Cooperation between Fukushima Prefecture and the IAEA

In the Area of Radiation Monitoring, Remediation and Waste Management, Following the Fukushima Daiichi Nuclear Power Plant Accident (Fukushima Prefecture Initiative Projects)

INTERIM REPORT (2013–2015)

(Temporary translation)

2016
Fukushima Prefecture

Introduction

Severe damage was caused by the Tohoku Earthquake that struck on March 11, 2011 and the accompanying accident at the Fukushima Daiichi Nuclear Power Plant operated by the Tokyo Electric Power Company. Restoring the environment after this unprecedented nuclear disaster and creating an environment in which residents of Fukushima Prefecture can live with peace of mind well into the future have become pressing challenges.

It is critical to gather the wisdom of the world and to work to overcome these challenges, and Fukushima Prefecture thus decided to collaborate with the International Atomic Energy Agency (IAEA), which has advanced knowledge in fields concerning nuclear technology. A memorandum of cooperation between Fukushima Prefecture and the IAEA was signed in December 2012.

According to this memorandum, practical arrangements in the fields of decontamination and radiation monitoring between Fukushima Prefecture and the IAEA were signed on the same date. (Projects based on these arrangements are referred to as FCPs.)

Following this, additional arrangements were signed for five projects (referred to below as FIPs) proposed by Fukushima Prefecture in April and October 2013 as a new framework with which to receive support from the IAEA for projects implemented by Fukushima Prefecture.

The five FIPs are the projects and activities listed below.

1) Survey of radionuclide movement in rivers and lakes

2) Survey of radionuclide movement with wildlife

3) Project for studying decontamination technology for rivers and lakes

4) Development of environmental mapping technology using GPS walking surveys

5) Project for the study of promoting the proper treatment of waste containing radioactive materials at municipal solid waste incinerators

FIPs began in 2013, the year in which the practical arrangements were signed, and it was decided to publish this interim report because 3 years have passed since.

Fukushima Prefecture has received various forms of support from the IAEA over the 3 years, the major contents of which are described below.

Contents of major support received from the IAEA

1) Survey of radionuclide movement in rivers and lakes

- Provision of a TODAM (Time-dependent, One-directional, Degradation and Migrational) model, which is a numerical simulation code of contaminant migration in a river network, for the quantitative estimation of radionuclides deposited in rivers.
- Technical guidance on the selection of monitoring points and monitoring items, and an indication of the importance of continuous monitoring at each monitoring point, based on previous studies for Chernobyl and Mayak.
- Regarding monitoring data obtained by Fukushima Prefecture, advice that measuring Kd values and ion concentrations (especially K^+ and NH_4^+) in river water at each monitoring point is important for the use of numerical models such as the TODAM model.
- Advice on the effectiveness of combining monitoring and models and adding small lakes and marshes as subjects of research in advancing future research on the dynamics of radioactive substances in rivers.

2) Survey of radionuclide movement with wildlife

- Provision of foreign literature describing the relationship between wild animals and radionuclides, such as the state of radiocaesium in the muscle tissue of wild animals including boars and deer in various regions following the Chernobyl nuclear disaster and changes in radiocaesium levels in the bodies of birds, such as the American gallinule and American wood duck, at the Savannah River Ecology Laboratory.
- Provision of information about the latest scientific results concerning the bioaccumulation of radiocaesium from experts investigating the relationship between wild animals and radioactive substances.
- Advice on the discussion of study results and data analysis methods, such as the potential that mushrooms are the cause of a high radiocaesium concentration in boars of Fukushima Prefecture, arising from the fact that mushrooms (deer truffles) were found to be the cause of a high radiocaesium concentration in the muscle tissue of European boars.

