Off-site decontamination and remediation following the Fukushima Daiichi NPP accident

Results elaborated in the Fukushima Prefecture and comparison with global experience

Cooperation between the International Atomic Energy Agency and Fukushima Prefecture

Final version: September 2023

FOREWORD

The 11 March 2011 earthquake off the Pacific coast of Tohoku and the subsequent tsunami and accident at Tokyo Electric Power Company’s Fukushima Daiichi Nuclear Power Plant (hereinafter referred to as ‘Fukushima Daiichi accident’) resulted in radioactive contamination deposited in various areas of Japan, including Fukushima Prefecture.

In December 2012 the International Atomic Energy Agency and the Fukushima Prefecture signed a Practical Arrangement with the objective to define the framework for cooperation between the Prefecture and the Agency to provide broad and extensive assistance to the Prefecture in areas related to radiation monitoring and remediation in order to ensure ongoing protection of people and the environment from ionizing radiation resulting from the 2011 Fukushima Daiichi accident. The cooperation was designed to complement existing Japanese activities and to provide immediate assistance and support which will be of direct benefit to residents of the Prefecture as well as visitors to the Prefecture.

This publication summarises the studies discussed as part of the cooperation project between the Fukushima Prefecture and the International Atomic Energy Agency on decontamination and remediation in the Fukushima Prefecture; this cooperation project ran from 2012–2022. The report covers the experience gained in Fukushima Prefecture in environmental monitoring of radionuclides and specific studies of the behaviour of radiocaesium in the environment. The focus is on comparing observations made in Fukushima Prefecture after the accident with data obtained in studies conducted in other parts of the world. Similarities and differences in observations following the Chernobyl and Fukushima Daiichi nuclear power plant accidents are highlighted. This publication is intended to share this work with all IAEA Member States.

The IAEA is grateful to all participants of the Cooperation Project from the Fukushima Prefecture and the International Atomic Energy Agency. The contributions of the Fukushima Prefecture and the international experts in drafting and review of this publications are acknowledged. The IAEA officers responsible for this publication are T. Yankovich and J. Brown of the IAEA Division of Radiation, Transport and Waste Safety.

CONTENTS

SUMMARY

The accident at the Fukushima Daiichi nuclear power plant, caused by an earthquake and tsunami on 11 March 2011, resulted in the release of radionuclides into the environment. The deposition of radiocaesium in Fukushima Prefecture was very heterogeneous; the most affected areas are located in the northwest of the power plant in a mountainous area that is predominantly covered by forests and is home to many freshwater bodies such as rivers, lakes and reservoirs.

In response to the accident, restrictions on the consumption of foodstuffs were imposed by the Japanese authorities. Immediately after the accident, monitoring programmes started to check compliance with the limits for activity concentrations in food and to assess gamma dose rates in air against the reference level for members of the public set by the Government of Japan. In addition, research programmes were initiated to analyse in detail the behaviour of radiocaesium in the terrestrial and aquatic environment. The Fukushima Prefecture played a key role in planning and implementation of countermeasures as well as in providing technical advice to the municipalities.

In December 2012, a cooperation between the Fukushima Prefecture and the International Atomic Energy was initiated in the fields of management of remediation waste, radiation monitoring and of decontamination and remediation of areas and water bodies affected by deposition of radionuclides. The focus of the cooperation was on analyzing and discussing the radiological situation in the Prefecture and providing technical advice to the Prefecture based on international best practices developed in these fields since the 1950s.

This report summarizes the results of this cooperation in the field of decontamination and remediation of areas affected by the deposition of radionuclides due to the accident in the Fukushima Daiichi Nuclear Power Station. The main topics covered in the report are: (i) the behaviour of radiocaesium in freshwater bodies; (ii) the dislocation of ^{137}Cs in watersheds of rivers in the Fukushima Prefecture; (iii) remediation work in the Fukushima Prefecture; (iv) aspects of the characteristics of microparticles containing ^{137}Cs (CsMPs); (v) and dissemination of information to the public on the radiological status in the Fukushima Prefecture, on the planning and on the progress of decontamination activities.

This report provides a compilation and analyses the radioecological information obtained during Fukushima Prefecture’s cooperative project with the IAEA between 2012 and 2022 with the objective of contributing to the global dissemination of the experience gained by Fukushima Prefecture in the field of the behaviour of radiocaesium in the environment and the effectiveness of decontamination and remediation after the accident.

1. INTRODUCTION

1.1. BACKROUND

As a result of the earthquake off the Tohoku Pacific coast on11 March 2011, and the resulting tsunami, an accident occurred at the Fukushima Daiichi nuclear power plant in Japan. Radionuclides were released into the environment and deposited particularly in Fukushima and the neighbouring Prefectures. Immediately after the accident, monitoring programmes were initiated to determine gamma-dose rates and their time-dependence, radionuclide levels in foodstuffs and in environmental media to study the behaviour of radionuclides in the environment.

Requirements for the protection of people and the environment in existing exposure situations in areas affected by enhanced levels of radionuclides are established in IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards [1]. Recommendations on planning and implementing the remediation of sites and areas affected by such past activities and events to meet the requirements established in the Basic Safety Standards are given in IAEA-GSG-15 [2].

To support Member States in the practical management of areas affected by past activities, IAEA has published technical reports describing decontamination and remediation techniques and their effectiveness in reducing activity and radiation levels in the environment. Important publications are e.g.: (i) Guidelines for Agricultural Countermeasures Following an Accidental Release of Radionuclides [3]; (ii) Guidelines for Remediation Strategies to Reduce the Radiological Consequences of Environmental Contamination [4]; (iii) Assessment of Radioactive Contamination and Effectiveness of Remedial Measures in Urban Environments [5]; and (iv) Ten Years of Remediation Efforts in Japan [6]. Technical Volume 5 the IAEA report on The Fukushima Daiichi accident [7] provides a comprehensive description of on-site and off-site recovery efforts implemented after the accident. The IAEA report on an International Expert Meeting on Decommissioning and Remediation after a Nuclear Accident [8] summarizes the experience gained and the lessons learned from decommissioning and remediation projects implemented in various Member States.

In December 2012 the IAEA and the Prefecture signed an agreement titled Practical Arrangements between Fukushima Prefecture and the International Atomic Energy Agency on Cooperation in the Area of Radiation Monitoring and Remediation (hereinafter referred to as ‘Practical Arrangements’).

The Practical Arrangements were modified and extended in April/May 2016 and again in December 2017 to consider other areas of work and activities in which cooperation may be pursued.

The activities that were part of the Practical Arrangements under which IAEA has provided assistance to the Prefecture can be summarized as:

- Research and studies on radiation monitoring in terrestrial and aquatic environments, including application of environmental mapping technology by using unmanned aerial vehicles and long term monitoring of radioactive materials;
- Research and studies on remediation of terrestrial and aquatic environments in the Prefecture;
- Research and studies on the management of radioactive waste from remediation.

The objective of the cooperation was to provide comprehensive support to the prefecture in these areas to ensure the protection of people and the environment from ionizing radiation resulting from the 2011 Fukushima Daiichi accident. The cooperation was designed to complement ongoing Japanese activities and to provide immediate assistance and support for the direct benefit to residents of the Prefecture as well as visitors to the Prefecture. IAEA's activities in implementing these projects focused on providing effective technical assistance and support to the prefecture based on international experience and best practices.

Some of the data summarised in this publication have been analysed within the IAEA Models and Data for Radiological Impact assessment programme (MODARIA) [9]. Results of radioecological studies carried out in Japan after the accident have also been summarized and compared with pre-accident data collected in Japan and with existing data from other parts of the world covering a wider range of topics and environments [10, 11].

1.2. OBJECTIVES

The objective of this publication is to provide a compilation and analyses of the radioecological information obtained during Fukushima Prefecture's cooperative project with the IAEA between 2012 and 2022 which can contribute to the global dissemination of the experience gained after the FDNPP accident in 2011. The focus of the report is on the behaviour of radiocaesium in the environment and the effectiveness of decontamination and remediation after the accident.

As part of the IAEA's cooperation with Fukushima Prefecture, international experts and IAEA staff provided technical advice based on IAEA safety standards and international best practices for evaluating measurements results as well as on planning and implementing the measures carried out by the Prefecture. Additionally, results of studies on the fate of radiocaesium in the environment conducted by other research institutes were also included in the discussion. The topics covered in the report are:

- The behaviour of ^{137}Cs in freshwater bodies including time-trends of radiocaesium in water, and suspended and bottom sediments;
- Loss of ^{137}Cs from catchments with surface run-off;
- Remediation activities and their effectiveness in freshwater bodies of the Fukushima Prefecture;
- Characteristics of Micro-Particles containing radiocaesium (CsMPs);
- Interaction with the public and experience with dissemination of results;
- Review of global experience in these areas gained during remediation activities following enhanced releases of radionuclides to the terrestrial and aquatic environment in other parts of the world.

The publication summarizes the information acquired during the cooperation project; it includes data obtained during the related programs on monitoring radiocaesium activities in the environment as well as research projects set up to investigate specific topics on the environmental transport of radiocaesium.

This publication is primarily intended to share this experience gained in the Prefecture on environmental transfer data from Japan after the release of radionuclides to the environment from the FDNPP with the IAEA Member States. The information compiled and summarized in this report compliments other reports that have aimed to summarize radioecological studies carried out in Japan after the accident and compare with pre-accident data collected in Japan and with existing data, for example see Refs [10, 11].

1.3. SCOPE

This publication provides information which is useful for informing the management of areas affected by enhanced levels of radiocaesium after an accident. The measurements and results of the research projects undertaken in the Prefecture can assist in the following ways:

- Estimation of the time-dependence of radiocaesium in water and sediments of freshwater bodies following short-term deposition on catchment areas;
- Estimation of the importance of surface run-off for the movement of radiocaesium in catchment areas;
- Evaluation of the effectiveness and persistence of remediation measures in freshwater bodies;
- The selection of decontamination measures using the information on the effectiveness of remedial actions in residential areas;
- The activities on the interaction with the public may also help to set up remediation strategies that are acceptable to stakeholders.

1.4. STRUCTURE OF THE REPORT

The report consists of nine sections and three appendices. A brief overview of the behaviour of radiocaesium in the environment is given in Section 2. Section 3 describes the possible structure for compiling the results into a matrix. Section 4 describes the behaviour of radiocaesium in the aquatic environment in Fukushima Prefecture and compares the results with the worldwide experience in this field. Section 5 summarizes Japanese and worldwide experience made during in decontamination work in freshwater systems. Section 6 focuses on the abundance and characteristics of radiocaesium-containing microparticles (CsMPs) released from the FDNPP during the accident. Section 7 compares the success of decontamination work in residential areas of Fukushima Prefecture with worldwide experience. Section 8 highlights some aspects of interaction with the public after the accident, and Section 9 summarizes the main findings of the report.

The report has three Appendices. Appendix I summarizes data on the dynamics of ^{137}Cs in Japanese and European rivers; Appendix II lists the ^{137}Cs activity concentrations in suspended sediments of rivers of the Fukushima Prefecture from 2011–2021; and Appendix III presents the flux of ^{137}Cs in rivers of the Fukushima Prefecture.

2. BEHAVIOUR OF RADIOCAESIUM IN THE ENVIRONMENT

During the accident, a wide spectrum of radionuclides was released. Most of them were short lived, so they decayed away within weeks or months. In the long term, the most important radionuclides are ^{134}Cs and ^{137}Cs. In 2011, the ratio of ^{134}Cs and ^{137}Cs was approximately 1. Due to the different half-lives of ^{134}Cs (2.06 years) and ^{137}Cs (30.1 years), the ^{134}Cs/^{137}Cs-ratio will drop to about 0.017 by March 2024.

The deposition of radiocaesium in the Fukushima Prefecture was very heterogeneous; the most affected areas are in the north-west of FDNPS (Figure 1). This is mountainous area, it is covered mainly by forests, and it houses many freshwater water bodies, such as rivers, lakes, and reservoirs.

Much of the knowledge on the behaviour of caesium in the environment has been gained during the last 70 years. Radiocaesium has been released to the environment during nuclear weapons testing, during operation of nuclear facilities, and during nuclear accidents. The key characteristic controlling the behaviour of caesium in the environment is its strong sorption to mineral components both in soils and in suspended and bottom sediments of water bodies. In general, this causes a slow migration in soil, a considerable accumulation in sediments and a low uptake of caesium by plants. However, uptake of caesium from soil may be higher by orders of magnitude on acid, organic soils with insufficient potassium supply [12], as well as on tropical soils with advanced degradation of clay minerals [13].

Due to the strong sorption to suspended matter in freshwater environments, caesium deposits effectively to bottom sediments, and caesium levels in the water column decline quickly. Therefore, the transport of caesium in rivers and lakes with moving sediments is an important process. The uptake of caesium by fish and other biota is effective, in particular in waters with low potassium concentrations.

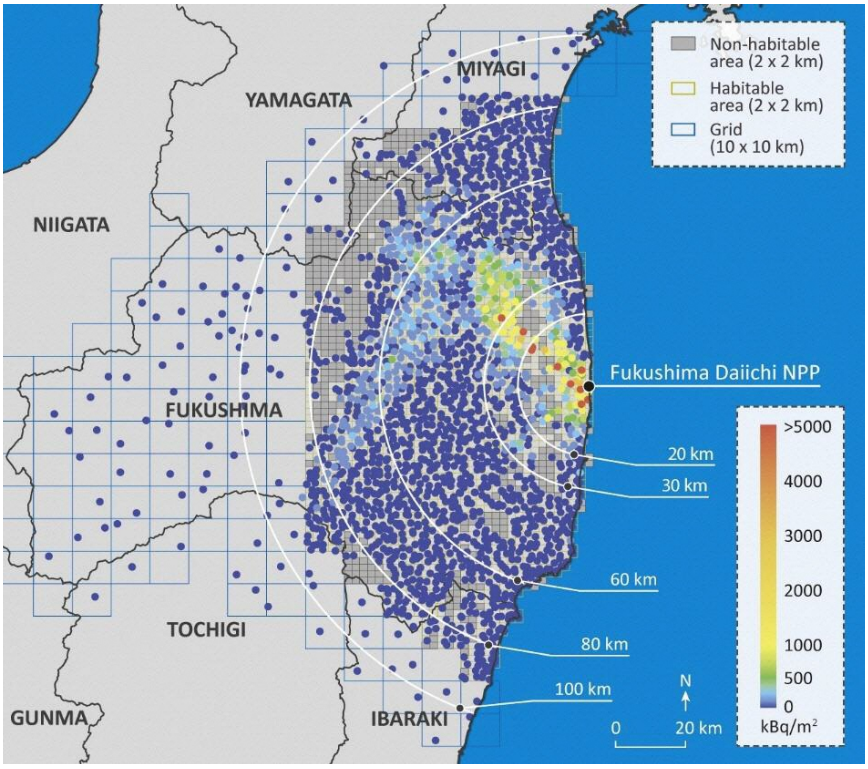

FIG. 1: Deposition of ^{137}Cs in the Fukushima Prefecture as of 14 June 2011 [14].

3. STRUCTURE FOR A COMPREHENSIVE COMPILATION OF RESULTS IN A MATRIX

Much work has been carried out in the Fukushima Prefecture to study the behaviour of radionuclides in the environment and various aspects related to decontamination of affected areas. For facilitating the access to the knowledge, the set-up of a matrix has been suggested to document the data in a structured manner. The comprehensive and concise compilation of the data in this way can facilitate the comparison of results achieved in the Fukushima Prefecture with global experience in these fields.

The proposed structure of the matrix is shown in Table 1. However, rather than a table, the matrix defines a structure for reporting the data and supporting information. In most cases it not possible to include the results of investigations as simple datapoints in a table. Many data sets consist of many individual data collected at different places over many years which require a parameter- and process-specific presentation.

For compiling results of studies on the behaviour of radionuclides and on decontamination work carried out in the Fukushima Prefecture and elsewhere, the following *processes* are included; more processes can be considered, as necessary and appropriate:

- Time dependence of ^{137}Cs in river water;
- Time dependence of ^{137}Cs in water of dams lakes and reservoirs;
- Time dependence of ^{137}Cs in bottom sediments of freshwater bodies;
- Loss of ^{137}Cs from catchments/catchment areas;
- Effective half-lives of ^{137}Cs in river water and suspended sediments;
- Micro-particles with enhanced levels of radiocaesium in the environment;
- Decontamination (rivers);
- Decontamination (residential area).

For each process, several descriptors are needed to allow a quick overview and a simple (preliminary) evaluation of the results. These descriptors are:

- Definition of the parameter/quantity;
- Sampling location;
- Observation period;
- Unit of the parameter/quantity reported;
- Results to be presented — as appropriate— as:
  - Single values, individual data points,
  - Time series of values (figures and/or tables),
  - Spatial distribution of quantities or parameter values,
  - Functions describing the results in dependence of one or more variables;
- Key influencing factor(s);
- Dependence of the process on the influencing factor(s), any other remarkable point to characterise the process considered.

