	
2	
3	
4	
5	
average	

Sampling

Hot staff (personnel to actually collect samples): ____________________

Cold staff (personnel not to actually collect samples): ____________________

d	Sample type	
d	Sampling area	cm〕 x 〔cm〕
d	Sampled part	☐ Whole ☐ Partially: ________
d	Cultivation conditions	
d	Remarks	

Confirmation of samples and records

e	Sample packaging	☐ Inner bag OK ☐ Outer bag OK ☐ Sealing OK
e	Omission	☐ None
e	Photo	☐ Entire view ☐ Sampling location ☐ Sampling conditions, close view

Recorded by ____________________ Ending time: ____ Hour ____ Minute

Sample identification code	
Sample classification	☐ Treat as a highly concentrated sample
Receipt	Date/time: / / Received by ________

Sampling record form	
B6	**Agricultural and livestock products**

Date: / /

Weather (on the day):

Team leader: Member:

Sampling location information

a	Location name, address, and the like	The name of the store where it was purchased and the like: Address: Note: Location of production, markets, and the like.

Sampling

b	Sample name	
b	Sample form	☐ Solid ☐ Liquid ☐ Powder ☐ Other:
b	Sampling date Manufacturing date	☐ Same as purchase date ☐ Different from the purchase date:
b	Producing area	
b	Cultivation conditions Manufacturing conditions	
b	Sample weight	kg
b	Remarks	

Confirmation of samples and records

c	Sample packaging	☐ Inner bag OK ☐ Outer bag OK ☐ Sealing OK
c	Omission	☐ None
c	Transportation conditions	☐ None in particular ☐ Refrigerated ☐ Frozen ☐ Other:

Recorded by Ending time: Hour Minute

Sample identification code	
Sample classification	☐ Treat as a highly concentrated sample
Receipt	Date/time: / / Received by

Sampling record form	
B7	**Seafood and algae**

Date: / /

Weather (on the day):

Team leader: Member:

Sampling location information

a	Location name, address, and the like	The name of the store where it was purchased and the like: Address: Note: Location of production, markets, and the like.

Sampling

b	Sample name	
b	Sampling date	☐ Same as purchase date ☐ Different from the date of purchase:
b	Sampling location	
b	Sample weight	kg
b	Algae condition	☐ Raw ☐ Dried ☐ Other:
b	Remarks	

Confirmation of samples and records

c	Sample packaging	☐ Inner bag OK ☐ Outer bag OK ☐ Sealing OK
c	Omission	☐ None
c	Transportation conditions	☐ None in particular ☐ Refrigerated ☐ Frozen ☐ Other:

Recorded by Ending time: Hour Minute

Sample identification code	
Sample classification	☐ Treat as a highly concentrated sample
Receipt	Date/time: / / Received by

Sampling record form	
B8	**Sediment**

Date: / /　　　Start time: Hour Minute

Weather (on the day):　　　Weather (on the day before):

Team leader:　　　Member:

Sampling location information

a	Location name			
b	GPS	N (latitude) E (longitude)		
b	Fallen snow	☐ Present ☐ Absent	Depth of snow	Approx. cm

Dose rate at the sampling location

c	Type of equipment	☐ NaI (Tl) scintillation survey meter ☐ Ionization chamber survey meter ☐ Neutron survey meter ☐ Other:
c	Model name (Serial no.)	
c	Time constant	sec. *Elapsed time to measurement:
c	Detector direction	

c	Dose rate (☐μSv / h ☐μGy / h)
	1 m above the ground (at waist height)
1	
2	
3	
4	
5	
average	

Sampling

Hot staff (personnel to actually collect samples): ____________________
Cold staff (personnel not to actually collect samples): ____________________

d	Classification	☐ River sediment ☐ Lake sediment ☐ Pond sediment ☐ Swamp sediment ☐ Sea sediment ☐ Other: ______
d	Name of the water system	
d	Number of sampling locations	☐ One location Multiple locations:(number of locations: ________)
d	Sampling device	
d	Sampling depth	Depth of water ☐ cm ☐ m
d	Sampling method	
d	Remarks	

Confirmation of samples and records

e	Sample packaging	☐ Inner bag OK ☐ Outer bag OK ☐ Sealing OK
e	Omission	☐ None
e	Photo	☐ Entire view ☐ Sampling location ☐ Sampling conditions, close view

Recorded by ____________________ Ending time: ______ Hour ______ Minute

Sample identification code	
Sample classification	☐ Treat as a highly concentrated sample
Receipt	Date/time: ___ / ___ / ___ Received by __________

Records of radiation exposure and contamination measurements

*Each EMC may have its own exposure management forms. In such cases, check them.

C1 External exposure dose and surface contamination measurement records

Handle with Care

Date and time of measurement: / /

Measured by Recorded by

Personnel Information

Name		Organization	
Gender	☐ Male ☐ Female	Age	
Team name			
Period of activity			
Activities	☐ Driver ☐ Hot staff ☐ Cold staff ☐ Other		
Dose control Standards			

External exposure dose (measured by electronic personal dosimeter)

Model name (Serial no.)	☐ Dosimeter reset OK			
	Date of reading	Time	Readings (μSv)	Reading place
At the start of the activity				
Active *Fill in if checked during the activity.				
At the end of the activity				
☐ Within the dose control standards	☐ Exceeding the dose control standards			

Surface contamination measurement results

Guideline for contamination	cpm
Model name (Serial no.)	
Result	☐ No contamination ☐ Contaminated (above the guideline for contamination) ⇒ **Remeasurement after decontamination** ☐ Parietal area ☐ Face (nasal area) ☐ Shoulder ☐ Arm ☐ Palm of the hand ☐ Back of the hand ☐ Chest ☐ Back ☐ Abdomen ☐ Waist ☐ Buttocks ☐ Leg ☐ Clothing ☐ Shoe sole

Stable iodine tablet use record

Date	Time	Amount used	Remarks	Initials (prescription)

Record of decontamination (If the guideline for contamination is exceeded in the surface contamination inspection)

Decontami-nation method	☐ Undressing ☐ Wiping ☐ Other ________
Contamination inspection results after decontamination	☐ No contamination ☐ Contamination (above guideline for contamination) ⇒ **Remeasurement after decontamination** ☐ Parietal area ☐ Face (nasal area) ☐ Shoulder ☐ Arm ☐ Palm of the hand ☐ Back of the hand ☐ Chest ☐ Back ☐ Abdomen ☐ Waist ☐ Buttocks ☐ Leg ☐ Clothing ☐ Shoe sole

Decontami-nation method	☐ Undressing ☐ Wiping ☐ Other ____
Contamination inspection results after decontamination	☐ No contamination ☐ Contamination (above the guideline for contamination) ⇒ **Remeasurement after decontamination** ☐ Parietal area ☐ Face (nasal area) ☐ Shoulder ☐ Arms ☐ Palm of the hand ☐ Back of the hand ☐ Chest ☐ Back ☐ Abdomen ☐ Waist ☐ Buttocks ☐ Leg ☐ Clothing ☐ Shoe soles

*If the contamination exceeds the guideline for contamination even after decontamination, take action as directed by the EMC Planning and Coordination Group.

Explanation

Explanation A - Effects of non-uniform distribution of radioactive materials in a measuring container on γ-ray spectrometry

A.1 Introduction

γ-ray spectrometry with a germanium semiconductor detector is an effective method for quickly determining the radioactivity concentration in an emergency because it can measure relatively large sample volumes non-destructively without chemical separation and purification. Quantifying radionuclides using this method requires filling the sample uniformly into a measuring container of a fixed shape. However, sampling in an emergency makes uniformly filling the measuring container difficult, often forcing measurements of radionuclides non-uniformly distributed in the container.

When measuring a volume sample by γ-ray spectrometry for quantifying radionuclides, uniform distribution of target nuclides in the measuring container is a prerequisite. When measuring a sample with a non-uniform distribution of radionuclides in the container, the change in the geometric positional relationship between the sample and the detector (hereinafter referred to as "geometry") changes the peak efficiency to a value different from the one obtained during calibration, affecting the analysis results. The degree of change in peak efficiency depends on the sample's radionuclides distribution and the measurement's geometry. It is a factor that contributes significantly to the uncertainty of the analysis results.

The change in peak efficiency with radionuclides non-uniformly distributed in the measuring container is pronounced when measuring the volume sample in a geometry contacting closely to the detector (e.g., in close contact with the detector end cap). It is particularly affected by non-uniform distribution in the vertical (coaxial) direction relative to the detector*.

This study evaluated the uncertainty of the measurement of a sample with radionuclides non-uniformly distributed inside a U-8 container with a germanium semiconductor detector using Monte Carlo simulations.

*The series of environmental radioactivity measuring methods No.7, "Gamma-ray Spectrometry using Germanium Semiconductor Detector" Document 2, Effect of non-uniform distribution of samples in measurement container (example of U-8 container)

A.2 Evaluation method

When the γ-ray spectrum of a sample is measured, and the count rate N of the peak caused by the γ-ray of the target nuclide is obtained, the radioactivity value of the sample is given by the following formula.

$$A = \frac{N}{I_\gamma \cdot \varepsilon} \cdots\cdots (1)$$

A: Radioactivity value per measuring sample (Bq)
N: Peak counting rate (cps)
I_γ: γ-ray emission probability
ε: Peak efficiency

The non-uniform distribution of radionuclides in the measuring sample changes the geometry from that of the peak efficiency calibration using a standard source, which varies the peak efficiency value. If the peak efficiency changes due to non-uniform distribution, the observed peak counting rate will change, affecting the calculated radioactivity value.

Let ε be the peak efficiency under the uniform distribution, A the true value of radioactivity, ε' the peak efficiency changed by the non-uniform distribution, N' the peak counting rate obtained when measured under the uniform distribution, and A' the calculated value of radioactivity.

$$N' = A \cdot I_\gamma \cdot \varepsilon' \quad \cdots\cdots(2)$$

$$A' = \frac{N'}{I_\gamma \cdot \varepsilon} = \frac{A \cdot I_\gamma \cdot \varepsilon'}{I_\gamma \cdot \varepsilon} = \frac{A \cdot \varepsilon'}{\varepsilon} \cdots\cdots(3)$$

From equation (3), the ratio (relative value) of the radioactivity value A' to the true value of radioactivity A obtained under the non-uniformly distributed condition is given as follows:

$$\frac{A'}{A} = \frac{\varepsilon'}{\varepsilon} \cdots\cdots(4)$$

In this study, we attempted to determine the range that the relative value of the calculated radioactivity value can take. We obtained the peak efficiency ε', which changes with the non-uniform distribution of radionuclides in the sample, using Monte Carlo simulation to calculate the uncertainty from the width of this range.