3) Project for studying decontamination technology for rivers and lakes

- Provision of information concerning the environmental dynamics of radioactive substances in rivers, lakes, and marshes of various countries.
- Provision of case studies of environmental remediation measures, such as the decontamination of radioactive substances in rivers, lakes, and marshes of various countries, including countermeasures for the inflow of high concentrations of radioactive substances to the Pripyat River and measures for suppressing the inflow of radioactive substances to the Kiev Reservoir.
- Advice on the effective implementation of verification tests targeting riverbeds, including the necessity of survey items, survey points, and advance simulations for studies confirming reduced effects of air dose rates and the necessity of survey items (e.g., the size distribution of particles in suspended phases) and weeding test sites when evaluating recontamination.
- Regarding studies of effective radioactive-substance countermeasures targeting river parks, advice to reference past flooding records when selecting survey sites and advice that the dredging and construction of embankments, as well as grit chambers in upstream basins, are effective at sites where there is a concern of recontamination.

4) Development of environmental mapping technology using GPS walking surveys

- Provision of information about efforts made by institutions such as the United States Environmental Protection Agency and Lawrence Berkeley National Laboratory regarding local radiation dose mapping.
- Advice that inverse-distance weighting (IDW) is more appropriate than Kriging as a means of interpolation for walking surveys using the GIS, and that considerations must be made for the shielding effect of buildings and the like.
- Advice to judge measurement conditions of walking surveys by the situation at each measurement point, as it is not always necessary to set uniform measuring conditions.

5) Project for the study of promoting the proper treatment of waste containing radioactive materials at municipal solid-waste incinerators

- Provision of information on treatment methods employed in other countries for fly ash,

treatment methods employed in other countries for low-level radioactive waste (i.e., incineration, melting treatment of metal, and plasma melting), and instruments for measuring the concentrations of radioactive substances in waste.

- Technical advice about the incineration of general waste, such as the necessity of studies conducted from the perspective of the caesium balance of payments, the importance of the comparative analysis of actual verification test data and model analysis results, and the necessity of identifying test conditions and assessing waste quality.
- Advice about the importance of countermeasures to the generation of hydrogen fluoride in the mixed incineration of bag filters (made from Teflon).
- Advice on the necessity of checking the safety (e.g. exposure protection and management) of facility workers.

In this manner, Fukushima Prefecture has implemented FIPs with support from the IAEA. The interim report including results of FIPs is provided as follows.

＜This document is issued under the authority and responsibility of the Fukushima Prefecture. ＞

1. FIP1: Survey of radionuclide movement in rivers and lakes

1.1. Purpose

Fukushima Prefecture has been widely contaminated by radioactive materials owing to an accident that occurred in 2011 at the Fukushima Daiichi Nuclear Power Station operated by the Tokyo Electric Power Company. Because river water is widely used for tap water and agricultural water, it is important to understand the movement of radioactive materials in rivers and to provide information necessary for the safe use of river water. Additionally, while the effect of redeposition during floods on the air dose is a concern when radiocaesium flows downstream on particles, it is also necessary to consider migration through the ecosystem when radiocaesium flows downstream in a dissolved state. It is necessary to grasp the movement of radiocaesium in both its forms. We therefore studied rivers flowing through Fukushima Prefecture with the purpose of understanding the dynamics of radioactive materials in rivers, while also aiming for verification of dynamics forecasting with models based on the monitoring data obtained.

1.2. Methods

In a survey of the Hirose River Basin (Figure 1(a)), we established monitoring points on the Hirose River and its tributaries from 2013 to conduct our survey. In the wide-area survey, we conducted multi-point surveys of the Abukuma River System and eight river systems in the Hamadori area (Figure 1(b)). At each monitoring point, we continuously monitored the turbidity and water level, and collected suspended sediment samples with a suspended sediment sampler.