Table 1. Proposed matrix to define a structure for comprehensive and concise compilation of data elaborated in the Fukushima Prefecture and elsewhere

	Process	Parameter/quantity	Sampling location	Observation period	Unit	Values	Influencing factor(s)
1	**Time dependence of Cs-137 in river water**	Measured levels of dissolved Cs-137			Bq/m^3	Time series for monitoring points in a river	Flow rate Turbidity Conc. of suspended sediments
		Measured levels of particulate Cs-137			Bq/kg		
		Simulated levels of dissolved Cs-137			Bq/m^3		
		Simulated levels of particulate Cs-137			Bq/kg		
2	**Time dependence of Cs-137 in dam lake / water reservoir**	Measured levels of dissolved Cs-137			Bq/m^3	Time series for monitoring points in dam lake / water reservoir	
		Measured levels of particulate Cs-137			Bq/kg		
		Simulated levels of dissolved Cs-137			Bq/m^3		
		Simulated levels of particulate Cs-137			Bq/kg		
3	**Time dependence of Cs-137 in bottom sediments of freshwater bodies**	Measured levels of particulate Cs-137			Bq/m^3	Time series for monitoring points in a river / dam lake /water reservoir	
		Simulated levels of particulate Cs-137			Bq/kg		
4	**Loss of Cs-137 from catchment areas**	Loss of Cs-137 from catchments/ catchment areas			Bq/ m^2 a, (lost activity per unit area per time)		Land use, slope of the terrain, precipitation, number of events with high precipitation, catchment area
5	**Ecological half-lives**	Reduction of Cs-137 in environmental media with time			days or year Number of components identified		Time after the accident, media considered, environmental conditions
6	**Micro-particles in the environment**	Cs-MPs found			Number of particles found Particles per unit area		Particle type
		Composition			Main elements in the particles (mg/kg)		
		Activity			Bq per particles Bq/kg		
7	**Decontamination (river)**	Decontamination measure (e.g. removal of shore sediments, removal of bottom sediments, removal of weed)			As applicable: Activity (Bq/kg) in before and after decontamination Activity (Bq/m^2) before and after decontamination Dose rate before and after decontamination		Rainfall after decontamination, High rainfall events after precipitation, Slope of the terrain Intensity of decontamination, area decontaminated, amount of material (soil, sediments, litter, etc.) removed, decontamination measures applied,
8	**Decontamination (residential area)**	Decontamination measure (e.g. removal of ……)					

The format of the results to be reported depends on the nature of the process. The results of studies may be reported as e.g. single values, time series of values, or functions describing the dependency of the results on one or more variables, as appropriate. Maps can be used to show spatial distributions of parameters or activity levels in environmental media. Since any process requires an individual format for presenting results, a more specific definition of the format is not possible.

Data available from other countries can be reported as well in the same structure. This will facilitate the comparison with the studies carried out in the Fukushima Prefecture.

The matrix should not be considered as a ‘big table’ to include data in formalized way. Very often, this is not possible, since the results are available as time series over many years with a large number of individual points.

The matrix provides a general structure for the reporting of data on the work done in the Fukushima Prefecture and in other parts of the world.

Results available from the Fukushima Prefecture are summarized in the following sections and compared with studies carried out in other countries, for different aspects of radioactive contamination of the environment. The results presented could provide the basis for integration in the data structure presented above.

4. RADIOCAESIUM IN FRESHWATER SYSTEMS

4.1. TRANSFER PROCESSES

Water from rivers, lakes, and reservoirs is widely used as drinking and irrigation water as well as for industrial purposes. The accident in 2011 led to catchment areas being contaminated that are essential for the water supply of the Fukushima Prefecture.

A scheme of the transport of caesium in a freshwater system is shown in Figure 2. The driving force for the transport of radiocaesium from the catchment area to freshwater bodies is the flow of water. Since radiocaesium is strongly absorbed by mineral components of the soil, it is mainly transported attached to sediments. The amount of radiocaesium in run-off water is the result of a complex interaction of land-use (vegetated, paved, bare soil), amount and intensity of precipitation, and the slope of the surface.

Freshwater systems include rivers, lakes, and reservoirs. The use of water for irrigation or as drinking water for humans represents a link to the human environment. The radiocaesium transport in a catchment is not continuous but varies depending on precipitation and surface water runoff. During dry periods, it may be very low, whereas it may increase by orders of magnitudes during high rainfall events. Then, rivers may overflow and areas within the catchment may become flooded and contaminated suspended matter carried with the water may deposit on flood plains.

With regard to the great importance of the freshwater bodies for the water supply of the Fukushima Prefecture, monitoring activities were initiated for caesium in freshwater bodies immediately after the accident in 2011. The monitoring programs included the following activities:

- Measurement of radiocaesium in water in dissolved and particulate form;
- Measurement of radiocaesium in bottom sediments;
- Loss of radiocaesium from catchments;
- Transport of radiocaesium with river water;
- Hydrological characteristics:
  - Measurement of water levels and flow rates,
  - Precipitation,
  - Turbidity;
- Water composition:
  - Concentrations of major ions (potassium, calcium, magnesium, and ammonium),
  - Concentration of suspended sediments.

For this purpose, along the Abukuma River and on rivers draining coastal catchments, 30 monitoring stations were installed (Figure 3).

4.2. RADIOCAESIUM IN RIVER WATER

4.2.1. Particulate and dissolved radiocaesium

Radiocaesium in freshwaters is present in dissolved and particulate form. Because of the strong sorption of caesium to clay particles, the greatest fraction of radiocaesium is attached to suspended sediments. In calm waters as lakes and reservoirs and in rivers with low flow rates, suspended sediments quickly deposit to the bottom sediments.

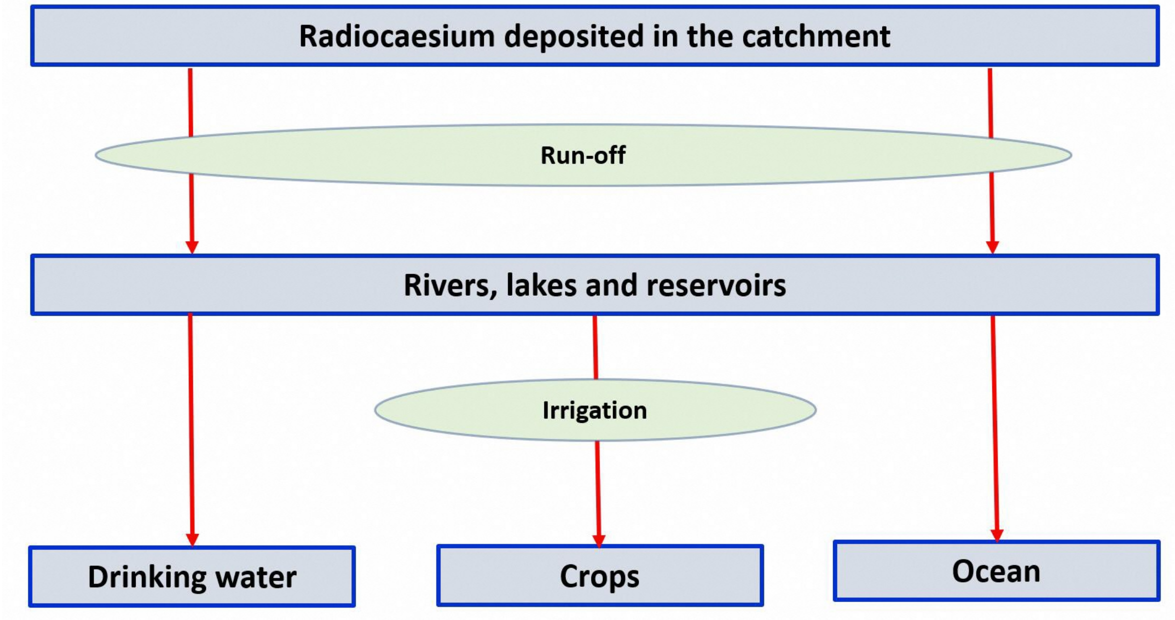

FIG. 2: Scheme of the transport of radiocaesium from the catchment to the ocean (red arrows indicate the transport between compartments).

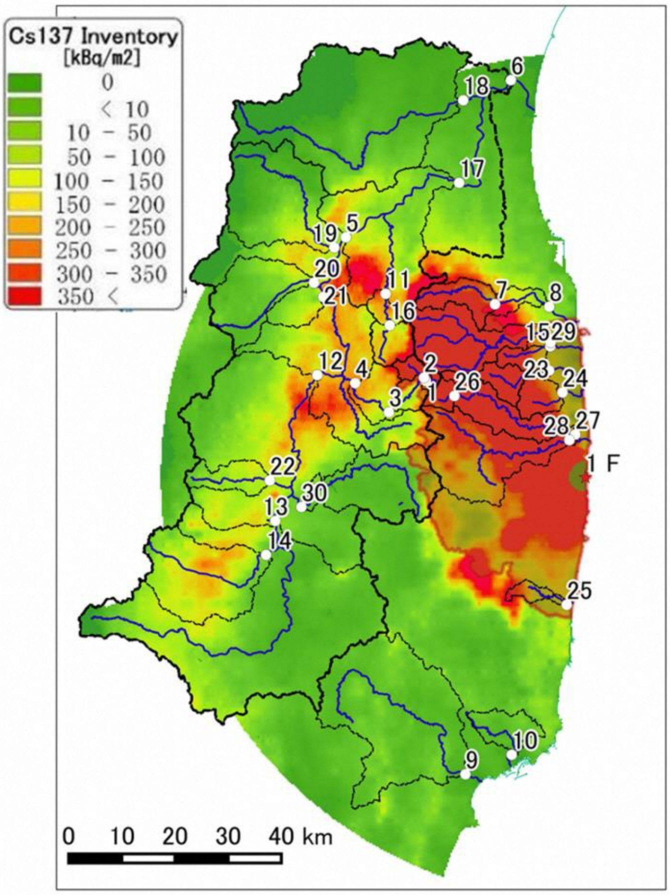

FIG. 3: Map of ^{137}Cs-deposition calculated for 2 July 2011. Red shaded areas indicate the original evacuation zone. The numbers in the map correspond to the sites listed in Table 6. (Figure from Ref. [15]).

Figure 4a shows the absolute and normalized ^{137}Cs-activity concentration in suspended sediments, and Figure 4b shows the absolute and normalized activity concentration of dissolved ^{137}Cs in water of rivers of the Fukushima Prefecture covering the period from 2011 to 2021 [15–17]. The normalized activity concentrations of particulate and dissolved ^{137}Cs represent the quotient of the activity concentrations of ^{137}Cs and the mean ^{137}Cs deposition per unit area in the catchment. Normalization allows for better comparability between watersheds by eliminating the influence of varying deposition densities. The data include the main channel of the Abukuma River system, and nine smaller river systems in the Hamadori area.

Immediately after the deposition, the values of ^{137}Cs-concentrations in suspended sediments exceeded 10 000 Bq/kg; since then, levels have steadily declined. The variations of the ^{137}Cs activity concentrations in suspended sediment are pronounced and cover 1–2 orders of magnitudes; in the rivers of the Hamadori area, the variations cover even up to three orders of magnitude. However, this variation is not surprising as the catchments related to the rivers vary in ^{137}Cs -deposition, size, slope, and land-use. The variation of the normalized concentration of suspended sediments is lower. The underlying data for Figure 4 for the activity concentration of ^{137}Cs in suspended sediments from 2011–2021 [16] are summarized in Appendix II below.

There are fewer measurements for dissolved ^{137}Cs in river water. Caesium is strongly sorbed by suspended sediments, therefore the concentrations of dissolved ^{137}Cs in river water is relatively low. In the Abukuma River and its tributaries, the values drop from some hundred mBq/L to some mBq/L at the end of the observation period. In the rivers of the Hamadori area, the decline is less pronounced. The levels of dissolved radiocaesium in water are far below the World Health Organization [18] recommended quality criterion for ^{137}Cs in drinking water of 10 Bq/L, this level is marked in Figure 4b (top). The underlying data for Figure 4 for the activity concentration of dissolved ^{137}Cs in river water from 2017–2021 [17] are also summarized in Appendix II.

The time-dependence of ^{137}Cs in freshwaters is quantified by the effective half-life[1], which integrates all processes that cause a decline of ^{137}Cs concentrations in environmental media [12] as e.g. radioactive decay, migration, and movement of sediments.

The effective half-lives determined for particulate and dissolved ^{137}Cs in the rivers monitored in the period of 2012–2021 are summarized in Table 2. The concentrations of particulate ^{137}Cs decline slightly slower, and the variation of half-lives is less than for dissolved ^{137}Cs. In general, the differences to dissolved ^{137}Cs are not considerable.

The time dependence of the concentration of particulate and dissolved ^{137}Cs in the Hiso and Wariki River from 2011–2021 is presented in Figure 5. In both rivers, there is a continuous, relatively smooth decline during the whole observation period. A fast component immediately after the deposition is followed by a slower component starting a few months after deposition.

Nakanishi and Sakuma [19] studied the decline of particulate and dissolved ^{137}Cs in water of the Ukedo and Ota Rivers during 2015 and 2018. In this period, effective half-lives for particulate ^{137}Cs were observed of 2.1 and 1.5 years for Ukedo and Ota River, respectively. The decline of dissolved ^{137}Cs was slower with effective half-lives of 3.3 for the Ukedo River and 2.2 years for the Ota River. The values are in the same range as given in Table 2.

The values in Table 2 for the effective half-lives for ^{137}Cs in river water are somewhat shorter; however, it should be noted that the observation period in Table 2 is from 2012 to 2021 [15–17, 20], whereas it is 2015–2018 in Ref. [19]. Therefore, it is important not to overemphasize the differences.

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[1] Decline of ^{137}Cs activity concentrations in river water due to ecological processes and physical decay.

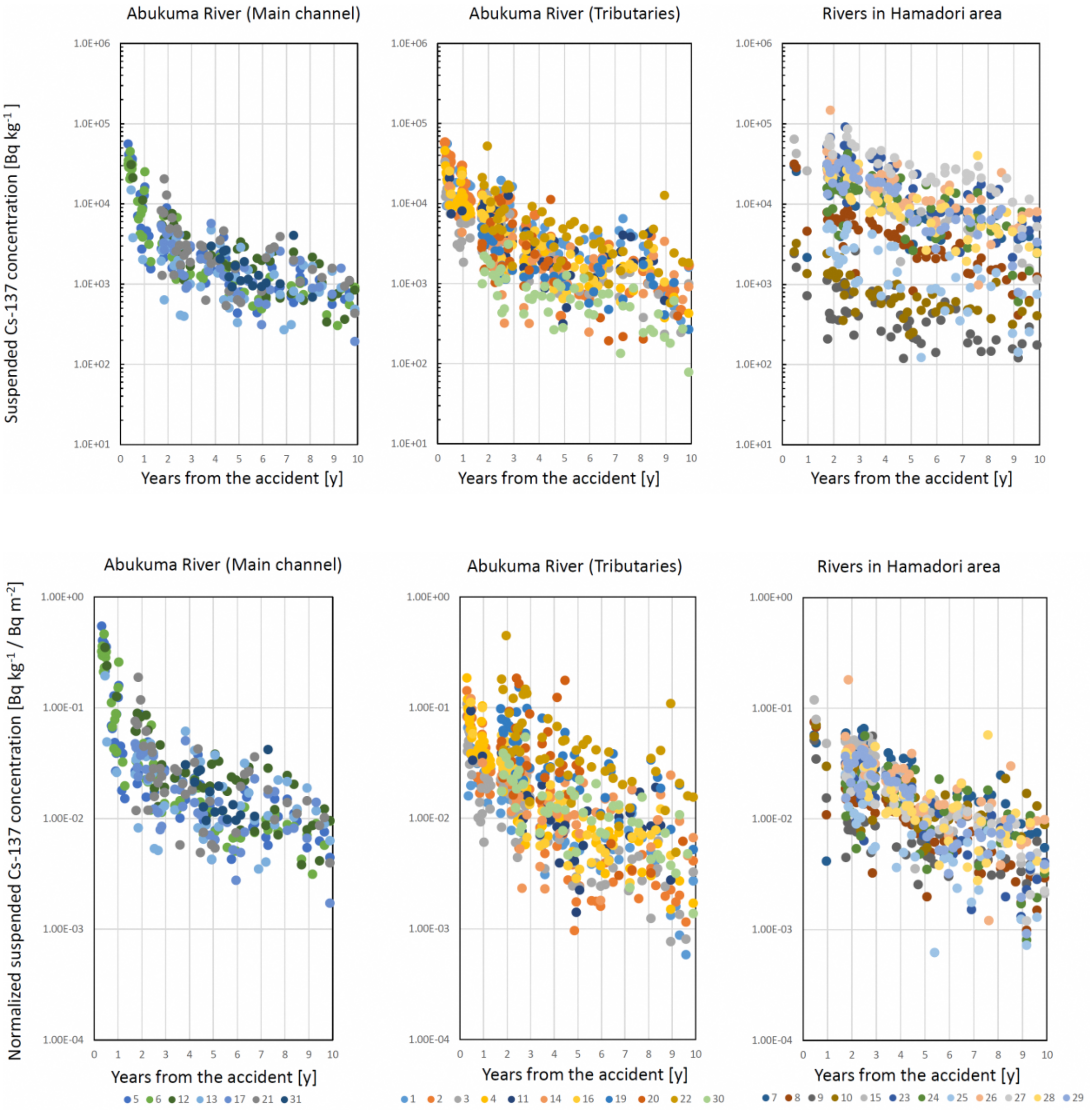

FIG. 4a: Absolute (top) and normalized (bottom) activity concentration in of ^{137}Cs in suspended sediments in water of rivers of the Fukushima Prefecture from 2011–2021 [16]. (The bottom of the figure on normalized ^{137}Cs activity concentration of ^{137}Cs in suspended sediments was kindly provided by the Fukushima Prefecture). Image credit: Fukushima Prefecture[2].