A.3 Examination

The conditions used for the Monte Carlo simulations were as follows.

Simulation code	EGS5（Electron Gamma Shower version 5）
Germanium semiconductor detector	p-type coaxial, 31% relative efficiency
Crystal size	50.47 mm(h) × 52.2 mm(Φ)
Measuring container	Polypropylene cylindrical container (U-8 container) (50 mmΦ)
Radionuclide	Cs-137 (γ-ray energy: 662 keV)
Sample material	soil
Composition	O(49.0 %), Si(36.5 %), Al(7.1 %), Fe(4.0 %), C(2.0 %), K(1.4 %)
Density	1.55 g/cm^3
Sample filling height (cm)	1, 2, 3, 4, 5
Distance between the detector and measuring sample (cm)	0, 5, 10, 15, 20, 25

The U-8 container was placed at a distance of h (cm) in the coaxial direction from the end cap of the germanium semiconductor detector (Figure A-1). The distribution conditions of each radionuclide with the maximum and minimum peak efficiencies were determined by Monte Carlo simulation for cases A and B in Figure A-2 and the uniform distribution condition: A (when localized at the center of the bottom surface of the measuring container) and B (when localized at a point at the periphery of the top surface of the measuring sample, farthest from the detector). Next, the range of values that the peak efficiency can take was converted to the range of radioactivity values (relative values) of the measuring sample. Then the standard deviation assuming a rectangular distribution is calculated to obtain the standard uncertainty of the radioactivity values (relative standard uncertainty). (The distribution of the actual peak efficiency (ε' in A. 2) without processing for uniform filling is not a rectangular distribution but a convex distribution with a peak at the center. Thus, the actual standard uncertainties are smaller than those given here.)

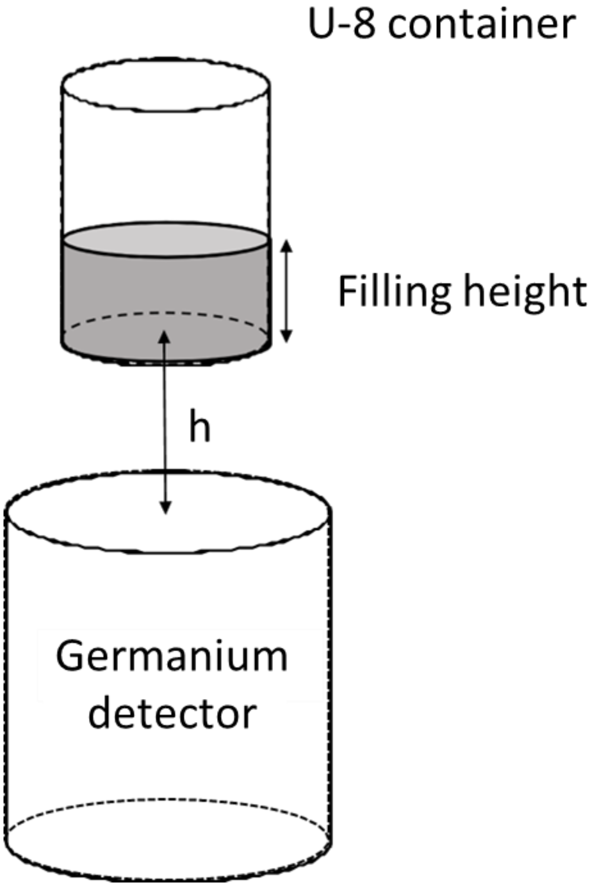
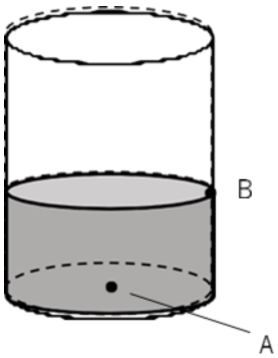


Fig. A-1 Arrangement of detector and sample



A: Localized at the center of the bottom surface of the measuring container (maximum peak efficiency)

B: Localized at a point at the periphery of the top surface of the sample (minimum peak efficiency)

Fig. A-2 Conditions for non-uniform distribution of radionuclides with maximum and minimum peak efficiencies in the measuring container

A.4 Results and discussion

Figure A-3 shows the change in uncertainty (relative standard uncertainty) of the Cs-137 radioactivity value when measuring a sample filled to a height of 1 to 5 cm in a U-8 container at different distances from the detector end cap.

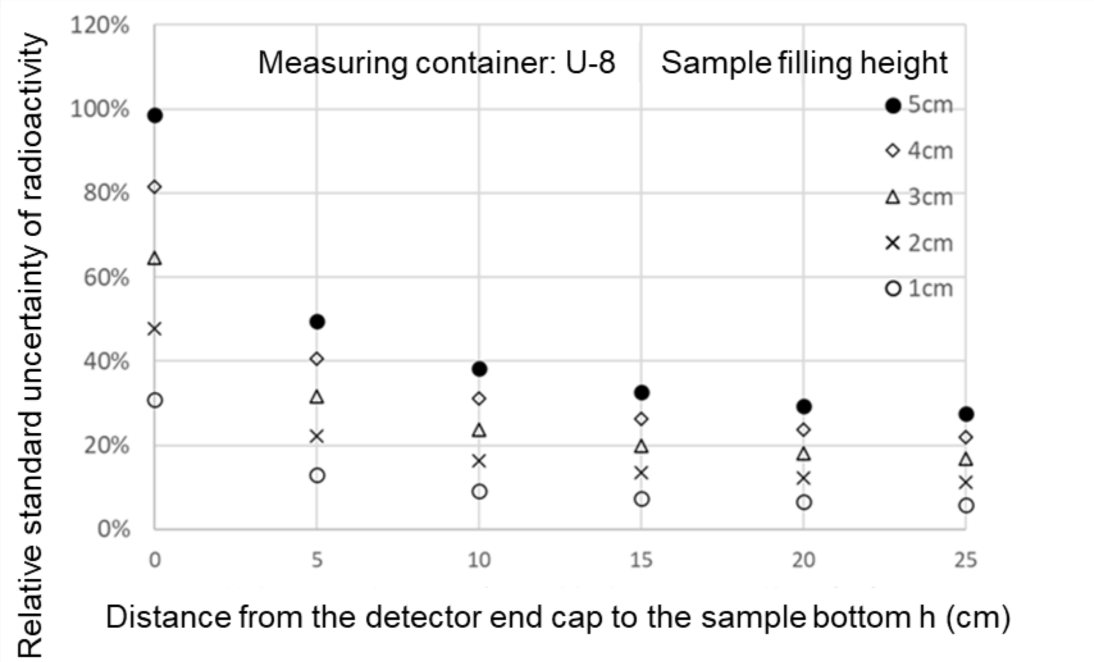


Fig. A-3 Measuring conditions vs. uncertainties

The uncertainty of the radioactivity value tended to increase with the filling height of the measuring sample and decrease with the distance from the detector. The effect of measuring a sample with a considerable filling height in a geometry contacting closely to the detector is the largest, reaching an uncertainty of almost 100 % when measuring a sample with a filling height of 5 cm in a geometry contacting closely to the detector end cap.

On the other hand, more distance from the detector to the sample relatively reduces the influence of changes in the position of radionuclides in the sample on the positional relationship with the detector, thus narrowing the range over which the peak efficiency varies and reducing uncertainty. Depending on the filling height of the measuring sample, a distance of 10 cm from the detector can also halve the uncertainty compared to a measurement made in close contact with the detector end cap.

Reducing the filling height of the measuring sample also reduces the uncertainty significantly. This is because changes in peak efficiency are sensitive to changes in vertical (axial) geometry relative to the detector. Narrowing the range of vertical variation (i.e., using a “thin” sample) reduces the range over which the peak efficiency changes, thus reducing the uncertainty.

A.5 Conclusion

In γ-ray spectrometry, uniform distribution of radionuclides in the measuring container is a prerequisite. Thus, samples should, in principle, be filled into containers uniformly. However, if the distribution in the measuring sample is unavoidably non-uniform, the following method effectively reduces the uncertainty caused by the non-uniform distribution.

a) Separate the detector from the measuring sample.
b) Reduce the filling height of the measuring sample.

In emergency measurements, samples with high radionuclide concentrations and significant dead time are expected. Therefore, measuring samples at a distance effectively reduces the detector's dead time and makes the measurement conditions appropriate. For an emergency, determining the efficiency of measuring at a long distance in advance is necessary.

However, since the above countermeasures may require a long measurement time for samples with low radionuclide concentrations, appropriately selecting the measurement conditions is desirable, corresponding to an acceptable uncertainty depending on the situation of the measuring sample.

Explanation B - Estimation of sampling depth sufficient for inventory estimation taking into account the depth profile of Cs-137

Radioactive materials released into the air due to the accident at the TEPCO's Fukushima Daiichi Nuclear Power Plant were deposited on the ground surface due to rainfall and other factors while diffusing over a wide area. The investigation of the vertical transmigration of radioactive cesium in the soil proceeded with the scraper plate method. This investigation was conducted as part of the project to consolidate distribution data of radioactive materials in the depth distribution survey of radioactive cesium in the soil following the accident at the TEPCO's Fukushima Daiichi Nuclear Power Station.

The depth distribution survey conducted in the first survey after the accident [1)] in FY2011 found the highest Cs-137 values, all within 1 cm from the surface, including vegetation and litter layer, in forests, paddy fields, and grasslands. In contrast, the depth distribution survey [2)] conducted in FY2013 found the highest Cs-137 values distributed from the surface to about 2 cm, and the vertical transmigration was generally similar (Figure B-1). However, the distribution trend and speed varied depending on the land category.