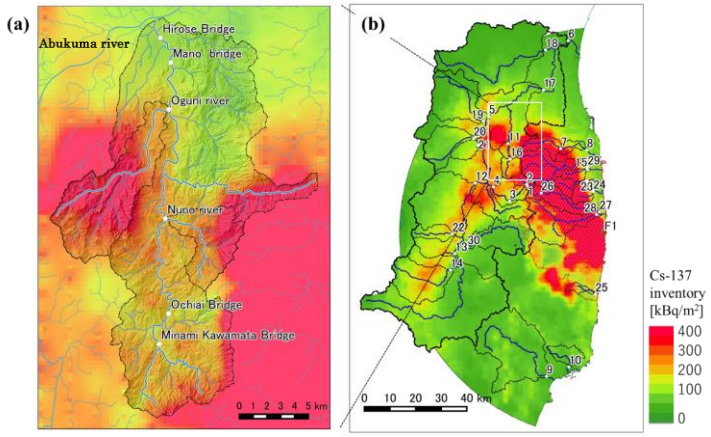

Figure 1: Map of the locations of monitoring sits and Cs-137 inventory on July 2, 2011
(a) Hirose River Basin.
(b) Area subject to a wide-area survey.

** Source: Results of the Third Airborne Monitoring Survey by MEXT (2011)*

1.3. Results

The International Atomic Energy Agency provided us with the TODAM (Time-dependent, One-directional, Degradation and Migrational) model, which is a numerical simulation code of contaminant migration in a river network, necessary for implementing radionuclide movement forecasting, and we established a monitoring network for collecting data in the Hirose River Basin. The particulate caesium-137 concentration at sites 1–6 in Figure 1(b) decreased to less than one-tenth of the initial values in the 5 years since the accident (Figure 2). The rate of decrease was extremely high compared with the half-life of caesium-137.

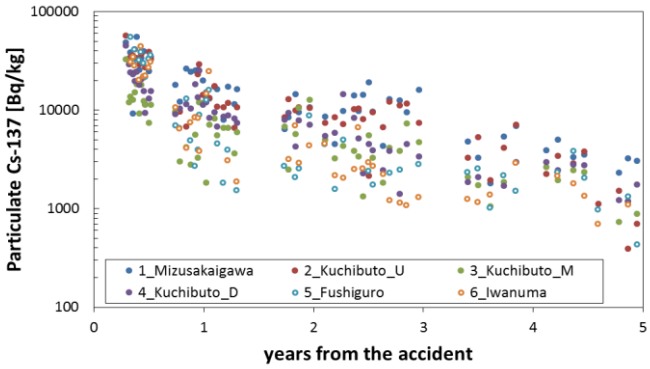

Figure 2: Temporal change in the particulate Cs-137 concentration at six long-term monitoring sites

1.4. Conclusion

Thus far, we have collected necessary data for application of the TODAM model and established a monitoring network necessary for the verification of dynamics forecasting in the Hirose River Basin. In the future, we will implement continuous monitoring and conduct numerical modeling for radionuclide dynamics forecasting in the Hirose River Basin using these results. We also performed a wide-area survey of the Abukuma River System and major rivers in the Hamadori area, and found that the concentration of particulate radiocaesium that is adsorbed by small particles and flows downstream tends to decline. It is important that we continue to accumulate data and continuously grasp the dynamics of radioactive materials in the wide area.

2. FIP2: Survey of radionuclide movement with wildlife

2.1. Purpose

Owing to the accident at the Fukushima Daiichi Nuclear Power Station, radionuclides, such as radiocaesium, have been found in many wild animals inhabiting the natural environment. Because of the lack of knowledge concerning the migration of radiocaesium from the environment to wildlife, we began surveys and research to understand the movement of radiocaesium in the ecosystem.

2.2. Methods

(1) Movement of radionuclides with wildlife

We conducted measurements of the caesium-137 concentration contained in the muscles of wildlife, such as boars and black bears, as well as composition analysis of the stomach contents of boars and surveys of food that is a high source of caesium for boars.

(2) Home range of wildlife

We surveyed the home range of boars using Global Positioning System (GPS) collars.