(The numbers represent the following rivers: 1 Mizusakai River, 2 Kuchibuto River, Upstream, 3 Kuchibuto River Midstream, 4 Kuchibuto River Downstream, 5 Fushiguro, 6 Iwanuma, 7 Mano, 8 Ojimadazeki, 9 Matsubara, 10 Onahama, 11 Tsukidate, 12 Nihonmatsu, 13 Miyoda, 14 Nishikawa, 15 Kitamachi, 16 Kawamata, 17 Marumori, 18 Funaoka Ohashi, 19 Senoue, 20 Yagita, 21 Kuroiwa, 22 Tomita, 23 Ota, 24 Odaka, 25 Asami, 26 Tsushima, 27 Ukedo, 28 Takase, 29 Haramachi, 30 Akanuma, 31 Watari.)

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[2] Available in English from: https://www.iaea.org/sites/default/files/23/06/fcp_final_report_2013-2022.pdf and in Japanese from https://www.iaea.org/sites/default/files/23/06/fcp_final_report_2013-2022_japanese.pdf

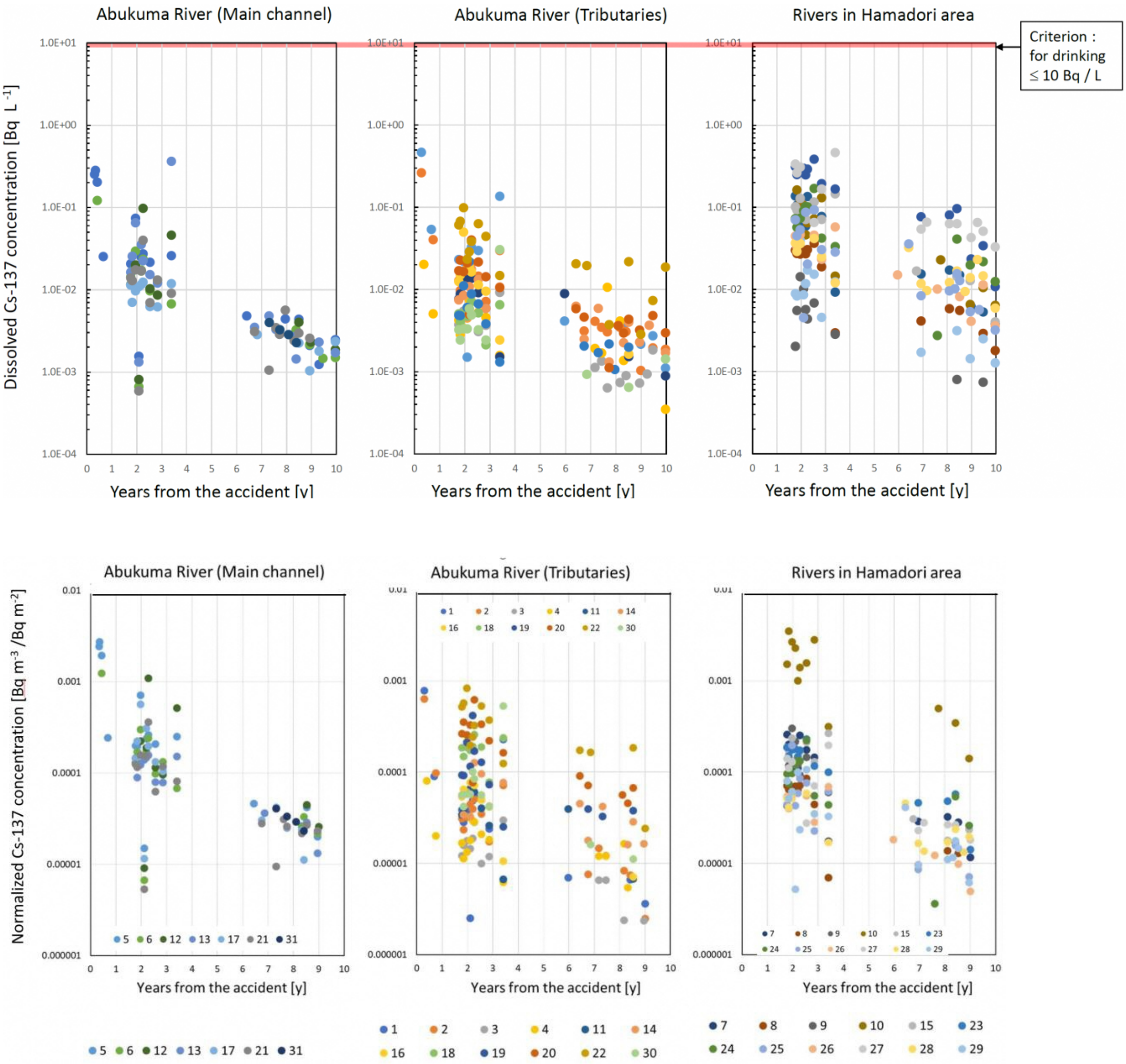

FIG. 4b: Absolute (top) and normalized (bottom) activity concentration of dissolved ^{137}Cs in water of rivers of the Fukushima Prefecture from 2011–2021 [17]. The red line in the upper figure marks the WHO guidance level of 10 Bq/L for ^{137}Cs in drinking water [18]. (The bottom of the figure on the normalized concentration of dissolved ^{137}Cs in river water was kindly provided by the Fukushima Prefecture). Image credit: Fukushima Prefecture[3].

(The numbers represent the following rivers: 1 Mizusakai River, 2 Kuchibuto River, Upstream, 3 Kuchibuto River Midstream, 4 Kuchibuto River Downstream, 5 Fushiguro, 6 Iwanuma, 7 Mano, 8 Ojimadazeki, 9 Matsubara, 10 Onahama, 11 Tsukidate, 12 Nihonmatsu, 13 Miyoda, 14 Nishikawa, 15 Kitamachi, 16 Kawamata, 17 Marumori, 18 Funaoka Ohashi, 19 Senoue, 20 Yagita, 21 Kuroiwa, 22 Tomita, 23 Ota, 24 Odaka, 25 Asami, 26 Tsushima, 27 Ukedo, 28 Takase, 29 Haramachi, 30 Akanuma, 31 Watari.)

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[3] Available in English from: https://www.iaea.org/sites/default/files/23/06/fcp_final_report_2013-2022.pdf and in Japanese from https://www.iaea.org/sites/default/files/23/06/fcp_final_report_2013-2022_japanese.pdf

Table 2: Effective half-lives of particulate and dissolved ^{137}Cs in rivers of the Fukushima Prefecture from 2012 to 2021 [16, 17]. The number of observations is given in brackets.

Form of Cs-137	**Effective half-life of Cs-137 in the period 2012-2021 (years)**			
	Abukuma River	**Affluents of Abukuma**	**Rivers in Hamadori**	**Mean of all rivers**
Particulate	3.7 (6)	3.2 (11)	3.1(12)	3.2 (29)
Dissolved	2.8 (6)	3.0 (10)	2.7 (11)	2.8 (27)

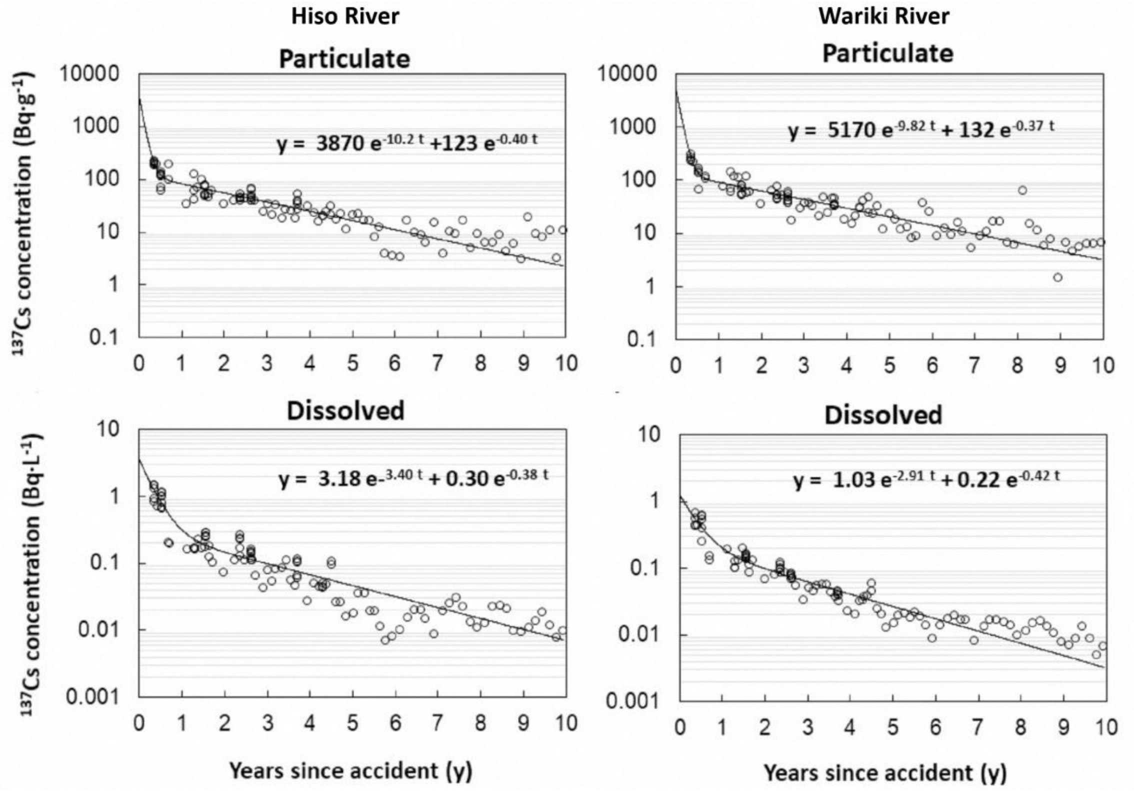

FIG. 5: Activity concentration of particulate and dissolved ^{137}Cs from 2011 to 2021 in the Hiso and the Wariki River. Image credit: Fukushima Prefecture (reproduced from Ref. [21]. (Please note: Some circles are on top of each other due to datapoints (open circles) being on top of one another and subsequently look like filled circles.).

4.2.2. Leaching of ^{137}Cs from litter and concentrations of dissolved ^{137}Cs in run-off water

A seasonal variation of dissolved ^{137}Cs in river water with a maximum in summer and minimum in winter was found by Nakanishi and Sakuma [19]. It is suggested that the release of ^{137}Cs during decomposition of litter in flooded areas is an important source of dissolved ^{137}Cs in rivers. The seasonal effect was less pronounced towards the end of the observation period (2015–2018).

These results are supported by another study by Tsuji et al [22] where the normalized concentrations of dissolved ^{137}Cs[4] in 66 rivers of East Japan were determined. It was found that

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[4] Normalized concentration of dissolved ^{137}Cs: Ratio of dissolved ^{137}Cs in river water and the average ^{137}Cs-deposition in the catchment area [m²/L].

the normalized concentrations of dissolved ^{137}Cs decreased with increasing coverage of forest in the catchment areas, whereas it increased with larger fractions of built-up areas. It is postulated that high concentrations of potassium and dissolved organic carbon in urban areas inhibit the sorption of ^{137}Cs to soil particles found in runoff water [22].

Furthermore, it was found that the normalized concentration of dissolved ^{137}Cs increased with the topographical wetness index TWI[5] [22]. TWI is high for flat areas, because run-off is low, and the periods of wetted surfaces are longer than on slopes. Forested areas are mainly on slopes and therefore have a lower TWI; this is consistent with the finding on the negative correlation between dissolved ^{137}Cs in water and the coverage of forest in the catchment area.

The leaching of ^{137}Cs from litter in Fukushima broadleaf forests were studied by Sakakibara et al [23], the key findings are:

- The amount of ^{137}Cs leached from litter increased with increasing contact area and time between litter and rainwater;
- The concentration of dissolved ^{137}Cs in run-off water increased with increasing amount of rainfall, which also increased contact area and time between litter and water.

In conclusion, the results given in Refs [19, 22, 23] consistently indicate a relationship between the leaching of ^{137}Cs from litter and the levels of dissolved ^{137}Cs in run-off water. However, these findings need to be put in context with the contributions of dissolved ^{137}Cs and of ^{137}Cs in suspended sediments to the total ^{137}Cs activity in river water. As both Figures 4 and 5 show, the by far dominating fraction of ^{137}Cs in river water is bound to suspended sediments.

4.2.3. Dynamic of ^{137}Cs in four headwater catchments

The time-dependence of the concentrations of dissolved ^{137}Cs and of ^{137}Cs bound to suspended sediments and coarse organic matter is studied in four headwater catchments of the Fukushima Prefecture from 2011 to 2016 by Iwagami et al [24].

The dynamics of the activity concentration of ^{137}Cs in run-off water was approximated by exponential functions with one or two components. The periods of the first 200 days and the period from 2012 to 2016 were considered separately.

The fastest decline was observed for dissolved ^{137}Cs, during the period June to December 2011 with an effective half-life $T_{eff,1}$ ranging from 44 to 77 d (Table 3).

In the second phase, the decline was differentiated between dissolved ^{137}Cs, ^{137}Cs bound to suspended sediments and ^{137}Cs bound to coarse organic matter:

- Dissolved ^{137}Cs declined according to an effective half-life in the range of 0.89-5.3 years;
- Caesium-137 bound to coarse organic matter declined according to $T_{eff,2}$ of 0.82–2.1 years.
- The largest fraction of ^{137}Cs in run-off water was bound to suspended sediments. The concentration of this fraction varied widely with reported T_{eff} values ranging from 1.6–22 years.

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[5] The topographical wetness index is defined as: TWI= ln(Area of the watershed area / [tan(slope)]).

Table 3: Effective half-lives of ^{137}Cs activity concentration in water discharged from headwater catchment for different forms of ^{137}Cs [24, 25].

Phase	Catchment area	Form of ^{137}Cs	Effective half-life	
			$T_{eff,1}$ (June to December 2011)	$T_{eff,2}$ (2012 to 2016)
June 2011 to December 2011	Koutaishi[a]	Dissolved	77 days	
	Iboishi[c]	Dissolved	44 days	
	Ishidaira[d]	Dissolved	44 days	
January 2012 to November 2016	Koutaishi[a]	Dissolved		2.2 y
		Suspended sediment		22 y
	Setohachi[b]	Dissolved		5.3 y
		Coarse organic matter		2.1 y
		Suspended sediment		2.5 y
	Iboishi[c]	Dissolved		0.98 y
		Coarse organic matter		0.82 y
		Suspended sediment		4.6 y
	Ishidaira[d]	Dissolved		0.89 y
		Coarse organic matter		1.0 y
		Suspended sediment		1.6 y

[a] Koutaishi: cedar forest 99%, grassland 1%, [b] Setohachi: cedar forest 100%); [c] Iboishi: cedar and deciduous forest 76%, grassland 23%, [d] Ishidaira: cedar forest 81%, grassland 19%.

In general, the decline of ^{137}Cs in run-off water was faster in catchments with a higher fraction of pasture than that in forested catchments. This observation agrees with the findings reported in Ref. [26], where a more rapid decrease of the ^{137}Cs activity concentration in grass compared with litter was observed.

4.3. RADIOCAESIUM OF CAESIUM-137 IN SUSPENDED SEDIMENTS

4.3.1. Interaction of flow rate, concentration of suspended sediment and Cs-levels of suspended sediments

The relationships between water level, concentration of suspended sediments and the ^{137}Cs levels in suspended sediments were investigated in a study by Arai et al [27]. The study was carried out in the catchment of the Hirose River, where water samples were taken near the confluence of the Hirose and Abukuma River.

The study is based on measurements of: (i) particulate ^{137}Cs in river water and in suspended sediments; (ii) the total organic carbon (TOC) in water and in suspended sediments; and (iii) the ^{137}Cs and TOC levels in adjacent forest soil, forest litter, riverbank soil and river sediments. Water samples were taken under base-flow conditions and under high flow conditions[6] during and after typhoons. The sampling was carried out from September 2017 to October 2019.

In addition, this study determined the fractions of forest soils, forest litter, forest soils, and river sediments in suspended sediments based on the concentrations of ^{137}Cs, TOC, and the

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[6] Base flow conditions are defined, if the sampling of water was carried out at least 2 days after the last precipitation, TSS concentration varied from 1.5 to 4.2 mg/L.
Sampling under high flow conditions was carried out during and after typhoons, SS concentrations varied from 5 to 930 mg/L.

δ^{13}C-signature[7] in these media. The fractions were estimated by means of a mixing model for base flow and high flow conditions.

The results are shown in Figure 6. With increasing concentration of suspended sediments in river water:

- The concentration of particulate ^{137}Cs in river water increased;
- The concentration of organic matter in water increased;
- The concentration of ^{137}Cs in suspended sediment declined;
- The total organic carbon in suspended sediments decreased; and
- The δ^{13}C-level in suspended sediments decreased.