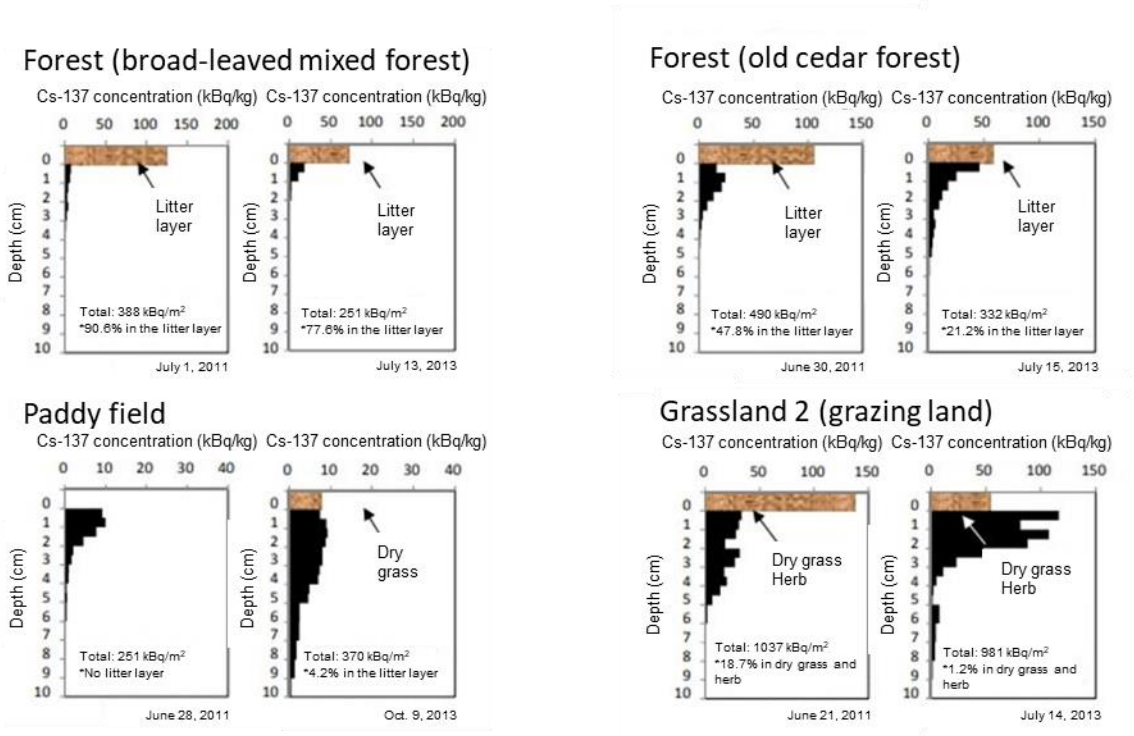


Figure B-1 Comparison of the depth distribution of Cs-137 in each land category (environmental condition) over time

The primary purpose of soil sampling during initial emergency monitoring is to confirm the spread of radioactive materials deposited on the ground and to determine their radionuclide composition. Therefore, a soil sampling depth of about 2 cm is sufficient to fulfill the objective. However, careful attention is necessary to treat vegetation and litter layers immediately above the sampled soil. In this regard, the first survey "revealed that up to 94% of the total accumulation of radioactive cesium is present in vegetation (agricultural land and grassland) and litter (forest) layers". [1)] Therefore, instead of sampling only the soil after removing the vegetation and litter layer and exposing the ground surface, the vegetation and litter layer directly above the soil should be sampled for an area similar to the area of soil sampled and measured separately to supplement the sedimentation volume. If there is a small amount of vegetation (weeds), such as bare ground, it may be collected as is with the soil.

The percentage of radioactive cesium present at each depth is essential in order to determine the soil sampling depth sufficient to obtain the total accumulation of radioactive cesium. Figure B-2 shows the concentration and percentage of radioactive cesium present at each depth in paddy fields, fields, forests, and orchards as a result of the first round of surveys. [1]. To evaluate the total accumulation the sampling depth required to ensure the presence of 90% of the accumulated amount is 5 cm below the surface.

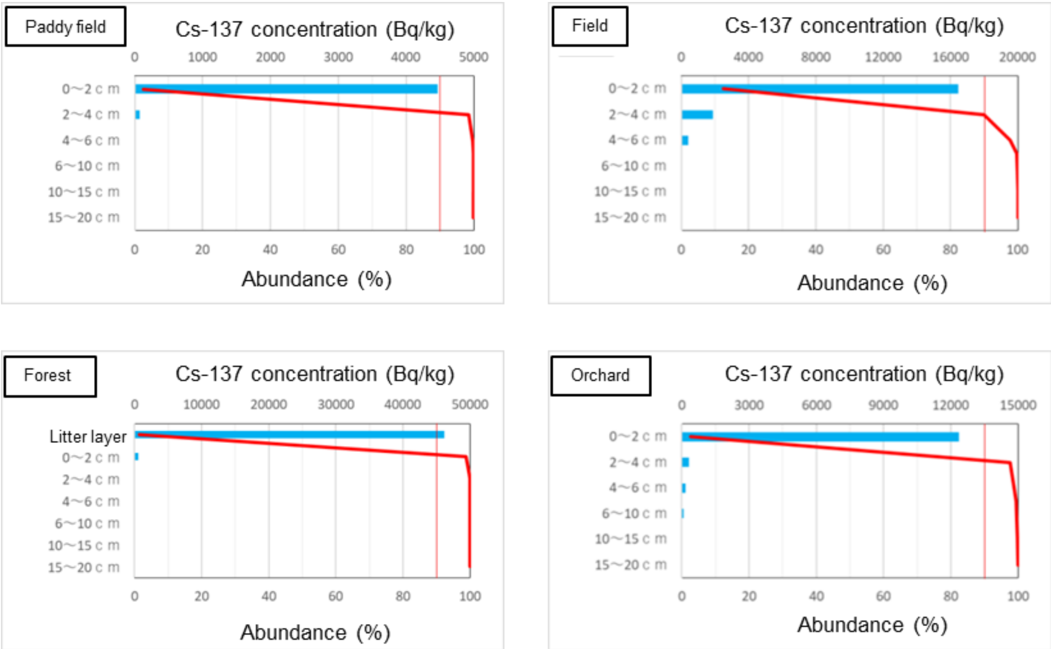


Figure B-2 Depth distribution and abundance curve of Cs-137 in uncultivated land

Distribution surveys after initial monitoring should increase the number of sampling points to improve the level of representation. In the mid-term and restoration phases, in addition to increasing the number of sampling points, methods to increase the sampling area are also effective at improving accuracy. Furthermore, increasing the sampling depth can accommodate vertical transmigration.

<u>Reference</u>

1) 文部科学省　原子力災害対策支援本部,農林水産省　農林水産技術会議事;東京電力株式会社福島第一原子力発電所事故に伴う放出された放射性物質の分布状況等に関する調査研究結果,平成24年3月

2) 日本原子力研究開発機構;「土壌に蓄積した放射性セシウムの移行状況調査」,平成25年度東京電力（株）福島第一原子力発電所事故に伴う放射性物質の長期的影響把握手法の確立事業　成果報告書,part2 105-139,平成26年3月

Explanation C - Number of sampling points and reliability in soil sampling

The confidence interval is a vital reliability index in evaluating the sample's representation level. For the same confidence level, the confidence interval is generally wider for the smaller number of sampling points and narrower for the more sampling points.

C.1 Soil sampling in fallout surveys

Yamagata [1] showed the relationship between the width of the confidence interval by an arbitrary confidence level and the number of sampling points for the objective component (Sr90 fallout) in a particular area of soil (Figure C-1). For soil sampling in fallout surveys, these results enable the estimation of the number of sampling points needed to achieve the desired confidence level.

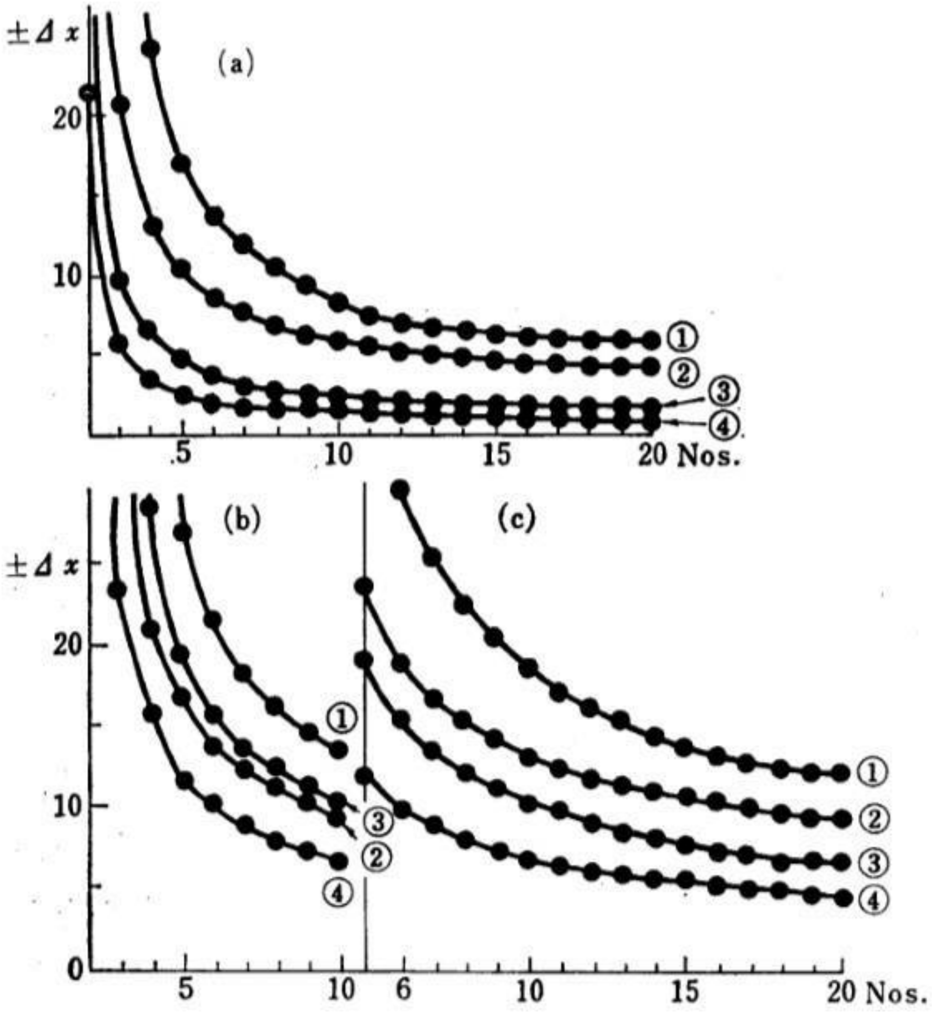


Figure C-1 Number of soil sampling points and width of confidence intervals

(a) Paddy field, A=Akita (mean concentration 71.3), T=Tokyo (mean concentration 22.8), (b) Field, A(71.4), T(37.5), (c) Uncultivated land, A(76.7), T(38.3), ① A (confidence level 99%), ② A (95%), ③ T (99%), ④ T (95%) Vertical axis: width of confidence interval (Ci/m^2) Horizontal axis: Number of points sampled

C.2 Soil sampling during a nuclear disaster accident

IAEA TECHNICAL REPORTS SERIES No. 486 (2019)[2] introduces a theory for determining the minimum number of sampling points in soil sampling from an acceptable error rate based on the findings of the Chernobyl accident by Khomutinin et al.

The conditions for soil sampling are as follows.

