

View of Environmental Monitoring in Emergency

–Based on the guide by Japan Nuclear Safety Commission–

Fujita Health University, Michikuni Shimo

Monitoring of environmental radiation is a modest task. Especially, environmental monitoring in emergency is not frequently thought about in normal times. However, one has to prepare for environmental monitoring constantly to avoid oversights during an emergency. The accident at Fukushima Daiichi Nuclear Power Plant unwittingly highlighted importance of environmental monitoring, and measures based on monitoring data became important. Environmental monitoring in emergency is prepared according to the guideline of the Nuclear Safety Commission. This paper will discuss the concept and operation of environmental monitoring following the guideline.

I. Introduction

Previously, monitoring of environmental radiation in emergency was differentiated from the monitoring of environmental radiation in normal times, and organized as a monitoring guideline of environmental radiation in emergency at the Nuclear Safety Commission. In March 2008, two guidelines were unified as part of the guideline review and newly positioned as “monitoring guideline of environmental radiation.” The reason behind this change was that instead of having two separate guidelines existing independently, it is easier to operate when they are unified, because the improvement in the monitoring technology standard is common and unification will lead to a continuous/sustainable relation. Thus, the contents of the new guideline are a continuation of those of previous ones without much change.

Since the new guideline closely relates to environmental monitoring in normal times, this commentary introduces the differences in environmental monitoring in emergency from environmental monitoring in normal times, and how it is expected to be conducted, and the way of thinking, based on the environmental radiation monitoring guideline of the Nuclear Safety Commission (March 2008).

II. Environmental Monitoring

1. Responses in Normal Times and Emergency

During normal times, the priority of environmental monitoring is to protect the health and safety of the residents around nuclear facilities. Therefore, the monitoring is led by local public organizations, and the operators collaborate with them while conducting their own monitoring.

On the other hand, if there is an accident in the facility and unexpected leaking of radioactive material or radiation, or there is fear of leakage, the Japanese government, local public organizations, designated public corporations, and the business operator of the facility must take appropriate disaster prevention measures following the respective disaster prevention plans of each organization based on the Basic Disaster Management Plan (Basic Plan) published by the Central Disaster Prevention Council, as stipulated by the Disaster Countermeasures Basic Act and the Act on Special Measures (Act on Special Measures Concerning Response to Environmental Contamination by Radioactive Material Released from the Accident of the Nuclear Power Plant Caused by the Tohoku District-off the Pacific Ocean Earthquake). Environmental radiation monitoring is to be conducted as a part of this disaster prevention plan. In particular, the disaster prevention measures at nuclear facilities are to be conducted according to the separate guideline by the Nuclear Safety Commission, which corresponds to the 4th Chapter, Emergency Monitoring, of the environmental radiation monitoring guideline to be discussed. The guideline is structured in the following categories: “Monitoring in Normal Time,” “Strengthening of Monitoring in Normal Time,” and “Emergency Monitoring.”

Note that the scope of this guideline includes nuclear reactor facilities, reprocessing plants, processing plants, usage facilities, waste treatment facilities, and waste management facilities.

2. Monitoring in Normal Times

The following four points are the concrete objectives and contents of environmental monitoring in normal times.

- (1) Estimation of local residents’ dose and its assessment.
- (2) Understanding the accumulation tendency of radioactive materials in the environment.
- (3) Early detection of unexpected release of radioactive materials and radiation from facilities and evaluation of its impact on the surrounding environment.
- (4) Preparation of implementation system of environmental monitoring in case of emergency or abnormal situation.

To explain each point succinctly, (1) aims to estimate the dose that originates from radioactive materials or radiation attributed to the nuclear facility and to verify if it is sufficiently below the yearly dose limit; (2) aims to grasp the accumulation situation of radioactive materials released through the operation of the facility in the environment; (3) aims to detect abnormality in a nuclear facility at an early stage; and (4) aims to prepare for a smooth and prompt transition from monitoring in normal times to strengthened monitoring in normal times or environmental monitoring in emergency (emergency monitoring).

Table 1 shows the representative monitoring survey contents, and **Figure 1** shows the flow of selections for measurement equipment. These correspond with monitoring in normal times, but can also be referred to during an emergency.