During high flow conditions, the concentration of suspended sediments in river water was higher than under base-flow conditions, as resuspension of bottom sediments becomes more and more important with increasing water levels.

4.3.2. Origin of suspended sediments in rivers during high water periods

The δ^{13}C-signatures, the TOC concentration in water and the ^{137}Cs activity concentration in suspended sediments were used to determine the source of carbon in a sample. The δ^{13}C-signatures in different media and forest soil samples indicate the origin of the increased amounts of suspended matter in river water. Table 4 summarizes the δ^{13}C-signatures, the ^{137}Cs concentrations and the TOC concentrations in various samples in the study site. The δ^{13}C-signatures for material from the river vary from -25.4 to -26.4 ‰, whereas the δ^{13}C-signatures in forest soil and litter varies from-26.4 to -30.0 ‰. This means, there is a clear difference of the δ^{13}C-signatures among river sediments, riverbank soil, forest soil, and forest litter.

The decline of the δ^{13}C signature with increasing concentrations of SS in water — and with a tendency to increasing flow velocities — indicates that the relative contribution of forest soil and forest litter declines. At the same time, the relative contribution of riverbank soils and river sediments to SS increases with increasing concentrations of SS in river water. A simulation of the different contributors to SS confirms this hypothesis:

- Under base flow conditions forest soil contributes nearly 70% to the SS. Riverbank soil and river sediments together contributed approximately 7%;
- At high flow, the absolute TOC concentration in river water increased. As a result, the relative contribution of forest soil to SS decreased to 48%, and the input of both riverbank soil and river sediments to SS increased to about 50%.

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[7] δ^{13}C-signature: ^{13}C is a natural stable carbon isotope, about 1.1% of the global carbon is ^{13}C. The δ^{13}C signature quantifies the deviation of the ^{13}C/^{12}C-ratio from Vienna PeeDee Belemnite (VPDB) standard [28] in an environmental sample in permille. The δ^{13}C signature is calculated from the concentrations of ^{13}C and ^{12}C in the samples and in the VPDB standard according to:

$\delta^{13}C = [(^{13}C_{sample}/^{12}C_{sample} - ^{13}C_{standard}/^{12}C_{standard})/ ^{13}C_{standard}/^{12}C_{standard})] \times 1000.$

The depletion of ^{13}C in organic material is due to the higher atomic mass of ^{13}C compared to ^{12}C, this facilitates the uptake of $^{12}CO_2$ by plants during the photosynthesis, and it causes the depletion of ^{13}C in plant material.

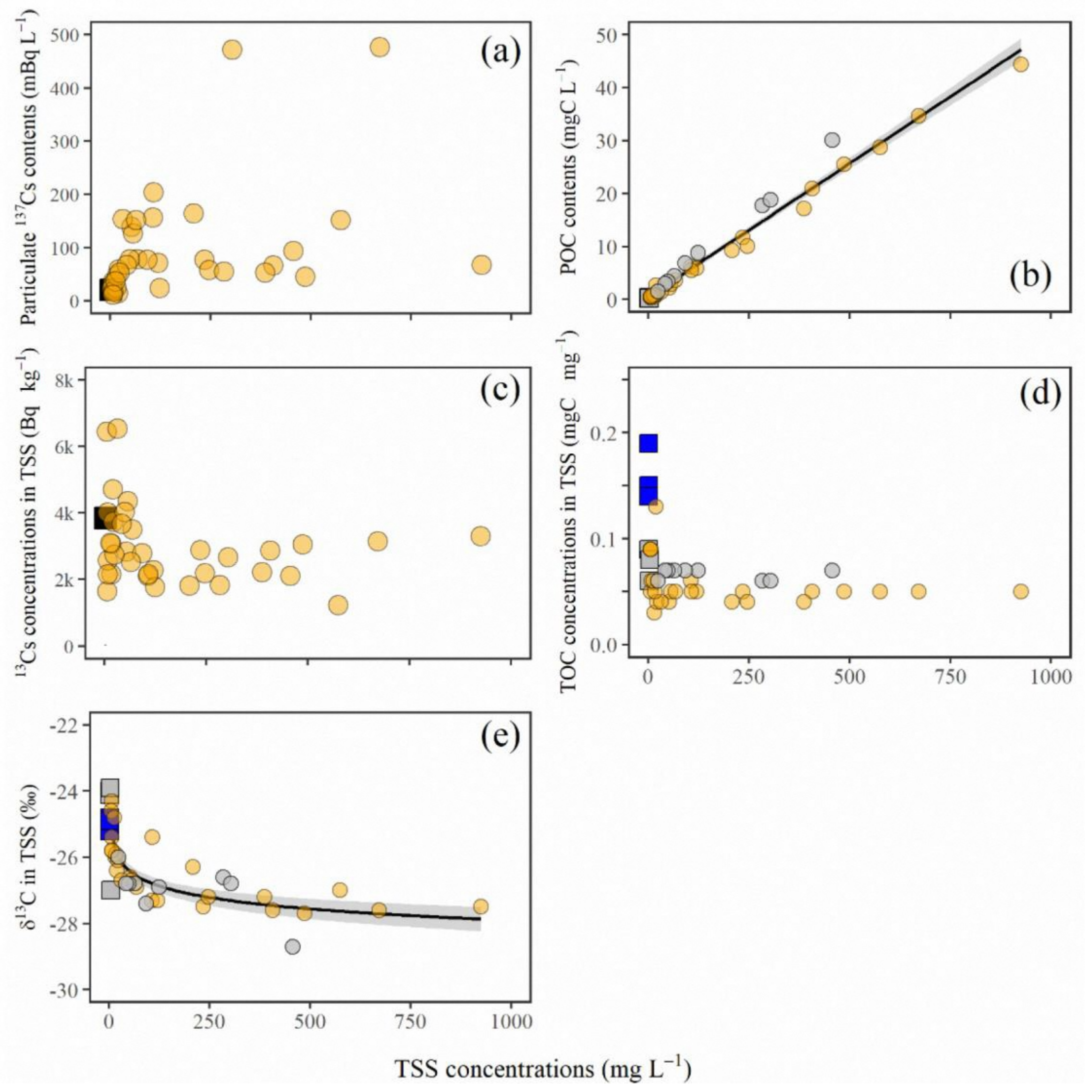

FIG. 6: Dependence of particulate ^{137}Cs, POC (particulate organic matter), TOC (total organic matter), and δ^{13}C on the concentration of TSS (total suspended sediment) in water. The average value and standard deviation under the base-TSS-load conditions (black squares) and all the data measured under high-TSS load conditions (orange circles) are shown. For POC, TOC, and δ^{13}C, measured and estimated values are shown separately for each of the river conditions (grey for estimated and blue and orange for measured values, and squares for the base- and circles for the high-TSS-load conditions). (a) Particulate ^{137}Cs concentration in river water; (b) POC content; (c) ^{137}Cs concentration of TSS; (d) TOC concentration of TSS; (e) δ^{13}C values in TSS. The shaded areas represent the 95% confidence intervals. Image credit: Fukushima Prefecture (Figure from Ref. [27]).

Table 4: δ^{13}C-signatures, ^{137}Cs activity concentration, total organic carbon and for river and forest samples [27]

Material	**δ^{13}C signature (‰)**	**Number of samples**	**Cs-137 activity concentration (Bq/kg)**	**Number of samples**	**Total organic carbon (mgC/mg)**	**Number of samples**
Forest soil	-26.9±0.6	12	5400±1600	12	0.11±0.021	12
Forest litter	-30.0±0.5	16	240±150	16	0.47±0.011	16
Riverbank soil	-26.4±0.8	15	470±530	46	0.018±0.015	15
River sediment	-25.4±0.8	21	110±110	175	0.001±0.001	21

4.3.3. Normalized ^{137}Cs activity concentration in suspended sediments

The long-term behaviour of radiocaesium in catchments is essential for the evaluation of possible impacts of radiocaesium on water supply, agriculture, and leisure activities.

Intensive measurements of radiocaesium were carried out in rivers in Fukushima for 30 monitoring points [15]. For comparing the dynamic of radiocaesium, the ^{137}Cs activity concentrations were normalized to the mean deposition density in the catchment related to the river basin [15]. The underlying data for the assessment are summarized in Appendix II below.

The time-dependence of the activity concentrations were approximated by exponential functions with two components. The results are shown in Figure 7. The data cover the period from 2011 to 2016. The post-deposition-decline of particulate ^{137}Cs concentrations is characterized by an initial rapid decline in the first year after the accident, which slows down during the following years.

For six monitoring sites in the Abukuma River system, a more detailed study has been carried out to estimate the ^{137}Cs loss from the catchment areas. For each of the catchments considered, the decline of the normalized particulate ^{137}Cs activity concentration C'(t) was approximated by single exponential functions for the phases June 2011 to March 2012 and April 2012 to August 2015 respectively:

- For the period June 2011 to March 2012: $C_1'(t) = a_1 \cdot e^{-\lambda_1 \cdot t}$ (Eq. 1a);
- For the period April 2012 to August 2015: $C_2'(t) = a_2 \cdot e^{-\lambda_2 \cdot t}$ (Eq. 1b),

where a_1 and a_2 are fitting parameters for period 1 and 2, respectively, and λ_1, and λ_2 describe the reduction rate of ^{137}Cs in suspended sediments of the rivers considered.

The values for the parameter a_n and $T_{eff,n}$ are given in Table 5 ($T_{eff,n}$ corresponds to λ_n in Eqs 1a and 1b according to: $T_{eff,n} = \ln 2/\lambda_n$). The ^{137}Cs activity concentrations in suspended sediments decline rapidly. In the first period, the normalized ^{137}Cs concentrations in suspended sediments decrease according to effective half-lives in the range of 0.3 to 1.6 years, in the second phase the decline rate slows down, it is equivalent to half-lives of 1.4 to 2.7 years.

Table 5 also includes the half-lives of ^{137}Cs in suspended sediments measured at 24 other sites in the period 2012–2016. Due to later start of the measurements, the short-term component of the decline could not be determined, and the half-lives are given for the second component of the decline only. For these sites, the estimated half-lives of the ^{137}Cs concentration in suspended sediments vary from 1.1 to 16 years.

4.3.4. Land-use and ^{137}Cs-loss with surface run-off

Additionally, in the Upper Kuchibuto catchment, the relationship of the land-use and the loss of ^{137}Cs with surface run-off [15]. The land-use was classified into forest – which are thought to have low run-off — and areas with Paddies, Farmland, and Urban use (PFU) with a higher run-off. Results are shown in Figure 8. Since immediately after the accident the loss of ^{137}Cs activity with surface run-off is more pronounced, the periods June 2011 to February 2012 (upper part) and March 2012 onwards are considered separately.

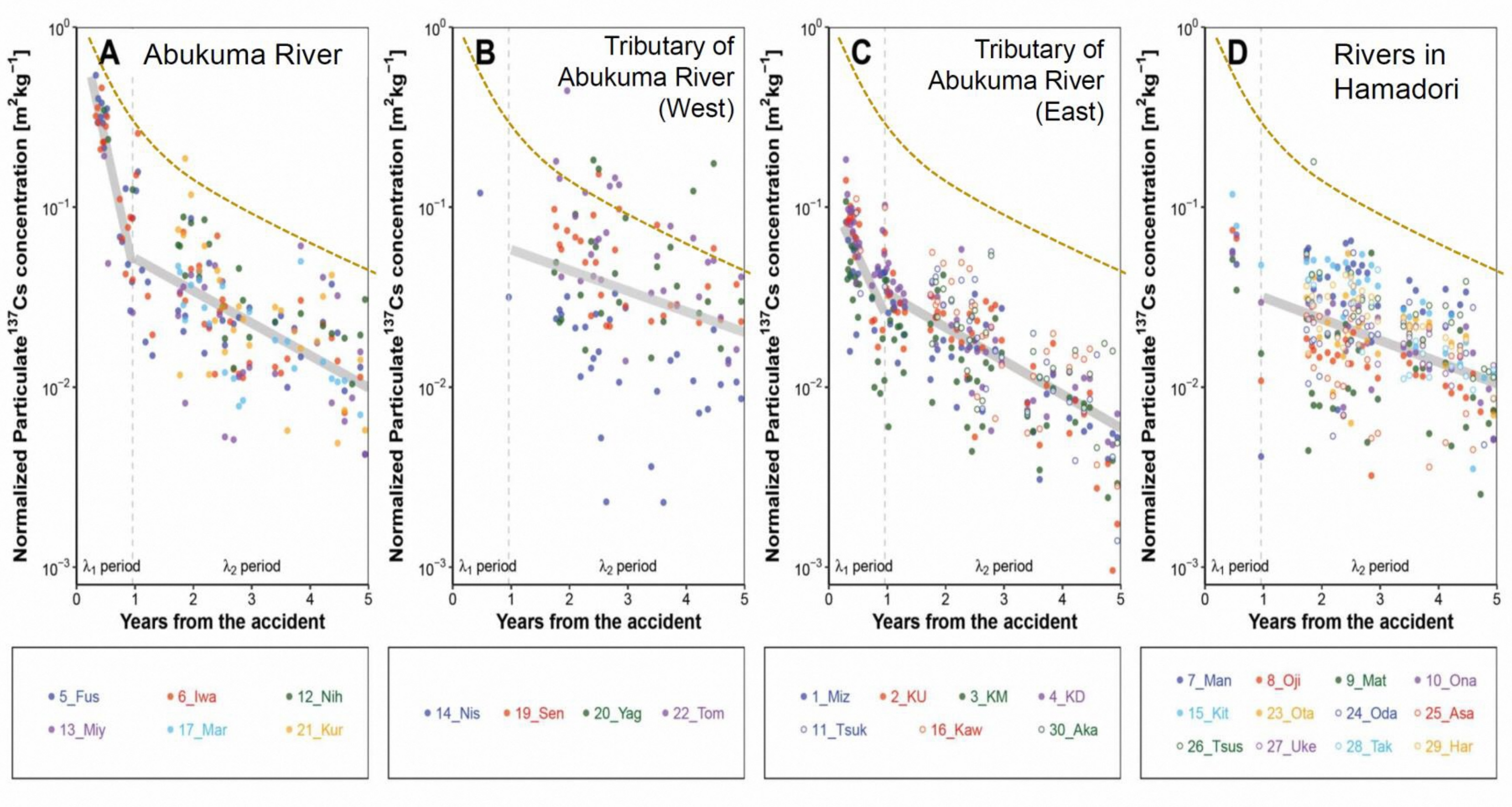

FIG. 7: Time-dependence of particulate ^{137}Cs in river water normalized to the deposition density in the related catchments for rivers of: (A) Abukuma mainstream; (B) Abukuma tributaries (West); (C) Abukuma tributaries (East); and (D) coastal catchments (Hamadori district). In plot C, sites 1_Miz and 2_KU were excluded from the analysis due to ongoing decontamination activities. Image credit: Fukushima Prefecture (Figure from Ref. [15]). The underlying data on the ^{137}Cs activity concentrations in suspended sediments for Figure 7 are summarized in Appendix II below.

Table 5: Parameters for the exponential functions to describe the time-dependence of the normalized activity concentration of ^{137}Cs in suspended sediments for the periods June 2011 to March 2012 and April 2012 to August 2015 [15], the measurements for sites 7–30 started in April 2012 only.