- The same contamination status throughout the site of soil sampling.
- The site area is more than $0.0054m^2$
- The sampler used for sampling is a cylinder type with a diameter of 3.7 cm and a height of 30 cm.
- 95% confidence level of measurement error within a 10% error rate

Under these conditions, the following equation for determining the minimum number of sampling points from the acceptable error rate is presented [3], and Figure C-2 shows the relationship between them for p=95%.

$$n \geq \left\{\frac{U(p) \cdot \sigma_{ln}}{\ln(1+\delta)}\right\}^2$$

n : Number of sampling points
U(p) : Upper bound of the confidence interval for confidence level p in a standard normal distribution
σln : Standard deviation by the logarithm of the concentration of Cs-137 in samples collected at each sampling point
δ : Error rate (1/2 of the width of the confidence interval of the confidence level p of the true value of radionuclide concentration divided by the mean value of radionuclide concentration)

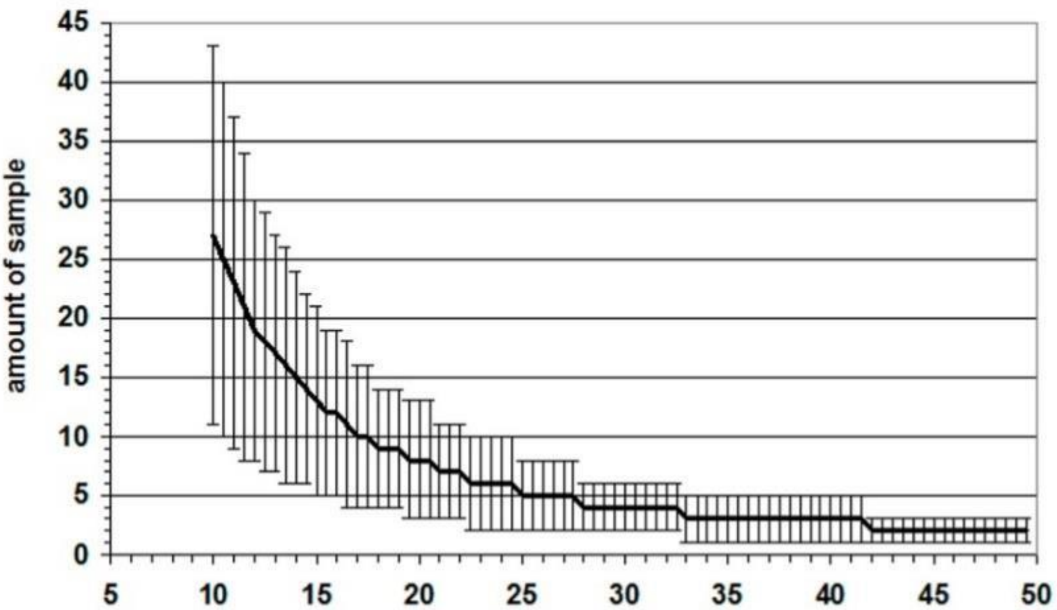


Figure C-2 Error rate vs. minimum number of sampling points required

The minimum number of sampling points increases when the error rate reduces, resulting in more significant statistical variability. Conversely, the minimum number of sampling points reduces when the error rate increases, resulting in less statistical variability.

Reference

1) 山縣登，(1973). 4.サンプリングの信頼度について. *Japan Analyst*, 22, 1402-1411.

2) Barnekow, U., et al. (2019). Guidelines on soil and vegetation sampling for radiological monitoring. *International Atomic Energy Agency Technical Reports Series*, 486, 39-40.

3) Khomutinin, Y.V., Kashparov, V.A., & Zhebrovska, K. I. (2004). Sampling optimization when radioecological monitoring, *Ukraine Institute for Agricultural Radiology*, Kiev 137,16, ISBN966-646-034-3

Reference document

Reference A - Additives for the preservation of water samples

Since rapidity is a priority in the initial emergency monitoring, additives to preserve the sample should not be used when collecting a water sample, in principle. If it takes several days from sampling to analysis, or if it is necessary to store the sample after measurement, some measures, such as the use of additives, are required to preserve the sample. An example of the preservation methods for water samples, as described in MARLAP (Multi-Agency Radiological Laboratory Analytical Protocols, 2004, Chapter 10), is given in Table A-1.

Table A-1 Preservation of water samples

Preservation method	Advantage	Disadvantage
Acidification of samples	･This is the method of choice to preserve most types of water samples. ･It keeps many radionuclides in solution and minimizes their possibility of being removed from the solution by chemical or physical adsorption or ion exchange.	･If tritium is the analyte, do not add acid. The addition of acid does not directly affect tritium but may affect the ability to make liquid scintillation measurements. ･If carbon 14 is the analyte, do not add acid. Adding acid to a sample containing carbon 14 produces $^{14}CO_2$, resulting in the loss of carbon 14 from the sample.
Addition of nitric acid	･This lowers the pH of the solution to prevent metal from adhering to the container walls.	･It is a strong oxidizer and can react with organic compounds. ･Tritium is preferentially separated as hydrogen ions from the acid. ･Carbon 14 can be lost as $^{14}CO_2$.
Addition of hydrochloric acid	･This lowers the pH of the solution to prevent metal from adhering to the container walls. ･Chlorides strongly bind to iron and uranium to form anion complexes.	It may corrode the stainless steel sample dish for gross β/ gross α measurement.
Addition of sulfite	･Converting volatile iodine (I_2) to non-volatile iodine (I^-) creates a reductive environment that prevents the volatilization of iodine. ･Sodium hydrogen sulfite ($NaHSO_3$), sodium thiosulfate ($Na_2S_2O_3$), or sodium metabisulfite (sodium pyrosulfite) ($Na_2S_2O_5$) are used.	･Using acid as a preservative for analyzing other radionuclides would cause the reducing agent to lose its efficacy. →Samples for iodine analysis should be collected and stored in separate containers. ･The reducing environment created by sulfite preservatives can reduce iron, uranium, and other easily reduced elements to form inert compounds. It has a negative impact on radiochemistry requiring chemical separation.
Addition of methanol and formaldehyde	･Preservation of organic samples. ･Inhibition of microbial activity.	･The problem of waste arises.

Preservation method	Advantage	Disadvantage
Cooling (ice-cooling.)	・Organic sample (water, food, and the like) preservation. ・It prevents drying and maintains moisture. ・It inhibits microbial activity.	・The ice needs to be replaced.
Freezing (chilled with dry ice.)	・This preserves organic samples (water, plants, animals, and the like).	・The dry ice needs to be replaced.
Paper pulp addition	・Its metal adsorption with a large surface area reduces adsorption on the walls of sample storage containers.	・The pH must be kept below 1. ・It requires filtration and wet ashing of the paper pulp, and the liquids must be adjusted again after treatment.

The primary purpose of water sampling for emergency monitoring is to determine the radioactivity concentration in the water. Analysis by forms, such as dissolved and suspended forms, may be more helpful in investigating the transmigration of radioactive materials in the environment. Clarifying the purpose of the sampling and appropriately selecting the treatment to be applied to the collected sample is essential. For dissolved Cs-137, which is highly bio-transferable, there is a report on the effects of storage conditions on changes in Cs-137 concentrations [1)]. The report states that solid-liquid separation quickly after sampling is ideal for analyzing dissolved Cs-137. If this is difficult, refrigerating it for a short period without additives and then returning it to the water temperature at the time of sampling can return the water to its original chemical state at the time of sampling to some extent.

One of the nuclides considered necessary for emergency monitoring is radioactive iodine. A report is available on iodine in storing water samples [2)]. This report describes an investigation of sample storage conditions for determining total soluble iodine in river water by ICP-MS. The report states that adding an alkaline reagent such as tetramethylammonium hydroxide (TMAH) for preservation is a known method for iodine measurement, but filtered water samples can be preserved at 5 °C for almost one year without the addition of an alkaline reagent such as TMAH. The study also states that adding a small amount of alkaline reagent was sufficient to retain the iodine in the solution when stored at room temperature. In addition, note the iodine volatility. A report studied whether boiling volatilizes I-131 in tap water [3)]. The report indicates that boiling does not remove I-131 from tap water.

Reference

1) Tsuji, H., Takechi, S., Ozaki, H., Nishikiori, T., Kubota, T., & Hayashi, S.(2020). Effect of Storage Temperature and Duration of Environmental Water on Dissolved ^{137}Cs Concentration. *Radioisotopes*,69,315-327, DOI:10.3769/radioisotopes.69.315

2) Tagami, K., & Uchida, S. (2005). Sample storage conditions and holding times for the determination of total iodine in natural water samples by ICP-MS. *Atomic Spectroscopy*, 26(6), 209-214.

3) Tagami, K., & Uchida, S. (2011). Can we remove iodine-131 from tap water in Japan by boiling? – Experimental testing in response to the Fukushima Daiichi Nuclear Power Plant accident, *Chemosphere*, 84(9), 1282-1284.

Reference B - Results of interviews with emergency monitoring workers at TEPCO's Fukushima Daiichi Nuclear Power Plant accident

In response to the accident at TEPCO's Fukushima Daiichi Nuclear Power Station, local government officials and personnel dispatched by the Japanese government and support personnel from other local governments cooperated and collaborated in emergency monitoring. The complex disaster of a large-scale earthquake and tsunami forced them to carry out the work under severe conditions. In developing this manual, it was interviewed the people involved in monitoring at the time, and the lessons learned are included in the text as points to keep in mind. For reference purposes, this section summarizes, by content, the main situations related to sampling encountered at monitoring sites at the time of the accident.

General and planning	・Basically, they acted according to instructions, but the scale of the situation exceeding expectations forced a flexible response. ・Inaccessibility due to sunken roads, damaged bridges, collapsed utility poles, and the like, and seawater intrusion due to broken breakwaters hampered monitoring. ・Prompt communication with the local team was not possible on changes in the accident situation, new instructions, and the like., raising concerns about the safety of the personnel. For this reason, they had been instructed to stay away from beaches, rivers, and other potentially hazardous areas and withdraw if the dose rate was high. ・The off-site center instructed them to take daily measurements at fixed points. On the other hand, the monitoring center instructed them to take measurements over a wide area to determine the areal extent, which was sometimes challenging to accommodate. Thus, sometimes multiple chains of command were involved. ・Since no team member was familiar with the area, a lack of knowledge of the names of places sometimes confused the team members. ・Most sampling locations were on public land, but some were on private land. ・There were urgent requests for interviews and requests from residents to measure dose rates.
Communication and liaison	・Power outages at base stations or dead batteries sometimes made calls by cell phones impossible. ・Satellite phones were not working at all in some places in the mountains. In addition, the effects of sheer cliffs and trees sometimes interrupted calls. ・The plan was to use RAMISES, but it was not useable. The administrative radio range was approximately 10 km, so it was impossible to report outside the radio area in real-time. They reported the dose rate after returning to the headquarter or from a joint government building equipped with a disaster prevention radio. ・They always listened to NHK and other radio stations.