2.3. Results

(1) Dynamics of radionuclides in wildlife

a) Measurement of the concentration of gamma-ray-emitting nuclides in the bodies of wildlife

Having compared the caesium-137 concentrations contained in the muscles of boars and black bears, we found that there is large variation between individuals among boars but a general downward trend in black bears; there are thus different trends depending on the species of wildlife (Figure 1).

b) Movement of radionuclides into the bodies of wildlife from the environment

We confirmed that the composition of the stomach contents of boars changes with the seasons. Although European research considers the radiocaesium concentration contained in the muscles of boars to be high because of their consumption of fungi, we were unable to find any pieces of fungi in the stomach contents of boars in the present research.

c) Form of radiocaesium contained in stomach contents

Regarding the migration of radiocaesium into the bodies of boars, we are proceeding with surveys to clarify the forms of radiocaesium contained in the stomach contents of boars and the effect of consuming soil.

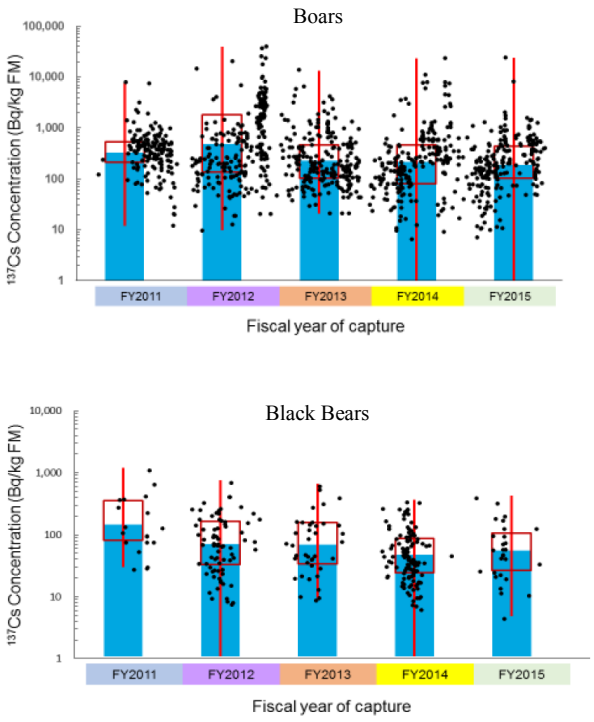

Figure 1: Caesium-137 concentration in the muscles of boars and black bears (data period: May 2011–December 2015)

(2) Home range of wildlife

Having surveyed the home range of boars using GPS collars, we found that compared with home range of boars outside the evacuation area, the home range of boars living inside the evacuation area tended to expand. It is thought that the decline of artificial pressures, such as the decline due to the evacuation of residents and the decline due to the decline of hunting in the evacuation area, has expanded the home range of boars in the evacuation area.

2.4. Conclusion

(1) The concentration of caesium-137 contained in the muscles of wildlife has different trends depending on the species.
(2) It was confirmed that the stomach content composition of boars changes with the seasons.
(3) It was found that compared with the home range of boars outside the evacuation area, that of boars living inside the evacuation area tends to expand.

3. FIP3: Project for studying decontamination technology for rivers and lakes

3.1. Purpose

Because the diffusion of radiocaesium due to the accident at the Fukushima Daiichi Nuclear Power Plant has caused failures and anxiety in the use and management of rivers and lakes, we have studied countermeasures by using existing knowledge and implementing surveys.

3.2. Methods

(1) Extract countermeasures applicable to Fukushima Prefecture from existing information
(2) Tests of decontamination on riversides with limited samples
(3) Survey of the state of contamination in river parks, which are lands for public use

3.3. Results

(1) Radiocaesium countermeasures considered to be applicable to Fukushima Prefecture

Problem	Media and Countermeasures
Internal exposure via drinking water	Rivers and lakes: change to alternative sources of drinking water
Immigration of radiocaesium from irrigation water to crops and external exposure during farm work	Rivers and lakes: mitigation of sediment inflow using silt fences, use of the sedimentation function of a dam Irrigation ponds: silt fences, decontamination of bottom sediment Overall: potassium fertilization of farmland
Internal exposure via the ingestion of aquatic products	Rivers and lakes: restriction of distribution, input of potassium (limited to closed lakes)
External exposure when using waterside areas (e.g., parks, roads, and housing)	Rivers, lakes, and irrigation ponds (when being drained): access control, decontamination of floodplains Rivers: excavation of riverbeds, building of embankments Irrigation ponds: decontamination of bottom sediment, covering with sand
Common to all problems	Sediment transportation prevention and decontamination of source areas of sediment, risk communication