Site name	**Exponential function describing the decline from June 2011 to March 2012**		**Exponential function describing the decline from April 2012 to August 2015**	
	a_1	**$T_{eff,1}$ (y)**	**a_2**	**$T_{eff,2}$ (y)**
1 Mizusakai	0.64	1.6	0.36	2.7
2 Kuchibuto_Upper	0.79	0.37	0.21	2.0
3 Kuchibuto_Middle	0.74	0.33	0.26	1.6
4 Kuchibuto_Down	0.64	0.75	0.36	1.4
5 Fushiguro	0.96	0.18	0.04	1.8
6 Iwanuma	0.92	0.22	0.08	1.5
7 Mano	–	–	0.040	8.2
8 Ojimadazeki	–	–	0.020	4.6
9 Matsubara	–	–	0.022	3.7
10 Onahama	–	–	0.060	2.1
11 Tsukidate	–	–	0.117	1.1
12 Nihonmatsu	–	–	0.128	1.6
13 Miyota	–	–	0.039	2.9
14 Nishikawa	–	–	0.032	2.5
15 Kitamachi	–	–	0.117	1.5
16 Kawamata	–	–	0.118	1.1
17 Marumori	–	–	0.063	1.8
18 Funaoka-ohashi	–	–	–	–
19 Senoue	–	–	0.133	2.4
20 Yagita	–	–	0.060	16.4
21 Kuroiwa	–	–	0.132	1.3
22 Tomita	–	–	0.286	1.5
23 Ota	–	–	0.031	3.8
24 Odaka	–	–	0.021	11.4
25 Asami	–	–	0.033	2.1
26 Tsushima	–	–	0.088	1.7
27 Ukedo	–	–	0.037	2.8
28 Takase	–	–	0.070	1.7
29 Haramachi	–	–	0.042	3.0
30 Akanuma	–	–	0.050	2.0

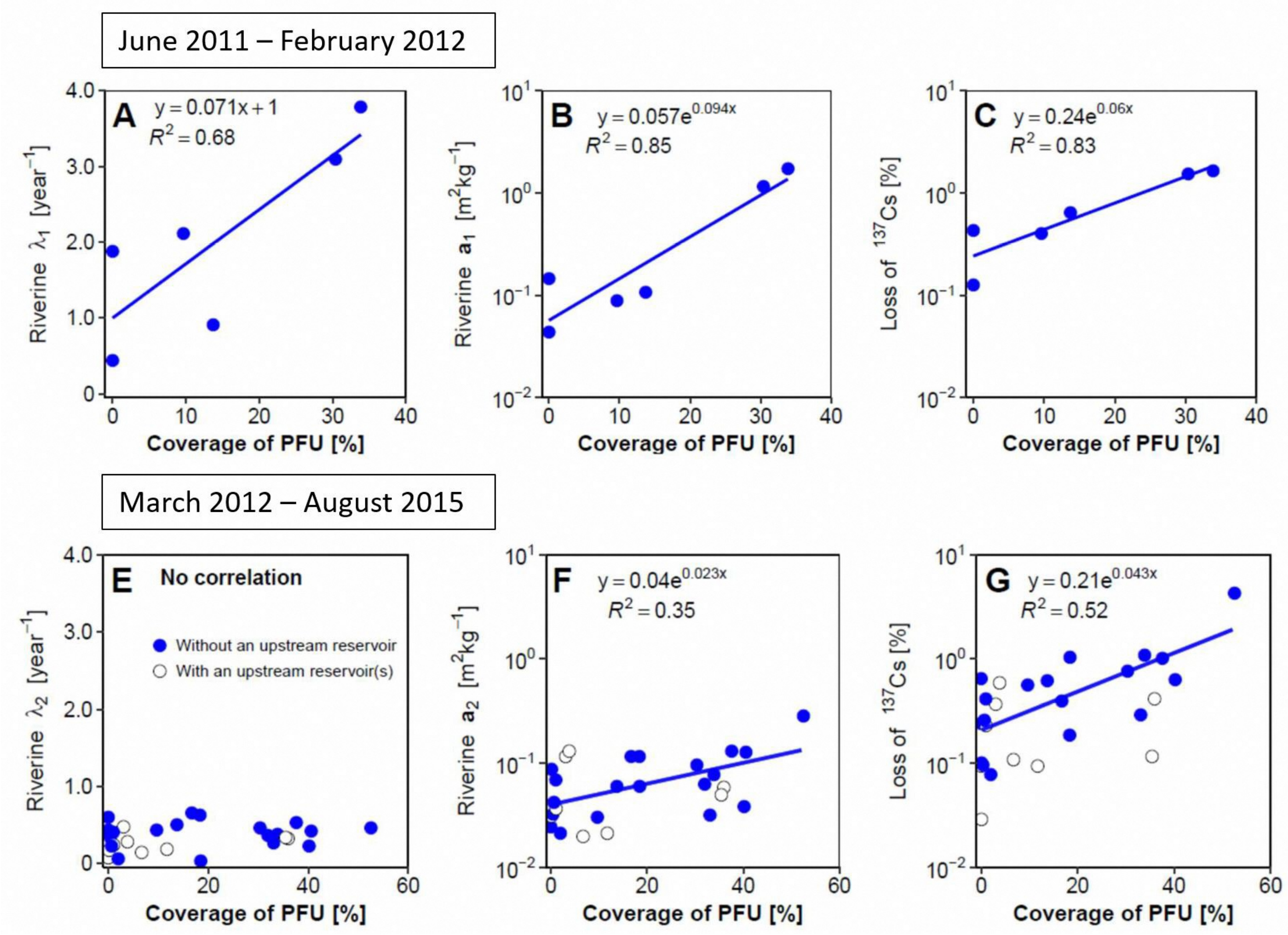

FIG. 8: Relationship between the coverage of the catchment with Paddies, Farmland, and Urban areas (PFU) and the scaling factor a, the decline rate λ of the normalized ^{137}Cs-activity concentration in suspended sediments, and the total loss of ^{137}Cs from the catchment with surface run-off. Image credit: Fukushima Prefecture (Figure from Ref. [15]).

The relationships of the coverage of the catchment with paddies, farmland, and urban areas (PFU) with the following parameters have been plotted in Figure 8 for the periods June 2011 to February 2012 and from March 2012 to August 2015:

- The reduction rates λ of the normalized ^{137}Cs activity concentration in suspended sediments (Eq. 1) increases with increasing PFU-coverage;
- The scaling factors a (Eq. 1) increases with increasing PFU-coverage;
- The total loss of ^{137}Cs from the catchment increases with increasing PFU-coverage.

The data clearly indicate that surface run-off from catchments increases with increasing fractions of PFU. These relationships are more pronounced in the first period (June 2011 to February 2012) compared to the time following. This observation is confirmed by the comparison of the ^{137}Cs flux from forests and from PFU (Figure 9) for the Iwanuma catchment [15]. It should be noted that the 1st period covers only 9 months, whereas the second period covers about 3.5 years:

- In the first period, the total ^{137}C flux from forests is about a factor of 3-4 lower than from PFU, although the area covered by forests is a factor of 2 larger than for PFU;
- In the second period, the ^{137}C flux from forests is similar to that in the first period. However, the ^{137}C flux from PFU is lower than in the first period by a factor of 2.

The total ^{137}C inventory of the Iwanuma catchment is about 470 TBq (Table 6). The total runoff from forests and PFU is about 10 TBq in the period 2011–2015, which is about 2% of the total inventory. During the same period, the reduction of the inventory by radioactive decay is about 9%. However, it is important to note that runoff can locally lead to significant changes in ^{137}C activity concentrations in soils and sediments.

4.3.5. Flux of ^{137}Cs with suspended sediments

For the monitoring stations in Table 6, the flux of ^{137}Cs during the observation period was estimated. The normalized ^{137}Cs activity concentrations in suspended matter are the basis for quantifying the total loss of ^{137}Cs from catchments via surface run-off and the subsequent transport with sediments in rivers. Additionally, the following quantities were considered to estimate the flux of ^{137}Cs from the catchments:

- Average initial deposition in the catchment areas considered as of June 2011;
- Hydrological data as flowrate and turbidity;
- Precipitation;
- Topographical data including elevation and land-use data.

The monthly fluxes of suspended sediments and of ^{137}Cs in the rivers are calculated monthly and integrated over the total observation period [15]. These analyses have been carried out for 30 monitoring sites of the Fukushima prefecture. The results are given in Table 6. The underlying data for Table 6 are summarized in Appendix III.

In general, the losses of ^{137}Cs activity from the catchments due to run-off and river transport are low. In the 1st year, the loss varies 0.13–1.7%, in the period from June 2011 to August 2015, the total loss ranges from 0.1–4.3%. In the same periods, ^{137}Cs activity is reduced due to physical decay by 1.7% and 9.2% respectively; for the investigated catchments, the activity loss of ^{137}Cs and ^{134}Cs due to physical decay is more important than run-off. More than 95% of the ^{137}Cs is lost in particulate form.

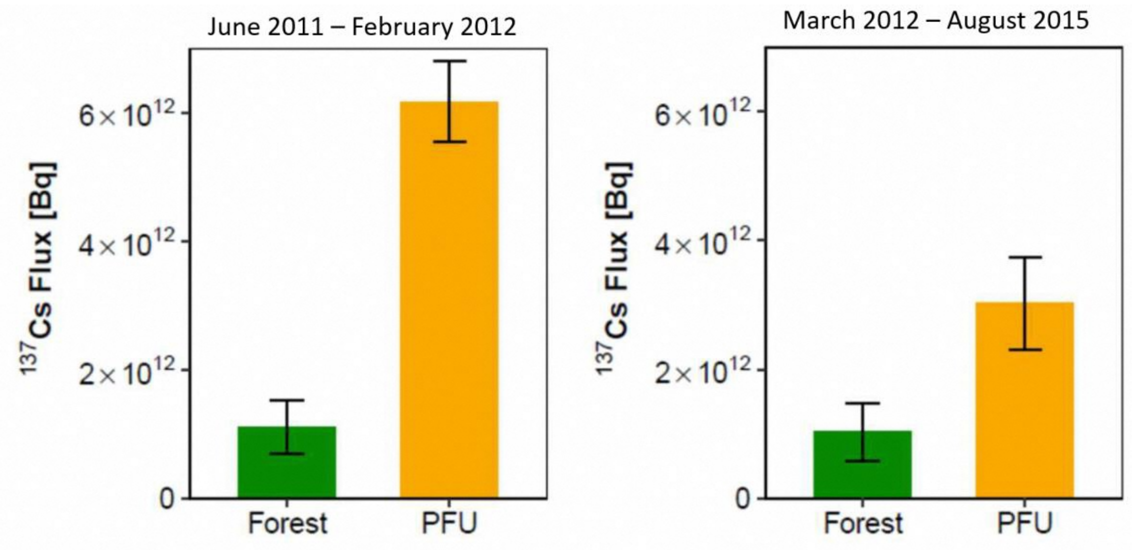

FIG. 9: Flux of particulate ^{137}Cs from forests and PFU from observed in the catchment Iwanuma (Forest: 62%, PFU 30%). Image credit: Fukushima Prefecture [15].

Table 6: Characteristics of the catchments included in the study on the loss of ^{137}Cs [15].

Site name	**Catchment area (km^2)**	**Average deposition (kBq/m^2)**	**Cs-137 loss from the catchment (%)**		**Particulate fraction of Cs-137 flux (%)**	**Cs-137 loss from the catchment (%)**	**Particulate fraction of Cs-137 flux (%)**
			6/2011 to 3/2012	**6/2011 to 8/2015**	**6/2011 to 8/2015**	**10/2012 to 8/2015**	**10/2012 to 8/2015**
1 Mizusakai	7.5	745	0.13	0.4	97.2	0.24	98.3
2 Kuchibuto-up	21.4	477	0.39	1.1	98.5	0.65	98.9
3 Kuchibuto-mid	62.8	357	0.4	1.0	99.6	0.57	99.7
4 Kuchibuto-down	135	269	0.64	1.4	99.7	0.62	99.7
5 Fushiguro	3640	95.9	1.7	3.3	98.7	1.09	97.5
6 Iwanuma	5310	88.4	1.6	2.7	96.5	0.78	96.6
7 Mano	75.6	499				0.10	90.0
8 Ojimadazeki	111	406				0.11	89.3
9 Matsubara	571	40.0				0.09	69.6
10 Onahama	70.1	38.8				0.42	66.7
11 Tsukidate	83.6	223				0.40	99.2
12 Nihonmatsu*	2380	81.8					
13 Miyota	1290	74.1				0.64	96.4
14 Nishikawa	290	132				0.30	97.6
15 Kitamachi	35.8	565				0.37	93.4
16 Kawamata	56.6	229				0.19	97.4
17 Marumori*	4120	105					
18 Funaoka-ohashi#	20.2	775					
19 Senoue	313	41.9				0.59	94.3
20 Yagita	185	52.7				1.04	92.1
21 Kuroiwa	2920	103				1.01	98.6
22 Tomita	72.6	98.5				4.3	98.3
23 Ota	49.9	1770				0.03	82.2
24 Odaka	50.3	724				0.08	83.4
25 Asami	25.8	194				0.10	91.4
26 Tsushima	25.4	952				0.10	98.0
27 Ukedo	153	2570				0.23	87.5
28 Takase	264	726				0.42	99.5
29 Haramachi	200	964				0.26	98.5
30 Akanuma	242	52.6				0.12	92.9

* Not included in the analysis since too few turbidity data were available.

Not included in the analysis because only data for dissolved ^{137}Cs were available.

4.4. MODELLING THE CONCENTRATIONS OF DISSOLVED AND PARTICULATE CAESIUM-137 IN RIVER WATER

The concentrations of dissolved and particulate ^{137}Cs in rivers of the Fukushima were modelled by application of the TODAM[8] model. The model was designed for estimating the transport of radionuclides in rivers. The model requires data on water flow, topography, land use and grain-size distribution. In the Fukushima Prefecture, it was applied to estimate the transport of dissolved and particulate ^{137}Cs downstream the Hirose River. Within the studied area, the rivers Takane, Nuno, Ishida, and Oguni join the Hirose River.

In Figure 10, the measured and predicted activity concentrations of particulate and dissolved ^{137}Cs in the Hirose River are shown. The simulation was performed for a relatively low flowrate. The activity concentrations of particulate and dissolved ^{137}Cs in water are the result of the interaction of water composition, silt, clay and sand content of the suspended sediments, turbidity, and flow rate. The ^{137}Cs concentrations in suspended sediments are of the order of several thousand Bq/kg, the concentration of dissolved ^{137}Cs is in the range 1–5 Bq/m³. Despite this complexity, measurements and prediction agree reasonably well. The understanding of the ^{137}Cs transport supports planning of remediation measures in rivers, the dislocation of riverbed sediments and the persistence of countermeasures.

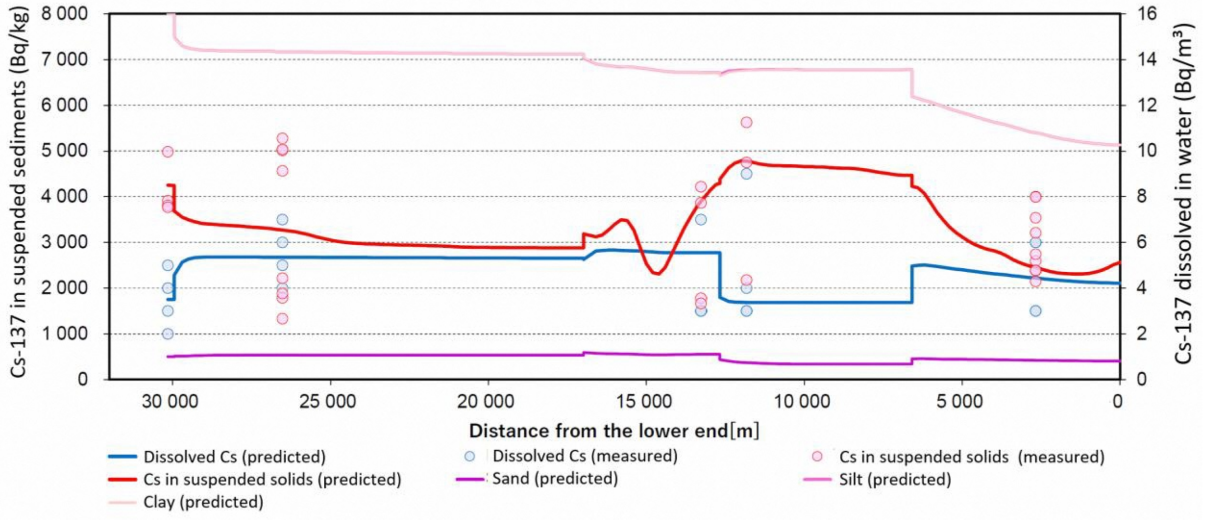

FIG. 10: Comparison of measured concentrations for particulate and dissolved ^{137}Cs in the Hirose River with simulations using the TODAM model. Image credit: Fukushima Prefecture.

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[8] The TODAM model (Time-dependent, One-dimensional Degradation And Migration) was developed [29]. This model has been applied in many countries to simulate the transport of radionuclides in freshwater systems as e.g. in the framework of remediation projects in Hanford (Washington, USA), Chornobyl (Ukraine), and Mayak (Russian Federation).

4.5. COMPARISON OF JAPANESE AND INTERNATIONAL EXPERIENCE ON THE DYNAMIC OF CAESIUM-137 IN RIVERS

4.5.1. Effective half-lives of ^{137}Cs in river water

Following the accident in the Chornobyl Nuclear Power Plant in 1986, freshwater bodies all over Europe have been monitored for ^{137}Cs in water and in suspended and bottom sediments [30]. However, ^{137}Cs activity concentrations in different water bodies are not directly comparable. The ^{137}Cs concentrations in the water bodies and their time-dependence are the results of an interaction of the deposition density, the catchment area, size of the water body, precipitation, rainfall intensity, slope, and land-use.

To facilitate the comparison of the behaviour of ^{137}Cs in freshwater systems, the time dependence of radionuclides in sediments, suspended sediments or water is approximated by an exponential function or a sum of exponential functions. If the available data allow, the activity concentrations may be normalized to the average deposition in the catchment to facilitate the comparison of different rivers and catchments:

$$C_w(t) = C_0 \cdot \sum_1^n a_n \cdot e^{-\lambda_\mathrm{n} \cdot t} \qquad \text{(Eq. 2a)}$$

$$C'_\mathrm{w}(t) = \frac{C_0}{D_0} \cdot \sum_1^n a_n \cdot e^{-\lambda_\mathrm{n} \cdot t} \qquad \text{(Eq. 2b)}$$

where:

$C_w(t)$ is the time-dependent activity concentration in sediments (Bq/kg) or water (Bq/L);
$C'_\mathrm{w}(t)$ is the time-dependent normalized activity concentration in sediments/water (m²/kg or m²/L);
C_0 is the initial concentration in sediments/water (Bq/kg) or water (Bq/L);
D_0 is the initial average deposition in the catchment (Bq/m²);
A_n is the weighting factor for the exponential function n;
λ_n is the decline rate of the exponential function n (a^{-1}) (corresponding half-live $T_{½,n}=\ln(2)/\lambda_n$).