Equipment	・They took photographs for sampling information, but most showed only personnel and their hands, and failed to capture a wide range of surrounding areas. In some cases, location information was ambiguous and could not be shown on a map, so they carried digital cameras with GPS functions as a countermeasure. ・Since gas stations were not open, they sometimes received supplies from the Self-Defense Forces and TEPCO material yards. ・They needed cash for the activities, but the lack of functioning financial institutions resulted in a shortage of cash on hand. ・Dosimeters installed at monitoring sites were sometimes stolen. ・The activity sites had only a few days' worth of consumables, which the Japan Atomic Energy Agency and the prefectures provided.
Radiation protection of personnel	・The dose rate differed significantly from prior information in some locations. ・In high-dose-rate areas, the personnel retreated to their vehicles if it took a long time to take measurements. ・While traveling by car, fellow passengers checked the fluctuation of the survey meter readings to identify areas with high dose rates.
Ensuring the safety of personnel	・Immediately after the disaster, monitoring took a long time, sometimes starting before dawn and continuing until the date changed. ・The daily mileage often exceeded several hundred kilometers in the monitoring immediately after the disaster. ・The work was long and exhausting. ・They could not eat or drink while wearing protective clothing. ・Refraining from eating and drinking sometimes resulted in mild dehydration. ・Wild dogs, boars, snakes, and other wild animals were sometimes life-threatening. ・In mountainous areas, the flies attracted by the exhaust gas sometimes hindered activities.
Other	・At sampling locations, they wore a Tyvek suit to prevent contamination. However, the scope of emergency monitoring was expanded to outside the evacuation zone, where residents were still living. Since they heard complaints that Tyvek suits would cause fear, they switched to ordinary rain suits.

Appendix

Appendix A - Emergency monitoring

1. Purpose of emergency monitoring

The Emergency Supplemental Reference Material states that emergency monitoring “refers to environmental radiation monitoring conducted in an event or a likely event of an abnormal release of radioactive materials or radiation” and describes the purpose of emergency monitoring as follows:

(a) Collection of information on the environmental radiation situation due to a nuclear disaster

(b) Provision of materials for making decisions on implementing protective measures based on OIL

(c) Provision of materials for the evaluation of radiological impacts on residents and the environment caused by the nuclear disaster.

Therefore, in emergency monitoring, it is essential to determine the radiation situation over continuous time and space.

The Nuclear Emergency Preparedness and Response Guidelines established the decision-making framework to enable prompt implementation of emergency protective measures based on observable indicators in order to determine the emergency category and implement preventive protective measures according to the status of the facility in the initial response phase, setting the Emergency Action Levels (EALs) based on the status of nuclear facilities as criteria for nuclear facility operators to determine whether or not a situation falls under one of the emergency categories and the Operational Intervention Level (hereinafter referred to as “OIL”), which is expressed in terms of measurable values such as the dose rate and concentration of radioactive materials in environmental samples.

In addition, the Nuclear Emergency Preparedness and Response Guidelines specify that priority measures should be taken by providing in advance a Precautionary Action Zone (hereinafter referred to as “PAZ”) in which rapid, preventive, and protective measures can be taken based on the emergency classification before releasing radioactive materials in order to prevent deterministic effects caused by radiation exposure and Urgent Protective Action Planning Zone (hereinafter referred to as “UPZ”), where emergency protective measures are prepared for prompt implementation based on EAL and OIL before or after releasing radioactive materials, depending on the emergency, in order to reduce the stochastic effects as much as possible.

Emergency monitoring should be conducted appropriately over time, considering the accident’s state and progress. The Nuclear Emergency Preparedness and Response Guidelines state that the initial response phase monitoring (initial monitoring) should prioritize monitoring items necessary for making decisions regarding protective measures based on OIL. In other words, what is essential in the initial monitoring of power reactor facilities is to obtain timely information necessary for making decisions on the implementation of protective measures such as evacuation, sheltering, temporary relocation, and restriction of food and drink intake (status (changes and extent of effects) of dose rate, radioactive material concentration, and the like and information on the release of radioactive materials) in the hours to several days after releasing radioactive material. It should be noted that the necessary monitoring items may differ depending on the region and the elapsed time because the protective measures to be determined depend on the region, even at the same time of year.

The response to emergencies for nuclear facilities for testing and research is fundamentally the same as the nuclear power reactor facilities. However, taking measures according to the situation of each region is important because the thermal output and type of nuclear facilities for testing and research vary, and the geographical and social conditions around the facilities also differ from region to region.

The response to emergencies for nuclear fuel facilities (i.e., uranium processing facilities, plutonium processing facilities, reprocessing facilities, spent fuel storage facilities, waste burial facilities, waste management facilities, and use facilities) are also fundamentally the same as the above-mentioned nuclear power reactor facilities. However, depending on the facility's characteristics and the accident type, it may be essential to measure neutron radiation and the concentration of radioactive materials in the air and environmental samples, mainly α-emitting nuclides. In addition, since the geographical and social conditions around the facility vary from region to region, it is essential to take measures according to the conditions of each region.

In the mid-term monitoring, enhance the monitoring of initial monitoring items, and use the results to evaluate and confirm the overall effects of radioactive materials or radiation on the surrounding environment, evaluate human exposure, to make decisions on implementation and termination of various protective measures, and to take measures against rumors, and the like. In monitoring during the recovery phase, continuously monitor changes in radiation doses and concentrations of radioactive materials over time in order to make decisions on the review of evacuation zones, determine measures to control and reduce exposure doses and estimate current and future exposure doses. The mid-term and recovery phase monitoring modalities will be further discussed and described in the Nuclear Emergency Preparedness and Response Guidelines.

2. Emergency monitoring implementation system

In order to implement emergency monitoring, it is essential to put an emergency monitoring implementation system in place in normal situations. The Nuclear Emergency Preparedness and Response Guidelines state that the Japanese government, local governments, and nuclear facility operators should share the same objectives, fulfill their respective responsibilities, and cooperate in implementing emergency monitoring at the Emergency Monitoring Center (hereinafter referred to as “EMC”), which the Japanese government supervises. The roles of each organization in emergency monitoring are shown in Appended Table A-1.

Appended Table A-1 Roles of each organization in emergency monitoring

	Normal situations	Emergency
Japanese government	・Develop a template for an emergency monitoring implementation plan ・Cooperate in the development of the emergency monitoring plan ・Survey the mobilization plan 1 ・EMC system development ・Conduct and cooperate during emergency monitoring drills	・Mobilize equipment and personnel and instruct for mobilization ・Launch EMC ・Participate in and supervise EMC ・Develop and revise an emergency monitoring implementation plan. ・Implement emergency monitoring (e.g., aircraft monitoring) conducted by the Japanese government ・Publish emergency monitoring results
Local government	・Develop an emergency monitoring plan. ・Cooperate in surveys related to the mobilization plan1 ・Cooperate in the development of the EMC system2 ・Conduct and cooperate during emergency monitoring drills	・Mobilize equipment and personnel ・Cooperate to launch the EMC ・Participate in the EMC
Nuclear facility operator	・Cooperate in the development of an emergency monitoring plan ・Cooperate in surveys related to the mobilization plan1	・Mobilize equipment and personnel ・Implement on-site monitoring (including the collection of information on plant conditions)

	Normal situations	Emergency
	・Conduct and cooperate during emergency monitoring drills	・Participate in the EMC
Relevant designated public institution	・Cooperate in the development of the emergency monitoring plan2 ・Cooperate in surveys related to the mobilization plan1 ・Conduct and cooperate during emergency monitoring drills	・Mobilize equipment and personnel ・Participate in the EMC
EMC	—	・Conduct emergency monitoring ・Propose and comment on the draft revision of the Emergency Monitoring Implementation Plan ・Cooperate (as needed) for emergency monitoring conducted directly by the Japanese government

1:...means the "Mobilization Plan for Emergency Monitoring" shown in (Securing Personnel and Equipment for Emergency Monitoring).
2:...not mentioned in the Nuclear Emergency Preparedness and Response Guidelines, but it will be implemented to the best extent possible.

The above is reproduced from the Emergency Supplemental Reference Material, including annotations.

3. Items for emergency monitoring

The items of emergency monitoring are broadly classified into the measurement of dose rate, measurement of the concentration of radioactive materials in the air, and measurement of the concentration of radioactive materials in environmental samples.

(1) Measurement of dose rate

Measurement of the dose rate is vital in the case of accidents at nuclear facilities for power reactor and testing, criticality accidents at nuclear fuel facilities, and accidents at spent fuel storage facilities in reprocessing plants, from the viewpoint of providing materials for judging the implementation of protective measures. In addition, even in cases of accidents at nuclear fuel facilities (excluding criticality accidents and accidents at spent fuel storage facilities in reprocessing plants), depending on the released nuclide, the measurement results of dose rate may be used to evaluate external exposure and the like.

Methods for measuring dose rate include continuous measurement systems, measurements using survey meters for γ-rays, and measurements using car-borne surveys and aircraft monitoring.

(2) Measurement of the concentration of radioactive materials in the air

The purpose of measuring the concentration of radioactive materials in the air is to collect information on the environmental radiation situation caused by the nuclear disaster and to provide materials for evaluating the radiological impact of the nuclear disaster on residents and the environment. For this purpose, establish a measurement system using an air monitor that can continuously monitor changes in radioactive materials in the air over time and an iodine sampler with an automatic sample changer that can continuously collect gaseous and particulate iodine by replacing filter paper and activated carbon cartridges at regular intervals. Use this system to confirm the spread of radioactive materials and to evaluate radiation exposure.

In addition, in order to respond to accidents at nuclear fuel facilities (excluding criticality accidents and accidents at spent fuel storage facilities in reprocessing plants), establish a system that can monitor changes in the concentration of radioactive materials in the air continuously over time, mainly for α-emitting nuclides, using air monitors, dust samplers, and the like.

(3) Measurement of the concentration of radioactive materials in environmental samples

Environmental samples are categorized into precipitation, soil, and the like. (in addition to soil, this includes land water, seawater, river sediment, lake sediment, sea sediment, indicator organisms, and the like), and food and drink. Moreover, considering regional food culture and the like, classify items mainly used for eating and drinking or as a substitute for green vegetables as food and drink. Soil and drinking water are critical environmental samples for determining the implementation of protective measures in the initial response phase. The concentration of radioactive materials in samples changes over time, so collect and analyze samples promptly. In particular, if the collected samples are expected to contain short-lived radionuclides, analyze them while they can be measured at significant values.