(2) Decontamination tests of riversides

Unlike the case for residential and agricultural areas, at riversides where sediment containing radiocaesium is deposited thickly in part, it has been shown that soil decontamination on the basis of the radiocaesium distribution is effective. After decontamination, there is the possibility of recontamination due to flooding, but there was no noticeable silt deposition 6 months after decontamination, and there was no change in the air dose rate.

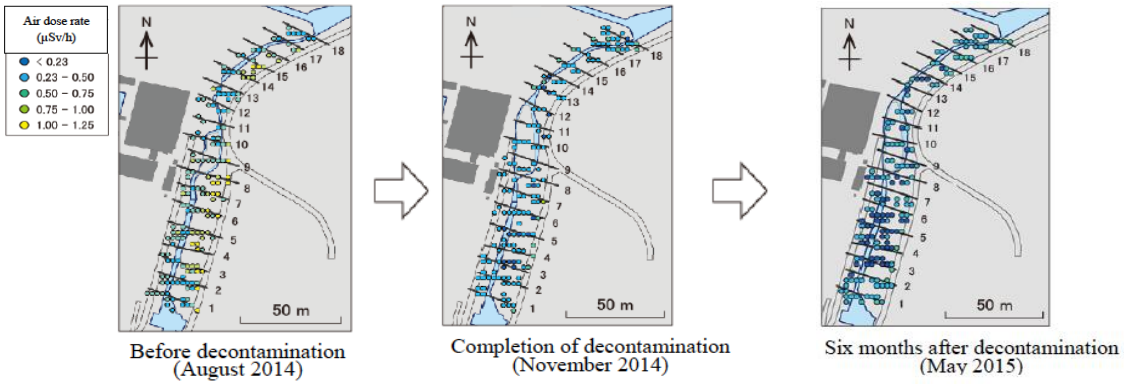

Figure1: Air dose rate distribution 1 m above the ground before and after decontamination (Kami-Oguni River, in the Abukuma River System)

(3) Survey of the state of contamination in river parks

The results of surveying a river park on the Niida River, a major river in the Hamadori region that has remarkable contamination upstream, show that the air rate dose rate on the riverside was 2 to 3 times that in the surrounding areas. However, heavy rains in September 2015 caused erosion and the deposition of sediment with a low gamma-ray-emitting caesium concentration, and the air dose rate decreased to 1.5 times that in the surrounding area. The additional external exposure dose was estimated at less than 0.1 mSv annually, and it is thus considered that there are no problems associated with using the river park.

3.4. Conclusion

We organized gamma-ray-emitting caesium countermeasures related to the use of water, and conducted decontamination tests for the purpose of reducing external exposure on a riverside that has been the subject of a few case studies. Considering also the contamination state of the park, it is advisable to make a judgment regarding countermeasure policies having comprehensively verified the spatial distribution and temporal changes in gamma-ray emitting caesium and the exposure dose.

4. FIP4: Development of environmental mapping technology with GPS walking surveys

4.1. Purpose

To grasp the air dose rate (hereinafter, simply referred to as the dose rate) in Fukushima Prefecture after the accident at the Fukushima Daiichi Nuclear Power Plant, we have measured the dose rate employing a variety of methods, and we provide this information on our homepage.

However, it is difficult to conduct fixed-point measurements or car-borne surveys in the alleys of residential areas, parks, or forests. We therefore developed environmental mapping technology that uses GPS walking surveys (hereinafter, simply referred to as walking surveys) to supplement other forms of monitoring.