The parameters of Eqs 2a and 2b, which reflect global experience, as well as those determined in studies conducted in Fukushima Prefecture after 2011, are compiled in Table AI.1 (Appendix I, with all underlying references). However, not all parameters included in Eqs 2a and 2b could be determined in all studies.

In the studies, the number of exponential functions identified varies, depending on the observation period, and the start of the observation period after the contamination event. In long-term studies, starting immediately after the deposition, a typical pattern of the long-term-decline of radiocaesium in water is characterized by 3 phases. However, in some cases, the observations started too late after the deposition, then the initial concentration in water could not be determined and the rapid decline immediately after the deposition was not covered by the observation period. In other case, the observation period was not long enough to identify the long-term component of the decline.

From the data compiled in Table I.1 (Appendix I), the following trends can be extracted:

General aspects:

- As expected, immediately after the deposition, the maximum level of ^{137}Cs in river water is observed.

- Most data are for suspended sediments. However, the effective half-lives observed for particulate and dissolved ^{137}Cs are in the same range.
- By and large, the time trends observed in Japan and in other parts of the world agree reasonably well. The general pattern of the decline is quite similar in both regions.

Initial decline:

- Initially, concentrations in water decrease rapidly, with time the decrease slows down.
    - In European rivers, immediately after deposition during a period of about 2–3 weeks, a decline of the ^{137}Cs according to an effective half-life of 5 days was observed.
    - In measurements of ^{137}Cs in river water, starting several days after deposition, effective half-lives in the range of 20–50 days were observed.
    - In some cases, the measurements started later (in 1987 following the Chernobyl accident, in 2012 following the accident in FDNPP). Then the very rapid immediate decline of concentrations is no longer reflected in the first component. In such cases, effective half-lives of 70–270 days were found, in one case 1.6 y were observed.
- The results achieved in the Fukushima Prefecture agree well with the global experience.

Decline within an observation period of 5–15 years:

- Many data sets do not include the initial phase with the fast decline; most data are available for the second component which covers observation periods of 5–15 years starting several months after radionuclide deposition.
    - For Ukrainian rivers, the effective half-lives found are in the range from 2.0–6.5 years.
    - In two Finnish rivers, effective half-lives of 3.5 and 6 years were observed.
    - In the Iput River (Russia), an effective half-life of 1.3 years was observed in the period 1987–1991.
    - For the Fukushima Prefecture, values for effective half-lives from 48 data sets are available ranging from 0.7–16 years. Three values were below 1 year, and three values were above 5 years. Fourty-two values were in the range from 1.1–4.6 years.
- The results from the Fukushima Prefecture agree very well with the effective half-lives observed in Ukraine, Russia, and Finland.

Long-term decline:

- If the observation period is long enough, in some cases a third phase can be identified. However, quantifying a third decline component requires observation times of at least 15 years, since the overall contribution of a third exponential term is very small. So far, in the studies carried out in the Fukushima Prefecture, such long observation periods are not possible.
- In an analysis of the time dependence of ^{137}Cs in water of 25 rivers in Europe and West Asia after the Chernobyl accident, a third component with an effective half-life of 16 years was identified. The contribution to the overall decline of this component was only 0.5% and the relevance in practice is of minor importance.

4.5.2. Loss of ^{137}Cs from catchments

As was the case for the releases during the accident in FDNPP, the releases from the Chernobyl accident occurred within a short time. For estimating the loss of activity from a catchment, in Ref. [31] a transfer function has been defined, which describes the loss rate of activity deposited in a catchment by run-off processes as function of time. In agreement with the studies carried out in the Fukushima Prefecture, the run-off depends on specific circumstances as the characteristics of the catchment, the radionuclide and the quantity considered (run-off of dissolved or particle-bound radionuclides, total run-off). The transfer function consists of 2 components:

$$f(t) = f_1 \cdot \lambda_1 \cdot \exp\left[-(\lambda_1 + \lambda_r) \cdot t\right] + f_2 \cdot \lambda_2 \cdot \exp\left[-(\lambda_2 + \lambda_r) \cdot t\right] \quad \text{(Eq. 3a)}$$

$$f_1 + f_2 = 1 \quad \text{(Eq. 3b)}$$

where:

f_1 is the fraction of activity that is available for short-term (rapid) run-off;
f_2 is the fraction of activity deposited which is subject to long-term run-off;
λ_1, λ_2, λ_r, are the loss rates for the short- and the long-term components of run-off and the physical decay respectively (a^{-1}).

The parameters f_1 and f_2 and the loss rates λ_1 and λ_2 have been determined from wash-off experiments and observations in the field.

Regarding total ^{137}Cs-run-off, the parameter f_1 covers a range of 0.2–7.4%. However, the upper bound of the range has been determined for experiments on small plots. For catchment areas, for f_1 a value of the order of a percent is given as a typical estimate for radiocaesium.

The loss rate for short-term wash-off λ_1 is estimated to be approximately 24 a^{-1}, which corresponds to a half-life of about 10 days [31].

The long-term ^{137}Cs -activity loss due to surface run-off is much less. The ranges for λ_2 for run-off of dissolved and particulate ^{137}Cs are 0.00007–0.02 a^{-1} and 0.00009–0.1 a^{-1} respectively; the values in the lower part of the range refer to flat terrains where the run-off is very low by nature. Regarding the total loss due to run-off, the λ_2-values for ^{137}Cs cover a wide range from 0.00004–0.01 a^{-1}. For catchment areas, λ_2-values of less than 1% are given as a typical estimate for radiocaesium [31]. The upper limit of λ_2 of 0.01 a^{-1} is lower than the activity loss due to physical decay rate λ_r of 0.023 a^{-1}, i.e. the decline of the total ^{137}Cs-inventory in a catchment area is generally dominated by the radioactive decay.

These findings are in general agreements with the findings of the studies carried out in the Fukushima Prefecture.

5. EXPERIENCE MADE DURING DECONTAMINATION WORK

5.1. EFFECT OF DECONTAMINATION ACTIVITIES ON RIVERS AND CATCHMENTS

In the upper part of the Kuchibuto River, from March 2013 to December 2015, a decontamination project was implemented on an area of 1600 ha. The area is mainly used as forest (730 ha) and for agriculture (610 ha), 71 ha are covered by roads; the rest is used for residential purposes. The decontamination work focused on removal of topsoil from agricultural and washing of roads and paved areas. Most of the work was carried out from April 2014 to March 2015.

The loss of suspended sediments from the catchment before, during and after the decontamination work is shown in Figure 11. Transport of suspended sediments increased during decontamination work, and it declined after it was completed. However, after termination of the decontamination project, the sediment loss remained higher than before the decontamination work.

The monthly loss of ^{137}Cs as a percentage of the total ^{137}Cs inventory from the upstream, midstream and downstream Kuchibuto catchment is shown in Figure 12. The monthly losses were highest immediately after the deposition. The monthly loss increased during the decontamination work as the disturbance of the upper soil layer intensified erosion processes. The area was hit by typhoons in September 2015 and 2016 that caused widespread flooding due to heavy rains, which was reflected in an increase in monthly ^{137}Cs losses in September 2015 and 2016. After decontamination was completed, ^{137}Cs losses decreased.

During the decontamination work, the total loss of ^{137}Cs from the catchment due to surface run-off is of the order of 0.03% per month and does not contribute significantly to the decrease of the overall ^{137}Cs inventory in the catchment, which is dominated by the radioactive decay (0.19% per month).

However, it is important to be aware that the loss is not homogeneous over the whole catchment. In some areas the ^{137}Cs loss may be considerable whereas other parts may not be affected by erosion at all. The same is true for the landscape element that receives the activity lost from the upstream catchment. The total inventory of the receiving landscape element may not change significantly, but locally, the activity concentration may be modified considerably.

5.2. DECONTAMINATION OF RIVERBEDS AND RIVERBANKS

Immediately after the accident, comprehensive decontamination activities were set up to reduce activity and radiation levels in residential and public areas, and on agricultural land. For public areas, focus was given to routes for children to schools and kindergartens, and to areas used for leisure activities.

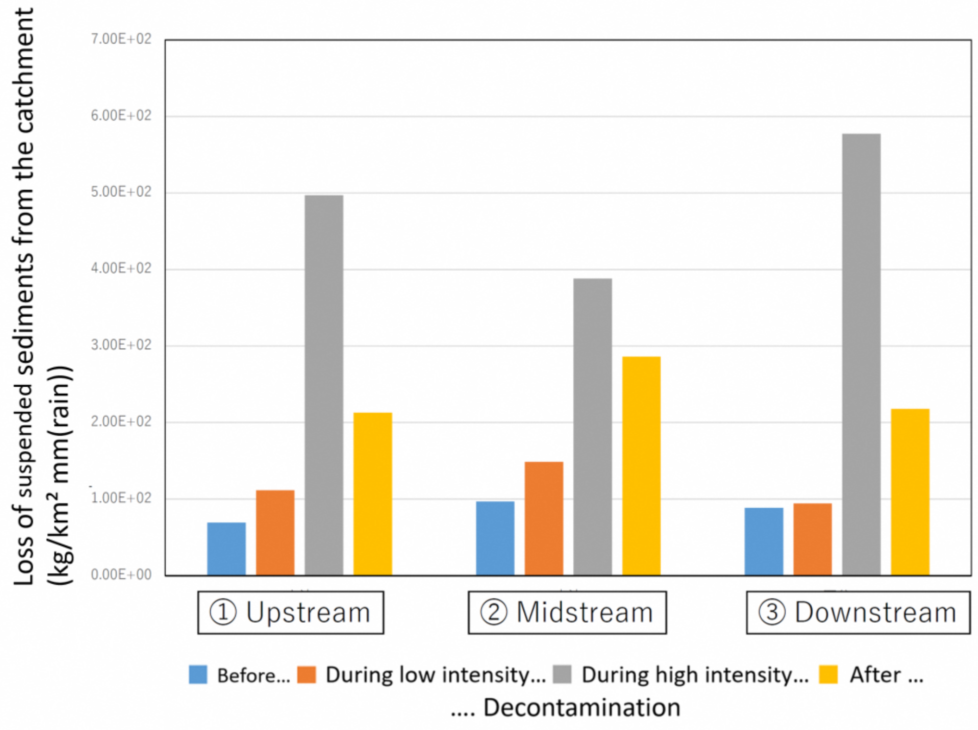

FIG. 11: Loss of suspended sediments from the Upper Kuchibuto catchment before, during, and after the decontamination work. Image credit: Fukushima Prefecture [32].

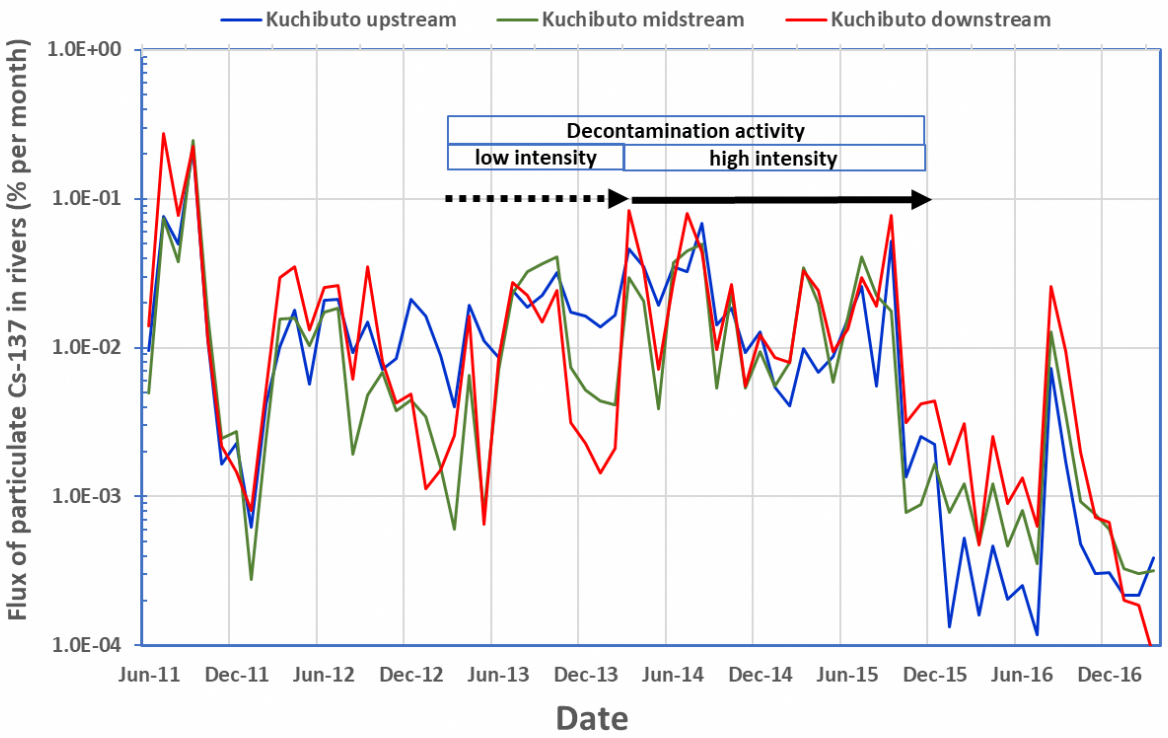

FIG. 12: Monthly loss of ^{137}Cs with suspended solids from the Kuchibuto catchment upstream, midstream and downstream. Decontamination work was carried out from April 2014 to March 2015, the decontamination intensity was highest from April 2014 to March 2015. Image credit: Fukushima Prefecture (Figure created from data in Refs [15, 20]). The underlying data for this figure are summarized in Appendix III.

For demonstrating the feasibility and for exploring the effectiveness of decontamination measures, in terms of reduction of gamma-dose rates in air, three sites of the Fukushima Prefecture were considered:

- Kami-Oguni River: A path along the river is used as route to a school and for recreation. Decontamination measures included pre-weeding and removal of sediments from the river bottom. Additionally, vegetation and soil were removed from the river dikes Figure 13. The decontamination activities were carried out from August to November 2014. Gamma-dose rate was reduced by about a factor of 2 [33].
- Niida River Park: An area close to the river which is used for leisure purposes. Model calculations were carried out to estimate the possible reduction of gamma dose rates.
- The Nature Park at the Mizunashi River in Minami-Soma city is used for leisure. The effectiveness of decontamination measures was studied by means of model simulations.

5.2.1. Impact of typhoons and flood events on the persistence of decontamination

The Fukushima Prefecture is occasionally hit by typhoons which are associated with high rainfall, overflowing of rivers and floods. Such high-water events cause considerable displacement of sediments and coarse material in the riverbeds; suspended sediments may also deposit on adjacent flooded areas. Investigations to explore the impact of typhoons on the persistence of decontamination measures were based on comprehensive measurements of gamma-dose rates. Figure 14 shows the time-dependent gamma dose rate in air for the studied area at the Kami-Oguni for the period from September 2014 to September 2015. A typhoon occurred in August 2015.

The decrease of the gamma-dose rate in Figure 14 from February 2015 to September 2015 appears to indicate the impact of a typhoon. It is interesting to note that the displacement of materials associated with the typhoon did not affect the effectiveness of the decontamination work.

Another typhoon, called ‘Typhoon No. 19’, hit the Fukushima Prefecture in October 2019. Gamma dose rates were comprehensively measured immediately after the typhoon in October 2019, and compared to those in January 2018 to estimate the impact of the typhoon. The results are shown in Table 7. At all three sites, the gamma dose rates dropped. The ^{137}Cs activity concentration of the material carried with the flood water is noticeably lower than of the riverbed sediments before the flood. These observations are consistent with the results reported by Evrard et al. [34] who measured ^{137}Cs-activity concentrations in sediments and related gamma dose rates in coastal rivers of the Fukushima Prefecture.

5.3. INTERNATIONAL EXPERIENCE ON REMEDIATION OF RIVERS

Since the early 1950s, experience has been gained world-wide in the management of contaminated rivers. Large amounts of radionuclides were released to the freshwater environment from the nuclear facility in Mayak (Russian Federation) in the late 1940s and 1950s [35]; this facility produced nuclear fuel and material for nuclear weapons since the late 1940s. Freshwater environments were also contaminated due to releases from the Hanford facilities (USA) and from inappropriately stored liquid waste at the Hanford site since the mid-1940s [36]. The Chernobyl accident in 1986 [37] caused a deposition of radionuclides on the floodplain of the Prypiat River (Ukraine), which triggered a long-term input of radionuclides to the Pripyat River.

In all cases, river water was used as drinking water, for irrigation, and for industrial purposes. Decontamination measures were introduced to mitigate the radiological consequences potentially arising from the contamination of freshwaters.

FIG. 13: The Kami-Oguni River before and during decontamination work in 2014. Image credit: Fukushima Prefecture [33].