(a) Measurement of the concentration of radioactive substances in soil

The primary purpose of measuring the concentration of radioactive materials in the soil is to confirm the spread of radioactive materials deposited on the ground and to determine their nuclide composition. In the initial response phase, sample, measure, and analyze the soil from the vicinity of monitoring station and other locations as soon as possible where dose rates exceeding OIL2 are measured. Sample, and measure and analyze the soil in the vicinity of the locations where the concentration of radioactive materials in the air is measured.

Collect samples for analysis of α- and β-emitting nuclides mainly at the locations where the OIL2 standard is exceeded. The EMC will review the implementation of the sampling based on the results of the measurement of dose rate and the like.

In order to respond to an accident at a nuclear fuel facility (excluding criticality accidents and accidents at spent fuel storage facilities in reprocessing plants), establish candidate sites in advance, taking into account geographical conditions (topography, ease of access to the site), social conditions, and other factors.

(b) Measurement of radioactive materials in food and drink

The primary purpose of measuring the concentration of radioactive materials in food and drink is to provide materials for making decisions on the implementation of protective measures and for evaluating the radiological impact of a nuclear disaster on residents and the environment.

Before the start of testing for radioactive materials in food and drink according to OIL6
・In order to evaluate the effects of radioactive materials on drinking water, sample and analyze drinking water supplied from water sources and the like located in PAZs and UPZs as soon as possible after confirming the release of radioactive materials. →Collect samples from the water supply, simple water supply, and others that may be contaminated. →Determine the candidate sampling locations and priorities in advance for each region, considering local conditions such as water catchment areas and water distribution systems. →If the dose rate is high where a water source is located, conduct focused sampling and analysis for the water supply, simple water supply, and the like that use the water source. ・In principle, consider the following locations as candidate sampling locations. →Collect water samples from indoor tap water to ensure the safety of monitoring personnel while releasing radioactive materials. →After the deposition of radioactive materials, select a representative and efficient sampling location, such as a water purification plant.
Inspect radioactive materials in food and drink according to OIL6
・In areas where the dose rate exceeds 0.5 μSv/h, measure the concentration of radioactive materials in food and drink produced there. ・In response to accidents at nuclear fuel facilities (excluding criticality accidents and

accidents at spent fuel storage facilities in reprocessing plants), measure the concentration of radioactive materials in food and drink (mainly α-emitting nuclides) throughout the UPZ.

(4) Other measurements

At facilities handling UF_6, it is necessary to know the HF in the air since the impact from HF resulting from the release of UF_6 can occur offsite.

Therefore, measure HF in the air generated in a UF_6-releasing accident of UF_6-handling facilities.

4. Details of emergency monitoring

(1) Environmental radiation monitoring in information collection situations (normal monitoring)

The information collection situation is the stage to confirm the release of radioactive materials and the like. The prefectures concerned should continue normal monitoring and monitor the operation status of nuclear facilities. In addition, the prefectures concerned should take necessary measures such as repairing monitoring stations, electronic dosimeters, air monitors, and the like if any abnormality is found in them due to natural disasters and the like.

(2) Monitoring during the initial response phase

Emergencies and monitoring are classified as shown in Appended Figure A-1.

Classification of emergencies	—	Information collection situation	State of alert	Facility site emergency	General emergency
Classification of response status in emergency	—		Initial Response Phase		(Mid-term and recovery phase)
Classification of monitoring	Normal monitoring		Emergency monitoring preparation	Emergency monitoring	

Appended Figure A-1 Classification of emergencies and monitoring

*Reproduced from the Emergency Supplemental Reference Material

(a) Alert monitoring

Since a state of alert is an occurrence or potential occurrence of an abnormal event at a nuclear facility, the relevant prefectures should confirm whether or not there is any abnormality at the nuclear facility and prepare for emergency monitoring, including strengthening normal monitoring, in case a facility site emergency occurs.

Specifically, the relevant prefectures should strengthen the measurement of dose rates and the like at the monitoring station and the like. (the guideline frequency of data collection is about once every two minutes or more). If there are any abnormalities in monitoring stations, electronic dosimeters, air monitors, or communication device due to natural disasters and the like, take necessary measures such as the installation of alternative equipment or repair. In addition, implement the following items and the like as preparations for emergency monitoring.

- Prepare the launch of EMC (check the operation of communication device and others and ensure the acceptance of personnel dispatched from the Japanese government, and the like, to the EMC)
- Install transportable monitoring posts and the like at the planned installation sites and start measurement
- Prepare start-up of air monitors and iodine samplers

The nuclear operator should collect information on the emission source and provide the information to the government and other parties. The Japanese government (Nuclear Regulation Authority) will also collect and compile information from the relevant prefectures and nuclear facility operators.

(b) Emergency monitoring of facility site emergencies

A facility site emergency at a nuclear facility could cause radiological consequences to the public. Thus, conduct monitoring to determine the progress of the situation in accordance with the emergency monitoring implementation plan.

Specifically, measure the dose rate by monitoring stations and electronic dosimeters installed around nuclear facilities under normal situations, monitoring stations installed to investigate environmental radioactivity levels, and transportable monitoring posts installed in states of alert. In addition, in order to measure the concentration of radioactive materials in the air, activate air monitors and iodine samplers according to the emergency monitoring implementation plan, depending on the status of the facilities.

In addition, install transportable monitoring posts and the like as soon as possible at locations where transportable monitoring posts and the like have not yet been installed, such as when a facility site emergency occurs without going through a state of alert.

(c) Emergency monitoring for general emergencies

In a general emergency, conduct the following emergency monitoring in accordance with the emergency monitoring implementation plan.

If road disruptions or other reasons during a complex disaster restrict the gathering or activities of monitoring personnel, give priority to monitoring to provide information for making decisions on the implementation of protective measures based on the OIL, in accordance with the purpose of initial monitoring in the guidelines for Nuclear Emergency Preparedness and Response Guidelines.

a) Monitoring for OIL1

[Indicators]

OIL1 is a standard to prevent the effects of exposure to radiation from the ground surface (radioactive materials deposited on the ground), inhalation of re-suspended radioactive materials, and inadvertent oral intake, and to have residents evacuate or shelter in place within a few hours. The default value is 500 μSv/h (ambient dose equivalent rate), a dose rate measured at 1 meter above the ground.

[Targets for measurement]

Measure the dose rate as monitoring to determine the implementation of protective measures in accordance with OIL1.

[Details of implementation]

Conduct continuous measurement at monitoring station as the priority, and if necessary, measure using a car-borne survey or using a γ-ray survey meter for high dose rate measurement, paying attention to the conditions of the nuclear facility and radiation protection of monitoring personnel.

b) Monitoring for OIL2

[Indicators]

OIL2 is a standard for restricting the intake of local products and temporarily relocating residents within about one week to prevent the effects of exposure to radiation from the ground surface (radioactive materials deposited on the ground), inhalation of re-suspended radioactive materials, and inadvertent oral intake. The default value is set at 20 μSv/h (ambient dose equivalent rate) as the dose rate in the air when measured at 1 meter above the ground.

Note： In cases where the dose rate (hourly value) exceeds the OIL2 standard value when approximately one day has passed from the time the dose rate (hourly value) obtained by emergency monitoring exceeded the OIL2 standard value.

[Targets for measurement]

Measure the dose rate as part of monitoring to determine the implementation of protective measures in accordance with OIL2.

[Details of implementation]

Conduct continuous measurement at monitoring station as the priority, and if necessary, measure using a car-borne survey or using a γ-ray survey meter for high dose rate measurement. In addition, the Japanese government will implement aircraft monitoring, which can supplement measurements at the monitoring station and the like.

c) Monitoring for OIL6

[Indicators]

・OIL6 is a standard for measuring and analyzing radionuclide concentrations in food and drink within a week and promptly implementing intake restrictions for those exceeding the standard, with default values shown in Appended Table A-2.

Appended Table A-2 OIL6 (default setting)

Nuclides*1	Drinking water, milk, and dairy products	Vegetables, grains, meat, eggs, fish, and others
Radioactive iodine	300 Bq/kg	2 000 Bq/kg
Radioactive cesium	200 Bq/kg	500 Bq/kg
α-emitting nuclides of plutonium and trans-uranium elements	1 Bq/kg	10 Bq/kg
Uranium	20 Bq/kg	100 Bq/kg

*1: Consider the necessity of setting values for other nuclides in the future. In doing so, use the OIL6 values in IAEA's GSG-2 as a reference for setting values.

*The above is reproduced from the Nuclear Emergency Preparedness and Response Guidelines, including annotations.

・The screening standard for food and drink identifies areas where radionuclide concentrations in food and drink should be measured within a few days. It is set at 0.5 μSv/h (ambient dose equivalent rate) when measured 1 meter above the ground.

[Targets for measurement]

・Measure the dose rate in the air as screening to identify where to measure the concentration of radioactive materials in food and drink (hereinafter referred to as "monitoring for screening").
・In areas where monitoring for screening exceeds 0.5 μSv/h (ambient dose equivalent rate), inspect the concentration of radioactive materials in food and drink.
・When accidents occur at a nuclear fuel facility, measure radionuclide concentrations (mainly α-emitting nuclides) in food and drink throughout the UPZ.

[Details of implementation]

・Since the area to be monitored for screening is broader than that for OIL1 and OIL2, utilize not only dose rate measurement at the monitoring station and the like but also car-borne survey, γ-ray survey meter, and aircraft monitoring.
・Utilize the measurement results of the environmental radioactivity level survey.
・Inspect food and drink intake restrictions in accordance with the "Nuclear Emergency Response

Manual".

d) Monitoring outside the UPZ

[Purpose]

・Extend the instruction to evacuate indoors to a certain area outside the UPZ based on the situation on the facility side and the results of emergency monitoring.

・In order to implement protective measures at an early stage, determine the scope of protection based on changes in the situation at the facility near the source, such as changes in the dose rate observed within the site or at the site boundary, and establish an effective scope such as administrative area units based on concentric circles.

・When the results of emergency monitoring, and others, lead to the determination that radioactive materials have passed out of the area, lift this instruction of evacuate indoors.

[The measurement target and implementation details]

・In addition to ascertaining information on the site and site boundaries, use observation equipment in the UPZ to obtain an overview of the radioactive plume flow traces and collect information that will contribute to judging the passage of the radioactive plume in the extended protective area.