Table 1 Representative Monitoring Survey Contents

Category	Survey Subject	Measurement Frequency	Notes	
Environmental gamma Radiation	Dose Rate accumulative dose	Continuously Measured Measured Quarterly	Possible to Calculate from the Dose Rate	
Environmental Sample	Land Sample	Atmosphere	Collect and measure continuously, Collect continuously and measure every 1–3 months	Gas monitoring/dust monitoring Airborne dust, etc.
		Inland water	Collect and measure every quarter	Drinking Water, etc.
		Milk	Collect and measure when necessary	I131 Analysis
		Soil	Collect and measure every half year–1 year	Surface soil
		Agricultural products	Collect and measure during the harvest	Greens, root vegetables, rice, etc.
		Index organism	Collect and measure every quarter–1 year	Artemisia princeps, pine needles, etc.
		Fallout and precipitation	Collect and measure every month	Basin method, etc.
	Marine Sample	Seawater	Collect and measure every 6 months	Surface water
		Marine Soil	Collect and measure every 6 months–1 year	Surface soil
		Marine Products	Collect and measure during the fishing season	
Index Organism		Collect and measure every quarter	Sargassum, etc	

(Note) When measuring the air dose rate, measure gamma-ray energy as necessary. Also, conduct nuclide analysis of the environmental sample as a rule.

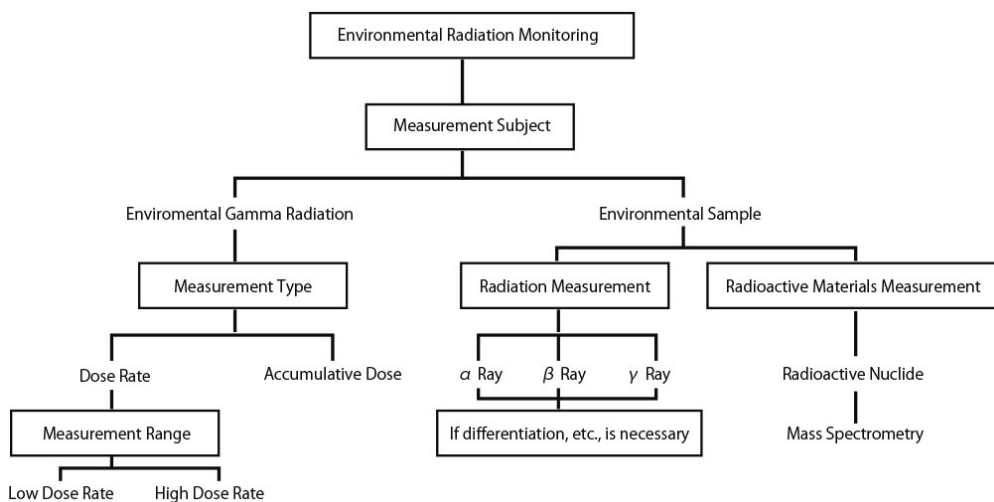


Figure 1 Measurement Equipment Selection Flow

3. Strengthening of Environmental Monitoring in Normal Times

The purpose of strengthening the environmental monitoring in normal times is to take measures for the transitional situation. In other words, when there is an abnormal situation at the facility, it must quickly ascertain its scale and whether there is an impact on the local residents and surrounding environment, as well as clarify the cause and state of the situation and prepare for emergency monitoring.

Following are its concrete contents:

- (1) Strengthening of ambient dose rate monitoring.
- (2) Strengthening of monitoring of radioactive materials in the atmosphere.
- (3) Strengthening of monitoring of meteorological observation.
- (4) Strengthening of accumulative dose monitoring.
- (5) Conduct moving survey.

It is not always necessary to conduct all of them. Instead, only the required action should be taken. In addition, when there is a possibility that a neutron ray is released, its measurement must also be conducted.

III. Emergency Monitoring

1. Purpose

“Emergency (environmental) Monitoring,” which is the main subject of this paper, follows the aforementioned monitoring in normal times and its strengthening. Its main purpose is to collect necessary information for implementing measures for protection against radiation (sheltering, evacuation, food intake restrictions, etc.) enacted during an emergency, and to evaluate their impact on local residents.