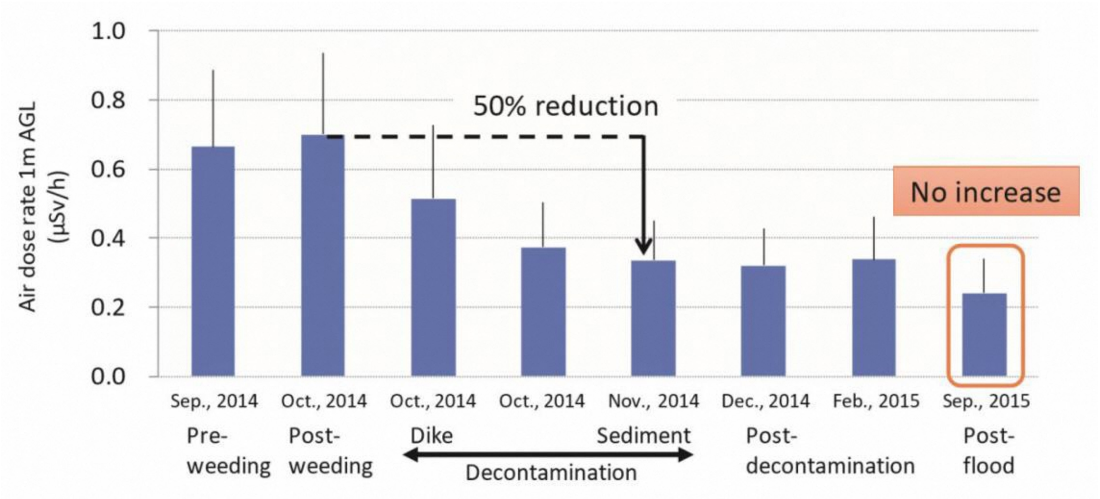

FIG. 14: Time-dependent γ–dose-rate at a demonstration site at the Kami-Oguni River for a decontaminated area(removal of weed, riverbed sediments, soil, and of vegetation from the dykes), a flood occurred in August 2015. Image credit: Fukushima Prefecture [32].

Table 7: Comparison of average gamma dose rates before and after Typhoon No. 19. [32]

Study sites	**Quantity**	**γ-dose rate at 1 m height (µSv/h)**	
		Before Typhoon No. 19 (31 January 2018)	**After Typhoon No. 19 (17 October 2019)**
Kami-Oguni River	Average	0.34	0.18
Niida River Park	Average	0.30	0.20
Mizunashi River Park	Average (range)	0.21 (0.07-0.42)	0.16 (0.02-0.32)

Freshwaters are dynamic systems with continuously changing conditions. Important factors are the variations of water level and water flow, the input from the surrounding catchment, and sedimentation and resuspension processes. All these factors lead to varying concentrations of radionuclides in dissolved and suspended form. Radionuclides in dissolved and particulate form are continuously dislocated. Due to the dynamic nature of freshwaters, there are only limited options for reducing activity levels in freshwaters and for interventions for reducing exposures to people. The measures can be classified into two groups [38, 39], the most important are:

Administrative measures:

- Restrictions on the use of drinking water for humans and livestock;
- Restrictions on access to contaminated riverbanks;
- Restrictions on fishing and freshwater fish consumptions/

Technical measures:

- Water treatment in waterworks;
- Modifying the water flow by the construction of dikes;
- Implementing sedimentation traps to force sedimentation of suspended sediments;
- Measures to reduce the radionuclide uptake by fish from water;
- Removal of dissolved radionuclides by means of agents that adsorb radionuclides.

5.3.1. Administrative measures

Administrative measures were applied within the management of the contaminations of rivers in Mayak, Chornobyl and Hanford [37, 40]. Experience from these sites show that such measures are effective and easy to implement provided that sufficient water and fish can be made available from other sources. This is easy to warrant for localized contaminations and for small water bodies, whereas it might be challenging for large-scale contamination that affect a larger group of population.

The radiological relevance of administrative measures in terms of reduction of doses depends strongly on the living habits, such as withdrawal of drinking water, use of river water for irrigation and consumption of local fish. An advantage of administrative measures is that restrictions can, in principle, be easily lifted when activity concentrations in water, sediments, and fish have declined due to radioactive decay and other attenuation processes.

5.3.2. Technical measures

In the early phase after the Chernobyl accident, charcoal and zeolite were applied in some waterworks. The activity concentrations of ^{131}I, ^{106}Ru, ^{134}Cs, ^{137}Cs, and ^{90}Sr were reduced by approximately a factor of two, with charcoal being effective for iodine and ruthenium, and zeolite effective for caesium and strontium. The limited capacity of the sorbents has to be considered; a replacement with new sorbents would be necessary if the treatment is needed for a longer time [37].

Experience from the Chernobyl accident shows that technical measures implemented in freshwater bodies to reduce activity levels in water and sediments need to be carefully planned to consider the specific local hydrological conditions.

For reducing the transport of particulate radiocaesium, sediment traps were installed in the Pripyat River. The effectiveness of this measure was very low, as a large fraction of caesium was in dissolved form which cannot be intercepted. Furthermore, the flow rates were too high to intercept small, suspended particles. However, it was found that the Kiev reservoir and deep reservoirs in the Fukushima Prefecture along the rivers Ota (Yokokawa Dam), Mizunashi, (Takanokura Dam), Ukedo (Ogaki Dam), and Kuma (Sakashita Dam) act as sediment traps [41, 42]. The low flowrate in dams favours the sedimentation of particulates. This is a general phenomenon which caused an effective sedimentation of radiocaesium in calm waters, such as lakes and reservoirs.

On smaller rivers in the Chornobyl region, about 130 dikes containing zeolite were installed for absorbing dissolved radionuclides [43]. The effectiveness was low, with only 5–10% of ^{90}Sr and ^{137}Cs being removed. Due to the saturation of the sorbents, this low effectiveness declined within a relatively short time; this measure is therefore not sustainable. Filtering of water through reed beds to remove ^{137}Cs and ^{90}Sr was considered as a potential option; however, it is a cumbersome procedure and the application for larger areas is unlikely [43].

Depending on the local conditions, hydrological measures may prevent the dispersion of radionuclides from contaminated land with water. In 1993, the Pripyat River was separated from the highly contaminated Prypiat flood plain by a dike constructed on the left bank of the river. This measure prevented the run-off of radionuclides from the highly contaminated floodplain to the Prypiat River [41]. This measure was technically feasible, as the area around the Chornobyl NPP is flat. Such hydrological measures in mountainous terrains as found in the Fukushima Prefecture, if technically feasible at all, may be much more complicated and costly.

In 18 Swedish lakes, the application of lime had no influence the ^{137}Cs levels in freshwater fish [44]. The antagonism of caesium and potassium was tested in 13 Swedish lakes by applying potash. However, the results do not allow to draw final conclusions, as the water turnover of the lake was too high to maintain sufficiently high levels of potassium concentrations in the lake water.

The application of potassium chloride to Lake Svyatoe (Belarus) with low natural potassium concentrations and a lower water turnover, leading to a longer residence time of the water in the lake, was more successful. After potassium application of 0.05 kg/m² to the lake surface in 1998, the ^{137}Cs activity concentrations in large perch were reduced by approximately a factor of 3 (see Figure 15 below) [45]. Model calculations indicated that the reduced ^{137}Cs levels in large perch would be reduced for about 15 years after the potassium application. However, application of potassium led to increased radiocaesium activity concentration in water due to competition with K in sediments, which could affect its use for drinking or irrigation.

Following the Chernobyl accident, numerous countermeasures were tested and implemented to prevent the input of run-off water to freshwater bodies. In general, the initial expectations of such measures were not met, as it is complicated to control the dispersion of material in dynamic systems as river. Engineering measures are costly and often difficult to implement; moreover, the overall impact on public doses in the affected countries were low [37]. In terms of reducing exposures to the public, restrictions on drinking water abstraction and fishing were most effective.

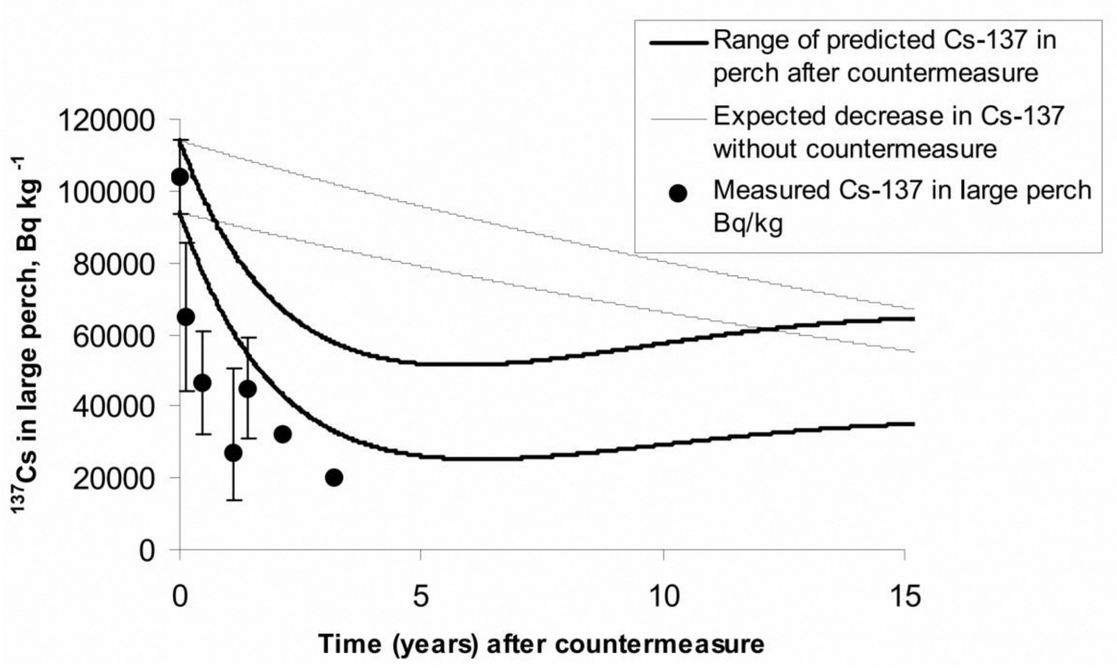

FIG. 15: Activity concentration of ^{137}*Cs in perch from the potassium application in 1998 to 2013. The expected decrease in the absence of countermeasures is shown as well, an effective half-life of 20 years has been assumed [45].*

6. MICRO PARTICLES CONTAINING CAESIUM-137

6.1. GENERAL INFORMATION ON MICROPARTICLES

In several investigations carried out in the Fukushima Prefecture, a kind of glassy particles containing radiocaesium were found by autoradiography methods in various materials such as air filters, house dust, soils, plant leaves near the accident site, agriculture materials, feathers of birds, and river water (see e.g. Refs [46–49]). The particles are usually called Caesium-Microparticles (CsMPs). These particles were released from the reactors and dispersed in the atmosphere. So far, most CsMPs have been found relatively close to the reactors, but some were also detected several hundred kilometres away from FDNPP [47].

Studies were carried out to investigate the chemical and isotopic compositions of the CsMPs, to identify the likely sources of the CsMPs and the processes generating CsMPs during the accident. Main elements of CsMPs are Si, Fe, Zn, Cs, and O. Two types of particles have been identified, called Type A and Type B particles [48, 50]:

- Type A particles are almost spherical, the diameter is typically less than 5 µm. Type A particles originate from silicate glass. The activity is several Bq ^{137}Cs per particle. The ^{134}Cs/^{137}Cs ratio is above 1, which reflects the fuel burn-up at the time of the accident in Units 2 and 3 of FDNPP. Therefore, it is thought that Type A particles originate from Units 2 and 3.
- Type B particles have various shapes, with diameters of a few to up to 400 µm. These particles appear to originate from fibre silicate, which is an insulation material used in the reactor. The activity is in the range of 30–19 000 Bq. The ^{134}Cs/^{137}Cs ratio is lower than 1. Type B particles are associated with Unit 1 of FDNPP.

Such caesium-microparticles (Cs-MPs) degrade slowly. A solubility experiment using a CsMP with a radius of approximately 1 µm was conducted [51]. Seawater and pure water were used as solvents. The dissolution rate in seawater was about a factor of ten higher than in pure water. For this experiment (given in Ref. [48]), a lifetime for this particle of less than 10 years in seawater has been estimated. In pure water, the lifetime is expected to be much higher than 10 years, so the results indicate a low solubility and a high persistence. Investigations in soil samples collected between 2011 and 2017 in the vicinity of FDNPP [52] indicate that 2–80% of the radiocaesium in soil may be associated with such particles.

6.2. CsMPs FOUND IN SUSPENDED SEDIMENTS OF THE HAMADORI RIVER

During investigations by Fukushima Prefecture on ^{137}Cs in suspended sediments at a monitoring point of the Hamadori River in October 2018, a sample with an exceptionally high ^{137}Cs concentration was taken. The concentration was about a factor of 5 higher than in other samples taken in the same period (see Figure 16 below). The enhanced ^{137}Cs-activity in the sample of suspended sediments was associated with the presence of radiocaesium microparticle (CsMP).

Characteristics of CsMPs found in the Kuchibuto River during campaigns carried out from 2011 to 2016 (see Table 8 below) were compiled by Miura et al [53]. The distribution coefficients, K_d for ^{137}Cs in the suspended sediment samples were calculated based on the ^{137}Cs activity in the sample excluding and including the activity of the CsMP. In all cases, the K_d-value based on the total activity (including the CsMP) is higher, which indicates the low solubility of the CsMPs.

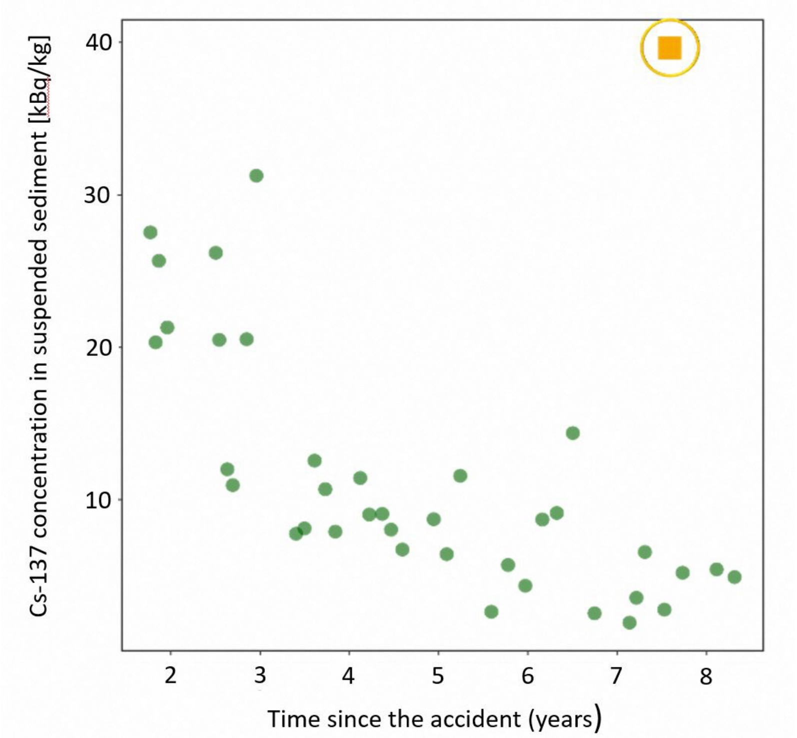

FIG. 16: Time dependent ^{137}Cs activity concentration in suspended sediments at a monitoring station of the Hamadori River, one sample has an exceptionally high ^{137}Cs concentration. Image credit: Fukushima Prefecture.

Table 8: Concentrations of ^{137}Cs in CsMPs collected in the Kuchibuto River; the number of CsMPs, and K_d-values with or without CsMP in the solid phase [53].

Sampling date	**Number of CsMPs**	**Cs-137 in CsMPs (Bq)**	**Fraction of CsMPs on filter (%)**	**K_d without CsMPs (L/g)**	**K_d with CsMPs (L/g)**
31 July 2011	17	4.3	15	1400	1700
3 August 2012	1	0.11	1.3	1910	1950
3 May 2014	6	4.1	36	1100	1700
22 November 2014	4	0.77	67	4600	14 000
22 November 2015	5	2.3	66	3200	9300
1 April 2016	3	0.48	36	850	1300

The characteristics of 5 CsMPs deposited on a non-fabric cloth 50 km west of the FDNPP were investigated by Kurihara et al [49]. Diameters varied from 1.6-2.7 µm, the total ^{137}Cs-activity ranged from 0.7–1.9 Bq, and ^{134}Cs/^{137}Cs-ratios between 0.96 and 1.17 were found. Based on these properties, and the on ratios of ^{235}U/^{238}U, all these CsMPs were classified as Type A originating from Unit 2.

The investigations of CsMPs in soil and suspended sediment samples [48, 53] indicate that only a minor fraction of the ^{137}Cs in the environment is associated with CsMPs. However, the long-term fate of CsMPs in the environment is not yet fully clarified. The low solubility in the freshwater system indicates low bioavailability [51].

6.3. INTERNATIONAL EXPERIENCE ON PARTICLES WITH ENHANCED RADIONUCLIDE CONCENTRATIONS

The occurrence of particles in the environment with enhanced levels of radionuclides was also a phenomenon that was detected after the Chernobyl accident [54]. However, due to the different reactor type and the different specifications of the accident at Chornobyl, the characteristics of the particles are quite different compared to those found in the Fukushima Prefecture. Due to the high activity of some particles released from the Chornobyl reactor, they were called ‘hot particles’. These particles from the Chornobyl reactor are classified into condensation particles and fuel particles.