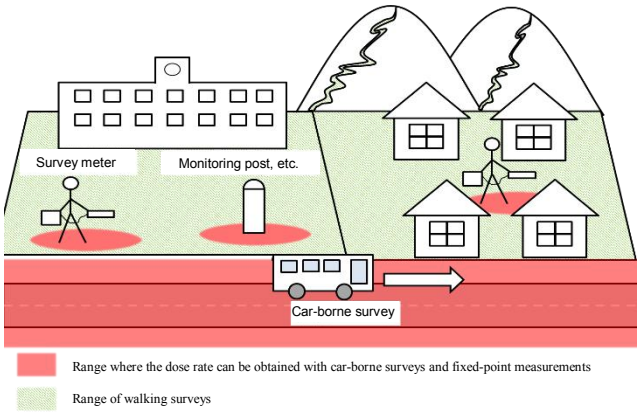

Figure1: Measurement range of walking surveys

4.2. Methods

(1) Development of equipment

We used KURAMA-II, which was developed by Kyoto University, for walking surveys. KURAMA-II is a system that can combine data obtained from a radiation detector and GPS device to map dose rates. We used a high-precision GPS device and stored the equipment in a backpack as a configuration that is appropriate for walking surveys.

Picture1: Image of a walking survey

(2) Gathering parameters necessary for walking surveys

Because the contribution of radiation sources varies depending on the direction in walking surveys, owing to obstruction by the measurer himself or herself, we confirmed the direction characteristics.

To decide the correction factor employing comparative tests with survey meters, we used the dose rate measured 1 m above ground by a NaI (Tl) survey meter, whose traceability has been established as the most certain, and compared that dose rate with the measurement obtained in walking surveys.

4.3. Results

Results for the direction characteristics indicate that the effect of direction characteristics on measurements of walking surveys is weak. Additionally, in our comparison with NaI (Tl) survey meters, we found that it is necessary to use different detectors for low and high dose rates with 1 μSv/h as the dividing line. In light of this, we set the correction factor as 1.3 when using a low-dose-rate detector and 1.1 when using a high-dose-rate detector.

4.4. Conclusion

Certain results have been achieved in the development of walking surveys by 2015, making it possible to measure the dose rate in a walking survey.

5. FIP5: Project for the study of promoting the proper treatment of waste containing radioactive materials at municipal solid-waste incinerators

5.1. Purpose

We conducted demonstration tests at operating incineration facilities to study the immigration behavior of radiocaesium to bottom ash and fly ash, and to confirm the effectiveness of methods of controlling this radiocaesium migration, as well as technologies that remove radiocaesium in the incineration ashes or make radiocaesium in ashes less soluble. All information and technologies obtained will be used for the safe and proper disposal of incineration ash (i.e., bottom ash and fly ash).

We also observed the effects of the coincineration of used filter cloth of bag filters generated by a solid-waste incineration facility with municipal solid waste (MSW). We focused on the change in the radiocaesium distribution to bottom ash and fly ash, and the effects of coincineration on the facility and environment.