・Outside the UPZ, collect information using mobile monitoring methods such as car-borne surveys and aircraft monitoring.

e) Monitoring to provide evaluation materials for radiological impacts on residents and others, and the environment

[Purpose]

・The monitoring results to provide the materials for decisions on implementing protective measures based on the OIL, as indicated in (a) through (c) above, can be used as part of the evaluation of radiological impacts.

・In addition to the above, determine the concentration of radioactive materials in environmental samples to evaluate radiological impacts.

・In the areas surrounding nuclear facilities not requiring the establishment of the Priority Zone for Nuclear Emergency Response, determine radioactive material concentrations and the like in environmental samples as necessary, taking into consideration the actual conditions of each area.

・Measurement of the concentration of radioactive materials in the air is essential for evaluating the radiological impacts of released radioactive materials. Continuously monitor over time the changes in the concentration of radioactive iodine, in particular, which affects the exposure dose due to inhalation, and monitor changes in areal conditions in the area surrounding the facility.

[Targets for measurement]

・Give priority to the measurement targets indicated in the monitoring for OIL1, OIL2, and OIL6.

・Measure the concentration of radioactive materials in the air and environmental samples.

・Collect gaseous and particulate iodine using an air monitor that can continuously determine the changes in radioactive material concentrations in the air and an iodine sampler with an auto-sample changer that can continuously collect gaseous and particulate iodine at regular intervals.

・In addition to the nuclides that are subject to public dose evaluation during accidents in the safety review of nuclear facilities, measure the concentration of Cs-134, Cs-137, and the like, released during the accident at the TEPCO's Fukushima Daiichi Nuclear Power Station.

・In the case of criticality accidents at nuclear fuel facilities, measure neutron radiation from the perspective of providing material for evaluating external exposure.

・In the case of a nuclear fuel facility accident (excluding criticality accidents and accidents at spent fuel storage facilities in reprocessing plants), mainly measure α-emitting nuclides from the viewpoint of providing evaluation materials for internal exposure.

[Details of implementation]
・The monitoring for OIL1, OIL2, and OIL6 is shown in (a) through (c) above.
・Determine in advance the candidate locations for measuring radioactive material concentrations and the like in the air and environmental samples in accordance with the numbers of personnel and equipment available. The EMC will consider the implementation based on the measurement results of dose rates and the distribution status of settlements.

f) Monitoring to collect information on the status of environmental radiation

[Purpose]
・The monitoring results to provide information for making decisions on the implementation of protective measures based on OIL and for the evaluation of radiological impacts, as indicated in (a) through (e) above, can also be used to collect information on the environmental radiation situation.
・In addition to the above, measure other radioactive material concentrations in environmental samples not measured in (a) through (e) above in order to collect information on environmental radiation conditions.

[Targets for measurement]
・Give priority to the measurement targets shown for monitoring for OIL1, OIL2, and OIL6 shown in (a) through (c) above.
・Conduct monitoring outside the UPZ as described in (d) above and monitoring to provide materials for evaluating radiological impacts on residents and the environment as described in (e) above. Measure radioactive material concentrations in other environmental samples not covered in (a) through (e) above.

[Details of implementation]
・The monitoring for OIL1, OIL2, and OIL6 is shown in (a) through (c) above.
・Monitoring outside the UPZ is described in (d) above, and monitoring to provide evaluation materials for radiological impacts on residents and the environment described in (e) above.
・Determine in advance candidate locations for measuring radioactive material concentration in other environmental samples not conducted in (a) through (e) above in accordance with the number of personnel and equipment available. The EMC will consider implementation based on the measurement results of dose rates and the distribution status of settlements, and others.
・Measure the dose rate at the location where the soil sample was collected to study the relationship between the dose rate and surface contamination.

5. Initial monitoring according to accident progress

The following is an overview of the initial monitoring of nuclear power reactor facilities in accordance with the accident progress, as shown in the Emergency Supplemental Reference Material.

[Initial monitoring of nuclear power reactor facilities in accordance with the accident progress]

Reproduced from the Emergency Supplemental Reference Material.

I. State of alert

Purpose of monitoring	Implementation guidelines	Items to be monitored for each area (Implementing entity)			
		On-site	PAZ	UPZ	Outside UPZ
Information collection	Monitoring by measurement of dose rates to prepare for radioactive material release	・Exhaust stack and water outlet monitors (nuclear facility operators) ・Site boundary monitoring stations (nuclear facility operators) ・Dust iodine monitors (nuclear facility operators)	・Monitoring stations and the like (municipalities) (*1) ・Monitoring stations and the like (nuclear facility operators) (*1)		・Monitoring stations for the environmental radioactivity level survey (Japanese government)
Information collection evaluation of radiological impacts	Preparation for measurement of radioactive iodine in the air			・Air monitors (municipalities) ・Iodine samplers (municipalities)	

II. Facility site emergency

Purpose of monitoring	Implementation guidelines	Items to be monitored for each area (Implementing entity)			
		On-site	PAZ	UPZ	Outside UPZ
Information collection	Strengthen monitoring by measuring dose rate and the like, in preparation for the release of radioactive materials	・Exhaust stacks and water outlet monitors (nuclear facility operators) ・Site boundary monitoring stations (nuclear facility operators) ・Dust iodine monitors (nuclear facility operators)	・Monitoring stations and the like.(municipalities) (*1) ・Monitoring stations and the like (nuclear facility operators) (*1)		・Monitoring stations for the environmental radioactivity level survey (Japanese government)
Information collection Evaluation of radiological impacts	Measure radioactive iodine in the air			・Air monitors (municipalities) (*2) ・Iodine samplers (municipalities) (*2)	

III. General emergency

(1) Before releasing radioactive materials into the air

<table>
<tr><th rowspan="2">Purpose of monitoring</th><th rowspan="2">Implementation guidelines</th><th colspan="4">Items to be monitored for each area (Implementing Entity)</th></tr>
<tr><th>On-site</th><th>PAZ</th><th>UPZ</th><th>Outside UPZ</th></tr>
<tr><td>Information collection</td><td>Strengthen monitoring by measuring dose rate, and others, in preparation for the release of radioactive materials</td><td>・Exhaust stacks and water outlet monitors (nuclear facility operators)
・Site boundary monitoring stations (nuclear facility operators)
・Dust iodine monitors (nuclear facility operators)</td><td colspan="2">・Monitoring stations and the like (municipalities) (*1)
・Monitoring stations and the like (nuclear facility operators) (*1)</td><td>・Monitoring stations for the environmental radioactivity level survey (Japanese government)</td></tr>
<tr><td>Information collection Evaluation of radiological impacts</td><td>Measure radioactive iodine in the air</td><td></td><td></td><td>・Air monitors (municipalities) (*2)
・Iodine samplers (municipalities) (*2)</td><td></td></tr>
</table>

(2) During the release of radioactive materials into the air

<table>
<tr><th rowspan="2">Purpose of monitoring</th><th rowspan="2">Implementation guidelines</th><th colspan="4">Items to be monitored for each area (Implementing Entity)</th></tr>
<tr><th>On-site</th><th>PAZ</th><th>UPZ</th><th>Outside UPZ</th></tr>
<tr><td>Information collection</td><td>Confirmation of radioactive material release through measurement of dose rate and the like</td><td>・Exhaust stacks and water outlet monitors (nuclear facility operators)
・Site boundary monitoring stations (nuclear facility operators)
・Dust iodine monitors (nuclear facility operators)</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Information collection Evaluation of radiological impacts</td><td>Confirmation of the spread of radioactive materials by measuring dose rates and the like.</td><td>・Site boundary monitoring stations (nuclear facility operators)</td><td colspan="2">・Monitoring stations and the like (municipalities) (*1)
・Monitoring stations and the like (nuclear facility operators) (*1)
・Air monitor (municipalities) (*2) [UPZ]</td><td>・Monitoring stations for the environmental radioactivity level survey (Japanese government)</td></tr>
<tr><td>Confirm the spread and composition of radioactive materials by collecting and measuring environmental samples and the like.</td><td>・Dust iodine monitors (nuclear facility operators)</td><td></td><td>・Sampling and analysis of drinking water (municipalities)
・Air monitors (municipalities) (*2)
・Iodine samplers (municipalities) (*2)</td><td></td></tr>
<tr><td>Determination of implementation of protective measures</td><td>Collection of data on dose rate and the like for OIL determination</td><td></td><td></td><td>・Monitoring stations and the like (municipalities) (*1)
・Monitoring station and the like (nuclear facility operators) (*1)</td><td>・Monitoring stations for the environmental radioactivity level survey (Japanese government)</td></tr>
<tr><td>Evaluation of radiological impacts</td><td>Collect data on radioactive iodine concentrations in the air</td><td>・Dust iodine monitors (nuclear facility operators)</td><td></td><td>・Air monitors (municipalities) (*2)
・Iodine samplers (municipalities) (*2)</td><td></td></tr>
</table>

(3) After releasing radioactive materials into the air

Purpose of monitoring	Implementation guidelines	Items to monitor for each area (Implementing entity)			
		On-site	PAZ	UPZ	Outside UPZ
Information collection	Confirm convergence of radioactive material release through measurement of dose rates and the like.	・Exhaust stacks and water outlet monitors (nuclear facility operators) ・Site boundary monitoring stations (nuclear facility operators) ・Dust iodine monitors (nuclear facility operators)			
Information collection Evaluation of radiological impacts	Confirm the spread of radioactive materials by measuring dose rates and the like.	・Site boundary monitoring stations (nuclear facility operators)	・Monitoring stations and others (municipalities) (*1) ・Monitoring stations and the like (nuclear facility operators) (*1)	・Car-borne survey (Municipalities) ・Aircraft monitoring (Japanese government) (*3) ・Air monitors (Municipalities) (*2)	・Monitoring station for the environmental radioactivity level survey (Japanese government) ・Car-borne survey (Japanese government)
	Confirm the spread and composition of radioactive materials by collecting and measuring environmental samples	・Dust iodine monitors (nuclear facility operators)		・Sampling and analysis of drinking water (municipalities) ・Soil sampling, analysis, or measurement (municipalities) ・Analysis of air monitor filter paper ・(municipalities) ・Analysis of iodine sampler filter paper (municipalities)	
Determine the implementation of protective measures	Collect data such as dose rates for OIL determination			・Monitoring stations and others. ・(municipalities) (*1) ・Monitoring station and the like (nuclear facility operators) (*1) ・Soil sampling, analysis, or measurement (municipalities) ・Car-borne survey (municipalities) ・Aircraft monitoring (Japanese government) (*3)	・Monitoring station for the environmental radioactivity level survey (Japanese government) ・Car-borne survey (Japanese government)
Evaluation of radiological impacts	Collect data on radioactive iodine concentrations in the air	・Dust iodine monitors (nuclear facility operators)		・Analysis of air monitor filter paper ・(municipalities) ・Analysis of iodine sampler filter paper and the like. (municipalities)	

*Conduct ocean monitoring as necessary.