2. Role

It is conducted by the national government, local public organizations, designated public corporations and the operator of the facility, and each of them must act according to the Basic Disaster Management Plan (Basic Plan) they prepared.

3. Plan and Content

Emergency monitoring would be pointless unless otherwise its system is immediately activated and implemented when an emergency situation occurs. It is therefore necessary to prepare the “emergency monitoring manual.” This emergency monitoring manual must contain the preparation of the system, preparation of material and equipment, and the implementation method.

Emergency monitoring is divided into phase 1 monitoring and phase 2 monitoring. Following are their contents.

Phase 1 monitoring

A monitoring that is conducted promptly at the time of an emergency. It includes

- (1) Grasping the ambient dose rate around the facility and the concentration of radioactive materials (radioactive noble gas, radioiodine, uranium, or plutonium) released in the

atmosphere.

- (2) Grasping the concentration of radioactive materials in the environmental samples that are deemed to have been influenced by the release of radioactive materials.
- (3) Prompt estimation of the predicted dose to assist the protection measures.

Phase 2 monitoring

A monitoring for evaluating the overall impact on the surrounding environment. It includes

- (4) Continuation of (1) and more detailed comprehension of the concentration of radioactive materials in the atmosphere, for instance, through increasing the subject nuclides.
- (5) Continuation of (2) and more detailed comprehension of the concentration of radioactive materials in the environmental samples, for instance, through increasing the subject nuclides.
- (6) Dose assessment of local residents who may have been exposed.

4. Organization of National System

At the time of an emergency, the national government establishes the “Government Nuclear Emergency Response Headquarters” and the “Local Nuclear Emergency Response Headquarters.” At the Local Nuclear Emergency Response Headquarters, a “radiation team” responsible for having an oversight on the information for emergency monitoring would be set up.

The responsibilities of the radiation team include

- (1) Collection and organization of emergency monitoring data.
- (2) Instructing and advising the emergency response headquarters of local public organizations on emergency monitoring.
- (3) Arrangement of necessary staff, material, and equipment for emergency monitoring.
- (4) Exposure dose prediction using resources such as SPEEDI network system^a.
- (5) Exposure dose assessment of local residents.
- (6) Preparation for the implementation and cancellation plan for the sheltering/evacuation in the designated areas.
- (7) Preparation for the implementation and cancellation plan for food and drink intake restriction in the designated areas.
- (8) Summary for the plan for measures such as food and drink intake restrictions.
- (9) Communication and coordination between respective group responsible for monitoring (e.g., monitoring center) of the Government Nuclear Emergency Response Headquarters and the emergency response headquarters of local public organizations.
- (10) Preparation of documents for joint action council or press briefing related to emergency monitoring.

5. System of Local Public Organizations

On the other hand, setting up a monitoring center and a monitoring team working under it as an organization for precisely and smoothly conducting emergency monitoring work at local public organizations is considered to be effective.

The functions of the monitoring center include

^a SPEEDI: System for Prediction of Environmental Emergency Dose Information

A system for quickly predicting the concentration of radioactive materials in the surrounding atmosphere or radiation dose during an emergency, such as release of radioactive materials from facilities such as a nuclear power plant.

- (1) Preparing plans, instruction, and general management.
- (2) Allocation of staff, material, and equipment.
- (3) Collection and analysis of monitoring information and weather information.
- (4) Report to the emergency response headquarters of local public organization.
- (5) Report to the Government Nuclear Emergency Response Headquarters.

Meanwhile, the roles of the monitoring team include

- (1) Conduct emergency monitoring.
- (2) Report to the monitoring center.

6. Implementation Method

To implement emergency monitoring promptly and smoothly, it is desirable to prepare concrete plans as much as possible in advance, such as the measurement subjects, measurement locations, sampling location, and measurement method for each monitoring phase, while considering the exposure route. By following the concrete plans, effective monitoring is carried out.

Upon implementation, it is necessary to effectively use vehicles and portable monitoring posts to improve mobility, and furthermore, use boats and aircraft when required.