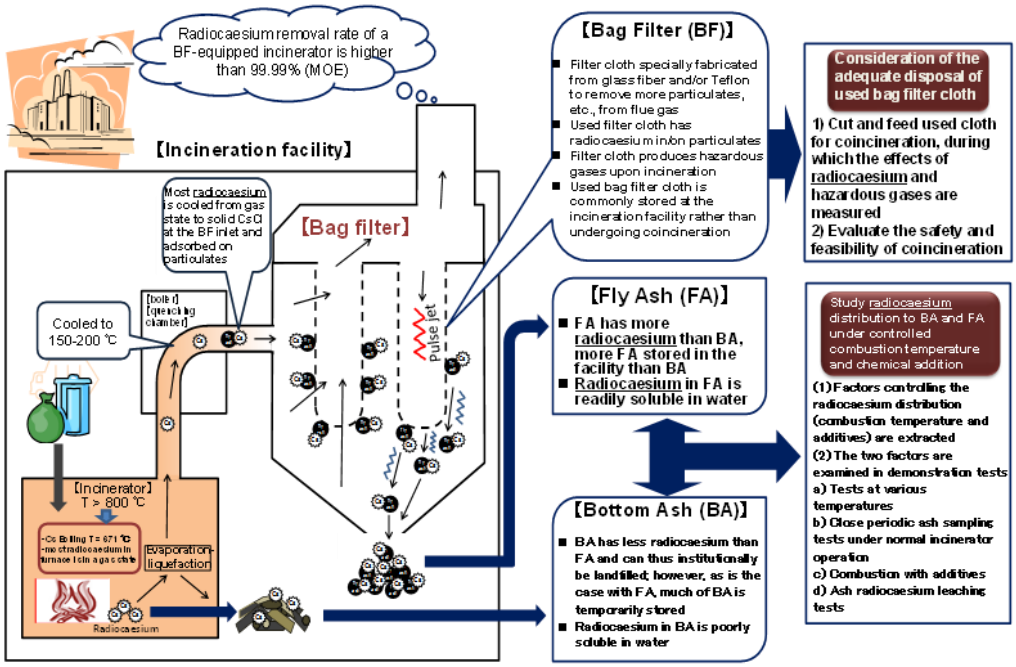

Figure 1: Issues in the waste combustion process and test study

5.2. Methods

(1) Distribution of radiocaesium to bottom ash and fly ash

・Tests for different combustion temperatures

We compared the distributions of radiocaesium to bottom ash and fly ash when the combustion chamber outlet temperature was raised or lowered 50° C from normal operation, and observed the effect of the temperature change on radiocaesium migration behavior.

・Continuous sampling tests

We continuously sampled bottom ash and fly ash during normal operation, and observed the relationship between the combustion temperature and the migration of radiocaesium to bottom ash and fly ash.

・Tests confirming the effects of a radiocaesium evaporation accelerator and inhibitor

We sprayed radiocaesium evaporation accelerator (hydrated lime) or inhibitor (bentonite) on waste fed into a hopper and observed the effects.

(2) Proper treatment of filter cloth covered in fly ash containing radiocaesium

・Used bag filter cloth coincineration tests at solid-waste incinerator facilities

In two facilities having different filter cloth materials, we conducted coincineration tests

while changing the used filter cloth input ratio and input intervals, and observed the effect on the radiocaesium distribution to bottom ash and fly ash, the exhaust gas, the facility, the environment, and the state of waste combustion.

(3) Understanding radiocaesium leaching characteristics of bottom ash and fly ash

・Leaching tests of bottom ash and fly ash

We conducted leaching tests on bottom ash and fly ash sampled from six solid-waste incineration facilities in Fukushima Prefecture, and surveyed the leaching characteristics of radiocaesium.

5.3. Results

(1) Distribution of radiocaesium to bottom ash and fly ash

Although a greater radiocaesium distribution to fly ash was observed with the addition of hydrated lime as a volatility accelerator, we were unable to confirm the reproducibility of this behavior. No clear relationship was confirmed between the combustion temperature and the migration behavior of radiocaesium.

(2) Proper treatment of used bag filter cloth adhered with fly ash containing radiocaesium

We confirmed that if the coincineration ratio is set properly, the coincineration of used bag filter cloth with MSW has no meaningful effect on the radiocaesium distribution to bottom ash and fly ash, the exhaust gas, the facility, the environment, or the state of waste combustion.

(3) Understanding radiocaesium leaching characteristics of bottom ash and fly ash

We confirmed a generally recognized trend that fly ash has a fairly high radiocaesium leaching rate while bottom ash has a low leaching rate.

5.4. Conclusion

We conclude that a safe and proper coincineration of used bag filter cloth and MSW can be achieved with a proper setting of the coincineration rate.

Regarding the relationship among the combustion temperature, the addition of chemicals, and the radiocaesium distribution to fly ash, very real problems such as a lack of clear reproducibility of the results remain unsolved.