Purpose of Monitoring

Information collection: collect information on the environmental radiation situation caused by the nuclear disaster.

Determine the implementation of protective measures: provide the materials for determining the implementation of protective measures in accordance with OIL.

Evaluate radiological impacts: provide materials for evaluating radiological impacts on residents and the environment caused by nuclear disasters.

Notes

(*1) Equipment for measuring dose rates (monitoring stations, transportable monitoring posts, electronic dosimeters, and the like) capable of continuous measurement. Activate transportable monitoring posts and electronic dosimeters during state of alert.

(*2) Depending on the status of the nuclear power reactor facility, activate the system in accordance with the emergency monitoring implementation plan.

(*3) Aircraft monitoring is under the jurisdiction of the Radiation Team of the ERC Team.

: Operate as a single entity as EMC

[Legend]

Blue: Japanese government

Green: municipalities

Brown: nuclear facility operators

Appendix B - Terms and definitions

Definitions of terms used in this manual.

Terminology	Description
EMC	**Emergency Radiological Monitoring Center** · The system under the direction of the Japanese government for emergency monitoring in cooperation with the Japanese government, local governments, and nuclear facility operators. · The aggregating of the functions necessary to conduct emergency monitoring · Consisting of personnel from the Japanese government, local governments, nuclear facility operators, and relevant designated public agencies · When the person from the Japanese government in charge is absent, the representative of the local government takes over the command.
OFC	**Offsite Center** A base where, in the event of a nuclear disaster, the local nuclear emergency response headquarters of the Japanese government and the disaster response headquarters of local governments and the like organize a joint nuclear emergency response council, share information, and take coordinated nuclear disaster countermeasures.
ERC	**Emergency Response Center** Nuclear Regulatory Agency Emergency Response Center An organization to ensure a complete backup system for the Secretariat of the Nuclear Emergency Headquarters and others. It consists of officials of the Nuclear Regulation Authority designated by the Director-General of the Nuclear Regulation Authority and officials designated by the Director-General for Disaster Management, Cabinet Office.
OIL	**Operational Intervention Level** As a criterion for determining the implementation of protective measures, it is expressed in terms of measurable values such as dose rate, and concentration of radioactive materials in environmental samples.
EAL	**Emergency Action Level** The criteria for a nuclear operator to determine whether a situation falls under an emergency category are determined based on the condition of the nuclear facility and other factors.
PAZ	**Precautionary Action Zone** · Areas where preventive, protective measures, such as immediate evacuation according to the EAL, are prepared from the stage before releasing radioactive materials in order to avoid or minimize deterministic severe effects due to radiation exposure. · The specific scope of a PAZ for a nuclear power reactor facility should be within "approximately a 5 km radius from the nuclear facility".
UPZ	**Urgent Protective action planning Zone** · Areas where emergency protective measures are prepared in accordance with EAL and OIL in order to reduce the risk of stochastic effects. · The specific scope of the UPZ for a nuclear power reactor facility is "approximately 30 km radius from the nuclear facility".
IAEA	**International Atomic Energy Agency**
Emergency phase	· Classify as "Preparation Phase", "Initial Response Phase", "Mid-Term Response Phase", and "Recovery Phase." · It is useful to consider the details of emergency response at each stage.
Preparation phase	· Nuclear facility operators, the Japanese government, local governments, and the like, should formulate their own action plans

Terminology	Description
	and disseminate them to all concerned parties. The action plan is verified, evaluated, and improved through training and the like.
Initial response phase	・Even with limited information, take prompt protective measures and other actions in order to avoid or minimize deterministic severe effects of radiation exposure and to reduce the risk of stochastic effects.
Mid-term response phase	・Take appropriate control of radioactive materials or radiological impacts. ・Fully grasp the radiation situation through environmental radiation monitoring and analysis. ・Based on the initial response phase results, change/cancel the protective measures implemented in the initial response phase, and consider long-term protective measures.
Recovery phase	・Assist in the return to normal social and economic activities based on a plan for long-term recovery measures in the affected areas.
Classification of emergencies	Classify as "state of alert", "facility site emergency", and "general emergency".
State of alert	The occurrence or threat of an abnormal event at a nuclear facility necessitates the initiation of information collection and preparation for protective measures such as emergency monitoring and evacuation of those who need to be evacuated in the facility site emergency.
Facility site emergency	・An event has occurred at a nuclear facility that can cause radiological consequences to the public, and it is necessary to start preparing for primary protective measures, such as evacuation, in the vicinity of the nuclear facility in case of an emergency.
General emergency	An event has occurred at a nuclear facility with a high probability of causing radiological consequences to the public. Prompt protective actions must be taken to avoid (minimize) severe deterministic effects and reduce the risk of stochastic effects.
Facility site emergency evacuee	・Persons requiring special consideration (as defined in Article 8, Paragraph 2, Item 15 of the Basic Act on Disaster Control Measures (Act No. 223 of 1961)) who require more time than usual to evacuate and whose health risk does not increase as a result of the evacuation. ・Those who have not been given stable iodine tablets in advance and those who are inappropriate to take stable iodine tablets, and who need to implement protective measures such as evacuation as soon as possible in the event of an emergency at the facility site.
Emergency monitoring	・Environmental radiation monitoring to conduct when there is an abnormal or threatened release of radioactive materials or radiation. ・It is divided into three phases: "initial monitoring", "mid-term monitoring", and "recovery phase monitoring".
Initial monitoring	・Monitoring to be conducted during the initial response phase. ・The initial monitoring results will be used to make decisions on protective measures in consideration of OIL. <u>Monitoring items</u> a) Dose rate and concentration of radioactive materials (radioactive noble gases, radioactive iodine, and the like.) in the air in the region centered on the nuclear disaster countermeasure priority area. b) Concentration of radioactive materials (radioactive iodine, radioactive cesium, uranium, plutonium, α-emitting nuclides of transuranic elements, and the like) in environmental samples affected by radioactive material releases. ・Dose rate and concentration of radioactive materials in a wide range of surrounding environments
Mid-term monitoring	・Monitoring to be conducted during the mid-term response phase c) The results of the mid-term monitoring will be used to evaluate and confirm the overall effects of radioactive materials or radiation on

Terminology	Description
	the surrounding environment, to evaluate human exposure, to make decisions on the implementation or termination of various protective measures, and to take measures against rumors and the like.
Recovery phase monitoring	・Monitoring during the recovery phase, even after the accident is under control. ・The monitoring results during the recovery phase will be used to make decisions on the review of evacuation zones and the like, to determine measures to control and reduce exposure doses, and to estimate current and future exposure doses.
Emergency monitoring plan	・The plan stipulates the emergency monitoring implementation system, measurement locations, items to be measured, and preparations for these items in prefectures. It constitutes the basis of the emergency monitoring implementation plan. ・The prefectures where nuclear power plants are located or adjacent to nuclear power plants prepare the plan in advance in cooperation with the Japanese government and in coordination with municipalities and nuclear facility operators.
Emergency monitoring implementation plan	・The implementation plan describes the specific items to be monitored and the entity to implement emergency monitoring according to the circumstances of the accident. ・The Japanese government prepares the plan with reference to each prefecture's emergency monitoring plan in case of a facility site emergency. ・The plan is revised as necessary in accordance with the progress of the nuclear accident and the expansion of contamination, and others, taking into account the opinions of the EMC. ・The plan describes the items that need to be defined for the implementation of emergency monitoring (details of measurement locations and frequency of measurement, as well as sampling locations and frequency of sampling, may be left to the discretion of the EMC.) ・The plan also describes the monitoring conducted directly by the Japanese government, such as aircraft monitoring.
Plume	・A group of air containing gaseous or particulate matter
External exposure	Exposure to radiation from a source outside the body.
Internal exposure	Exposure to radiation from radiation sources in the body following ingestion of radioactive materials into the body by inhalation, oral intake, and the like.

Reference and bibliography list

1. Reference

[Explanation B].

1) 文部科学省　原子力災害対策支援本部, 農林水産省　農林水産技術会議事;東京電力株式会社福島第一原子力発電所事故に伴う放出された放射性物質の分布状況等に関する調査研究結果, 平成24年3月

2) 日本原子力研究開発機構;「土壌に蓄積した放射性セシウムの移行状況調査」, 平成25年度東京電力（株）福島第一原子力発電所事故に伴う放射性物質の長期的影響把握手法の確立事業　成果報告書, part2 105-139, 平成26年3月

[Explanation C].

1) 山縣登, (1973). 4.サンプリングの信頼度について. *Japan Analyst*, 22, 1402-1411.

2) Barnekow, U., et al. (2019). Guidelines on soil and vegetation sampling for radiological monitoring. *International Atomic Energy Agency Technical Reports Series*,486, 39-40.

3) Khomutinin, Y. V., Kashparov, V. A., & Zhebrovska, K. I. (2004). Sampling optimization when radioecological monitoring, *Ukraine Institute for Agricultural Radiology*, Kiev 137,16, ISBN966-646-034-3

[Reference A].

1) Tsuji, H., Takechi, S., Ozaki, H., Nishikiori, T., Kubota, T., & Hayashi, S. (2020). Effect of Storage Temperature and Duration of Environmental Water on Dissolved ^{137}Cs Concentration. *Radioisotopes*,69,315-327, DOI:10.3769/radioisotopes.69.315

2) Tagami, K., & Uchida, S. (2005). Sample storage conditions and holding times for the determination of total iodine in natural water samples by ICP-MS, *Atomic Spectroscopy*, 26(6), 209-214.

3) Tagami, K., & Uchida, S. (2011). Can we remove iodine-131 from tap water in Japan by boiling? – Experimental testing in response to the Fukushima Daiichi Nuclear Power Plant accident, *Chemosphere*, 84(9), 1282-1284.

2. Reference document

U.S. Environmental Protection Agency (EPA)., et al. (2004). *Multi-Agency Radiological Laboratory Analytical Protocols Manual (MARLAP)*, Part II, Chapters 10-17 Appendix F (Volume II), NUREG-1576, EPA 402-B-04-001B, NTIS PB2004-105421

FEDERAL RADIOLOGICAL MONITORING AND ASSESSMENT CENTER. (2019). *Monitoring and Sampling Manual*, Volume 1, Revision 3 Monitoring Division Operations

INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA). (1999). *Generic Procedures for Monitoring in a Nuclear or Radiological Emergency*, Section B, Field Sampling, IAEA-TECDOC-1092

INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA). (2019). *Guidelines on Soil and Vegetation Sampling for Radiological Monitoring*, STI/DOC/010/486

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