The detailed explanations of phase 1 and phase 2 are described below.

Phase 1 monitoring

As described above, phase 1 monitoring is conducted immediately after the occurrence of an emergency. Thus, the highest priority is speed, accuracy is in second. Results are used for the estimation of predicted dose in conjunction with the release source information, weather information, and information from the SPEEDI network system.

The measurement subjects include

- (1) Air radiation dose rate.
- (2) Concentration of radioactive materials (radioiodine, uranium, or plutonium) in the atmosphere.
- (3) Concentration of radioactive materials (radioiodine, uranium, or plutonium) in the environmental samples (drinking water, green vegetables, raw milk, and rainwater).
- (4) Accumulated dose.

The weather condition and the prediction result of the SPEEDI network system must be considered when the measurement location and sampling location are selected. These locations include

- (1) The location where the maximum spatial radiation dose rate, as well as a few more locations nearby that point, is predicted to appear.
- (2) The location where the maximum concentration of radioactive materials in atmosphere, as well as a few more locations nearby that point, is predicted to appear.
- (3) A few locations that are in the area within approximately 60° with the downwind direction, which pass the location where the maximum concentration of radioactive materials in the atmosphere is predicted to appear and run through the downwind axis.
- (4) The number of measurement locations in the densely populated areas, settlements, evacuation facilities, etc., in the downwind direction should be decided according to the population distribution and other factors.

In addition, when measures such as evacuation are put into effect, environmental monitoring must also be conducted at evacuation facilities.

Phase 2 monitoring

Phase 2 monitoring is started at the stage where the prediction of the accident state is certain and the release of radioactive materials or radiation begins to decrease. Thus, accuracy is more important than speed for this monitoring. To achieve this monitoring, it must be conducted in a wider area than that of phase 1 and its frequency should be daily or every few days after the release of radioactive materials or radiation is stopped. The results are used for understanding the dose assessment of residents and the radiation state of the environment, as well as for lifting various protective measures.

The measurement subjects include

- (1) Ambient dose rate.
- (2) Radioactive concentration in the atmosphere.
- (3) Radioactive material concentration in the environment: Besides the monitoring samples of phase 1, soil, plants, agricultural products, water (rivers, water purification plants), seafood (when there has been release to rivers and the ocean).

Extra caution must be taken for samples that require tracking of how radioactive materials released in the environment change through time. They require sampling and measurements at certain intervals.

7. Estimation and Evaluation of Dose

At the time of an emergency, the first action must be to calculate the concentration of radiation of the surrounding environment and the predicted dose for the residents. This should be followed by the evaluation of the actual concentration of radioactive materials and dose based on the monitoring result. The predicted dose is the estimation of the dose a resident staying in a given area would receive when no protective measures are taken, based on the released amounts of radioactive materials and radiation, weather condition, etc. Needless to say, the predicted dose changes with the situation.

Preparation of predicted dose distribution map

The calculation methods for obtaining the information for the predicted concentration of radioactive materials and predicted dose include a detailed calculation method that uses a computer (SPEEDI network system) and a simple calculation method that uses diagrams.

The detailed calculation method receives weather data in real time and calculates the distribution of concentration of radioactive materials and dose distribution that move and diffuse through the atmosphere using various databases of information, such as topography prepared and stored in advance, and displays them as diagrams. In an emergency, the calculation can also be performed by speculating the release source information.

The simple calculation method prepares diagrams based on the calculation result of the atmospheric diffusion equation when online information of the SPEEDI network system is not available.

8. Estimation of Predicted Dose

From the perspective of taking protective measures, the predicted dose must be estimated quickly. As the situation differs depending on the type of facility, it is categorized into the following two cases.

In the case of nuclear reactor facilities

The dose assessment of nuclear reactor facilities is mainly conducted from the effective dose of external exposure by using a radioactive noble gas and from the thyroid equivalent dose of internal exposure by radioiodine. This is because as a nuclear reactor is sheltered in multilayered protective walls, there is hardly any need for considering direct radiation and the possibility of solid or liquid radioactive material leaking to a large area is small. The radioactive materials that have high likelihood of leakage are the noble gases such as krypton and xenon, and radioiodine, which is volatile. In addition, aerosol accompanying them moves within the atmosphere, and thus, can be responded with the same measures as those mentioned above.

In the case of nuclear fuel facilities

At a nuclear fuel facility, release of uranium or plutonium in the form of aerosol due to fire, explosion, or leakage is assumed. In that case, direct release following an explosion and the amount of the release must be considered besides the release/diffusion in the plume form. Note that particles are deemed to settle relatively faster than gases.

Moreover, when there is a critical accident, exposure by neutron ray and γ ray must also be considered. However, as the strength of radiation decreases mostly in proportion with the inverse square of the distance, the impact is limited to the short distance. Even during a critical accident, estimation of external exposure by a radioactive noble gas and thyroid equivalent dose by radioiodine is necessary depending on the type of accident.

9. Points to be Cautious about When Estimating the Predicted Dose

As promptness is required in the predicted dose, accuracy tends to be neglected. Following are the points that require caution when estimating the predicted dose.

- (1) Obtaining and verification of the release source information (accurate released amount, composition of released nuclide, properties, and the time for which the release continued).
- (2) Recognition and notification of the uncertainty of the calculation result based on insufficient release source information.
- (3) Balance of speed and accuracy when preparing diagrams.
- (4) Continuous adjustment of calculated value based on the monitoring value and complementation of the monitoring value using the calculation diagram.
- (5) Addition of information related to the trustworthiness of the calculation result (date, information source, etc.).

These points can easily be overlooked at a busy emergency site, but must be followed with calm judgment and composed action.

IV. Conclusions

This paper explained the view of environmental radiation monitoring in emergency and its implementation methods based on the guideline of the Nuclear Safety Commission.

When the emergency monitoring conducted after the Fukushima Daiichi Nuclear Power Plant Accident is studied, it shows that while most of the points/method discussed here were sufficient as the response to the accident, there were events that were beyond the preparation.

For instance, the category of facilities itself did not fit the predicted categories. The facts that there was a meltdown of the nuclear reactor, the hydrogen explosion broke the multilayered protective walls of the nuclear reactor, and the radioactive materials were released from the spent fuel storage pool were phenomena that were not assumed in the environmental monitoring guideline.

Regarding individual responses, not enough information was provided quickly in the operation of the SPEEDI network system despite its praised prediction function. Suggested reasons for this include uncertainty of radiation source information. As it is the responsibility of monitoring to contribute to the safety of the residents, it is imperative to conduct thorough examination of both hardware and software and to promptly implement the necessary improvement. Moreover, it is regrettable that there were delays even though quick information disclosure is discussed in the monitoring guideline, regardless of the reasons for the delays. In addition, there are rumors that some information was not shared. The fact that there are such rumors at all is already a problem.

Though there are many problems, as discussed above, there is no doubt that environmental radiation monitoring in the emergency was somehow conducted by unifying the monitoring data measured by municipalities, universities, and various research institutes at the Ministry of Education, Culture, Sports, Science and Technology, which contributed to the disaster prevention activities. Needless to say, an appropriate, reliable, and accurate monitoring is required in a situation that is predicted to continue for a long time. In order to achieve this, it is necessary to quickly and resolutely improve the environmental radiation monitoring that were not adequate for this unprecedented accident.

General References

- 1) Nuclear Safety Commission. Environmental Monitoring Guideline. 2008 March. [in Japanese]
- 2) Ministry of Education, Culture, Sports, Science and Technology. Radiation Measurement Methods Series. [in Japanese]
- 3) Chino M. Study on nuclear energy and atmospheric diffusion. *Nihon-Genshiryoku-Gakkai Shi (J. At. Energy. Soc. Jpn.)*. 1990; 32: 1080–1086. [in Japanese]
- 4) Yoshida H, Nagai H, Furuno A. Development of system for prediction of environmental emergency dose information (World Version) WSPEDI 2nd Version. *Nihon-Genshiryoku-Gakkai- Wabun-Ronbun Shi (J. Jap. Papers of At. Energy Soc. Jpn.)*. 2008; 7: 257–267. [in Japanese]