6.3.1. Condensation particles

Condensation particles were generated at high temperatures during the breakdown of fuel elements and typically have a size on the order of 1µm. Volatile fission products (isotopes of I, Cs, etc.) were released into the atmosphere and condensed on inert particle carriers. Particles of such kind were also detected after the test of nuclear weapons in the atmosphere. Some condensation particles had relative high activities containing one dominating radionuclide as e.g. ^{106}Ru and ^{140}Ba (half-lives 374 d and 12.8 d) with activities in the range of 500–10 000 Bq/particle. Due to the relatively short half-lives of these isotopes, there is no long-term impact of such particles [54].

6.3.2. Fuel particles

Fuel particles are small fragments of nuclear fuel, generated during the breakdown of fuel elements. Fuel particles had higher activity concentrations than condensation particles. They were composed of uranium oxides, the radionuclide composition was like the fuel composition in the damaged unit, but volatile nuclides (^{131}I, ^{134}Cs/^{137}Cs, ^{106}Ru, etc.) were depleted. The size of fuel particles ranged from a fraction of a micrometres to hundreds of micrometres; their activity was typically 100–1000 Bq/particle.

6.3.3. Environmental behaviour

Within the 30-km exclusion zone around the damaged Chornobyl reactor, up to 10^5 fuel particles per m² were found. Deposition of fuel particles decreased with distance from the reactor site. Fuel particles have a low solubility in water. Therefore, with increasing distance from the reactor, the fraction of water soluble and exchangeable forms increased since the contribution of more soluble particles increased with distance. Due to the presence of water-insoluble fuel particles, the fraction of non-exchangeable ^{137}Cs in the fallout near Chornobyl about 75%, whereas it was 40–60% in the Bryansk region at a distance of 200 km from the reactor, and only 10% in Cumbria (UK) at a distance of 2000 km [54].

Near the Chornobyl reactor, in the first years after the accident, leaching of radionuclides from fuel particles was an important process; this caused an increased migration of radionuclides, in particular for ^{90}Sr. In soils, fuel particles had virtually disintegrated within 10 years. Due to the low solubility of hot particles, radiocaesium released during the Chernobyl accident had higher distribution coefficienst (K_d) than e.g. of radiocaesium originating from atmospheric nuclear weapons tests. Consequently, migration in soil was slower, and the bioavailability radiocaesium was lower in the area close to the NPP [54].

Far away from Chornobyl, the situation was different. In the first year after deposition, the uptake of ^{137}Cs by plants was 4–5 times higher than that in areas with considerable fuel particle deposition. In subsequent years, in particular the transfer of radiocaesium from soil to plants declined due to the increasing sorption of caesium to clay minerals.

6.3.4. Fukushima CsMPs and Chernobyl hot particles

Following both accidents in Fukushima and in Chornobyl, particles with enhanced levels of radionuclides were found. However, the particles are quite different:

- Fukushima type A particles have a similar size spectrum as condensation particles that were found e.g. after weapons’ fallout. However, type B particles are smaller than Chernobyl hot particles;
- Chernobyl-hot-particles are mainly fuel fragments, whereas CsMPs are of glassy nature generated during any liquifying and evaporation processes of reactor materials [48];
- The total activity of the CsMPs is in general lower than of Chernobyl hot particles;
- The hot particles released from the Chernobyl reactor contain a wider spectrum of radionuclides, whereas the Fukushima-CsMPs contain mainly ^{137}Cs;
- Due to their larger diameter, Chernobyl hot particles deposited close to the reactor site, the number of hot particles decreases with the distance from the reactor.

Due to their size, solubility, activity and chemical composition, particles with enhanced levels of radionuclides raise several questions regarding dosimetry. These questions are currently being investigated for the CsMPs.

A key parameter for dosimetric calculations is the gut absorption (transfer of radionuclides from the gut to the blood). For the calculation of dose conversion coefficient for intake of ^{137}Cs with food or water [55], a gut absorption of 100% is assumed, which is a conservative assumption. The solubility of the CsMPs is relatively low, which may cause a lower gut absorption and lower values for the dose per unit intake [Sv/Bq]. Further studies are needed to confirm this hypothesis.

7. SUCCESS OF DECONTAMINATION WORK

7.1. DECONTAMINATION ACTIVITIES IN THE FUKUSHIMA PREFECTURE

For planning of decontamination, the areas affected by the enhanced deposition of radionuclides were classified in August 2011 [56] into the Special Decontamination Area (SDA) and the Intensive Contamination Survey Area (ICSA):

- The SDA consists of the former 'Warning Zone within a 20 km radius of the Fukushima Daiichi NPP, and the former 'Planned Evacuation Zone', which was situated beyond the 20 km radius from the NPP and where the additional annual dose for individuals could exceed 20 mSv in the first year after the accident [14].
- The ICSA includes those municipalities where the additional radiation dose in the first year was estimated to be between 1 and 20 mSv for individuals in some parts of the municipality. Areas with an ambient dose rate of 0.23 µSv/h and above were assigned to the ICSA. This value was used as criterion for designation of the ICSA, but it was not a decontamination target.

By March 2018, the decontamination activities in the Fukushima Prefecture except for the Difficult-to-Return Zones (DRZ) were terminated. In the SDA, decontamination was performed on 23 000 houses of residential areas, on 8700 ha of farmland, on 7800 ha of forests close to residential areas and on 1500 ha of roads. In the ISCA, decontamination works were carried out at 418 583 houses including the gardens, 11 958 public buildings, on 31 061 ha of farmland, 4478 ha of forest near residential areas, and on 18 841 km of roads [57].

During the decontamination, approximately 14 million m³ [58] of soil and waste was generated that is stored in Temporary Storage Sites (TSS). The transport of the soil and waste from the TSS to an Interim Storage Facility started in 2015, and the transport was completed in 2022, except for the DRZ.

The effectiveness of the decontamination work is compiled in Ref. [59]. The results are summarized in Table 9 for agricultural land, forest, roads, and residential areas [59–61]. The data are based on demonstration tests carried out by JAEA [59]. The effectiveness is quantified as a reduction factor, which is determined as ratio of the gamma dose rates at 1-meter height before and after the decontamination work. Interestingly, the effectiveness was higher in areas with higher ambient dose rates.

The effectiveness of decontamination work under field conditions is shown in Figure 17 for the Special Decontamination Area [57]. Depending on the land-use, the average gamma dose rate immediately after the decontamination work was reduced by 44–60%. Six to twelve months after the decontamination work, the gamma dose rate was 55–76% lower than before the decontamination; this decrease is due to ongoing attenuation processes, such as migration in soil, street cleaning, and radioactive decay (of the relatively short-lived ^{134}Cs). The results achieved under field conditions are consistent with those obtained for a dose-rate of 1µSv/h in the demonstration tests, as shown in Table 9.

Table 9: Reduction of gamma dose rate in percent resulting from decontamination work for the Intensive Contamination Survey Area (ICSA) [59–61]

Decontamination measure	**Reduction *factor* of gamma dose rate due to decontamination measures**			
	Dose rate before remediation			
	≤1 µSv/h	**1–3 µSv/h**	**3–10 µSv/h**	**>10 µSv/h**
Farmland				
Interchange topsoil and subsoil, add zeolite and potassium	1.5	2.0	1.9	5.0
Ploughing with zeolite and potassium	1.3	1.4	1.4	2.0
Forest				
Remove fallen leaves	1.1	1.2	1.3	1.4
Roads				
Cleaning roads and ditches	1.1	1.2	1.3	1.5
Residential areas				
Full remediation	1.4	1.5	2.0	3.3
Localised remediation	1.2	1.2	1.3	1.5

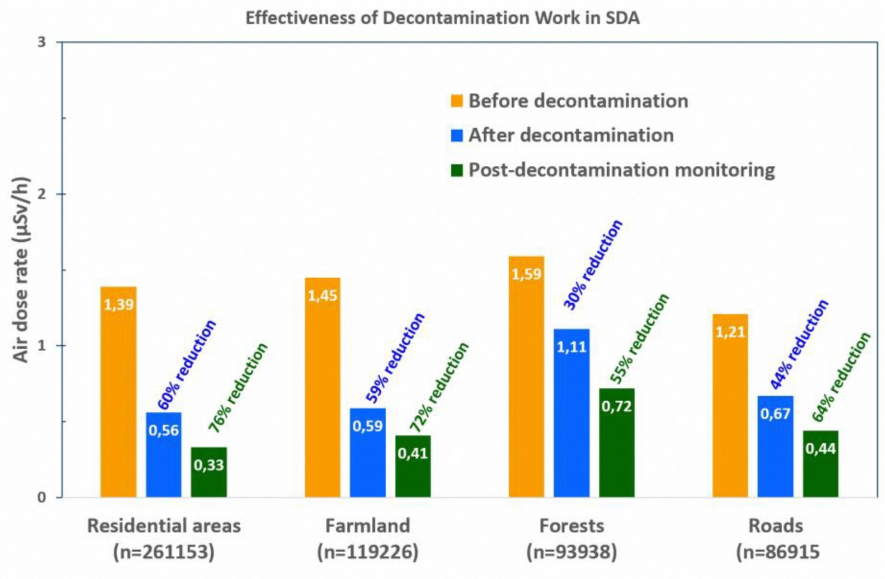

FIG. 17: Effect of decontamination work for different land-uses in the Special Decontamination Area. Image credit: Fukushima Prefecture (redrawn from data in Ref. [57]).

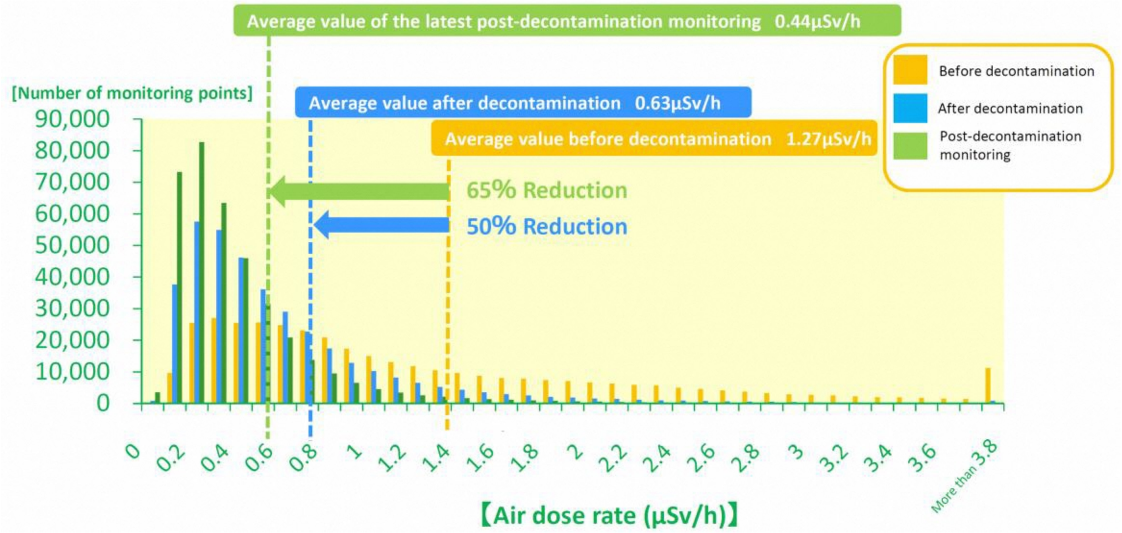

FIG. 18: Distribution of gamma-dose rates in the Special Decontamination Area before and after decontamination work. Image credit: Fukushima Prefecture [62].

The distribution of the gamma dose rates before and after the decontamination work for the SDA is shown Figure 18 above [62]. The measurements were performed before, immediately after, and a few months after termination of the decontamination activities. The average value of the gamma dose rate declined from 1.27 µSv/h to 0.63 µSv/h and 0.44 µSv/h, respectively. These findings are in accordance with the results in Table 9 and Figure 17. The ongoing decline of the gamma-dose rate after the termination of the decontamination work confirms the persistence of the measures; the results indicate that re-contamination is, if there is any, a phenomenon of minor importance.

7.2. INTERNATIONAL EXPERIENCE IN DECONTAMINATION AND REMEDIATION IN TERRESTRIAL ENVIRONMENTS

The effectiveness of decontamination measures is the result of a complex interaction of a spectrum of factors e.g. the radionuclide, the surface, the depth profile of radionuclide concentration in soil, and the land-use. Much experience in decontamination and remediation of contaminated land has been gained in the decades after the Chernobyl accident [37]. Studies have been carried out under controlled experimental conditions as well as in the field. Remediation work focused on both the reduction of external and internal exposure.

Table 10 summarizes the achievable decontamination factors for contaminated surfaces for a variety of measures [63] tested in an area affected by the Chernobyl fallout. The highest reduction of the dose rate can be achieved if the radioactivity is removed from the surfaces (e.g. removal of soil, sandblasting of surfaces, lining of asphalt). The large variation is due to the varying thickness of the removed surface layers; in general, the reduction factor increases with the thickness of the removed layer. However, it should be noted that the results represent very well controlled experimental conditions [63], which are extremely difficult to achieve if applied in a normal living environment. For field conditions, decontamination factors from the lower part of the range are considered more realistic. Nevertheless, the data indicate that carefully implemented measures under favourable conditions may be quite effective. The decontamination factors elaborated during demonstration tests in Japan (Table 9) under more realistic conditions are smaller; they are consistent with the lower values of the range presented in Table 10. Similar techniques were also applied during the decontamination work in areas affected by the Chornobyl fallout. However, due to the high costs, not all affected areas were systematically treated after the Chernobyl accident [37].

The reduction of the annual effective dose from external exposure due to decontamination work was studied where gamma dose rate measurements and individual external dose measurements before and after large-scale decontamination campaigns in the Bryansk oblast (Russian Federation) in 1989 were carried out [64]. For the average population, annual effective doses from external exposure were reduced by 10–20%. The effect for outdoor workers was less than 10%, whereas the reduction for children in schools and kindergartens was approximately 30%.

In Belarus, Russia, and Ukraine, after the Chernobyl accident, the intake of food was in many areas the dominating contributor to the annual exposure of people. Therefore, much attention was given to the uptake of ^{137}Cs from soil, as this process represents a potential long-term source for internal exposure of people. A strong emphasis was given to exploring the effectiveness of countermeasures to reduce the ^{137}Cs-uptake by agricultural crops.

The situation in the Fukushima Prefecture was different. Due to the intensive food monitoring and the low activity limits for radiocaesium in food, doses from the intake of radiocaesium in food remained low. It should also be noted that the uptake of ^{137}Cs from soils in the Fukushima Prefecture is relatively low due to the strong sorption of radiocaesium to clay minerals.

Table 11 compares the effectiveness of a spectrum of countermeasures for reducing the uptake of radiocaesium from soil[9] applied after the accidents at Chornobyl and the Fukushima Daiichi NPPs [14]. Most effective, but also most expensive, is the removal of the soil. A similar effectiveness can be achieved with deep ploughing, where the activity is buried to a depth where the radionuclides are no longer available for root uptake. However, deep ploughing represents a severe impact for the soil quality, and it cannot be applied at all sites. The other countermeasures are part of the normal agricultural practice. The reduction factors depend on the prevailing conditions, such as the site-specific agricultural practice and the soil and plant type; these factors differ between the areas affected. Nevertheless, the range of reduction factors obtained after both accidents is similar for the various remediation measures.

Table 10: Achievable decontamination factors (dimensionless) for various urban surfaces [63]

Surface	Decontamination technique	Decontamination factor
Windows	Washing	10
Walls	Sandblasting	10–100
Roofs	Hosing and /or sandblasting	1–100
Gardens	Digging	6
Gardens	Removal of Surface	4–10
Trees and shrubs	Cutting back or removal	≈10
Streets	Sweeping and vacuum cleaning	1–50
Asphalt	Lining	>100

Table 11: Comparison of reduction factors for radiocaesium transfer to agricultural products derived after the accidents at Chornobyl and Fukushima Daiichi (Annex IV of Ref. [14])

Remediation option	Reduction factor for the uptake of radiocaesium from soil	
	Chernobyl	Fukushima
Topsoil removal	Not applied	4–5
Normal ploughing	2.5–3	1.5–2.5
Deep ploughing [a, b]	3–8	2–3
Reverse tilling of soil	10–16	Not applied
Application of potassium	1.5–3	1.5–3
Application of organic fertilizers	1.5–2	1.3–2.5
Application of sorbents	1.32	1.5–1-8
Radical renovation	2–9	8
Simple renovation	2–3	4

[a] Deep ploughing to replace topsoil up to a depth of 5 cm with soils taken from a depth of 50 cm.
[b] Reduction of the external dose rate at the height of 1 m.

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[9] Decontamination is quantified in terms of reduction of the uptake of ^{137}Cs from soil. In Table 10, the effectiveness is quantified in terms of the reduction of the gamma dose-rate over the treated area.

8. INTERACTION WITH THE PUBLIC

8.1. ACTIVITIES IMPLEMENTED AFTER FUKUSHIMA ACCIDENT

The release of man-made radionuclides to the environment attracts much attention among the population in the affected areas. Fears, anxieties, concerns on the future development, scepticism about the radiological impacts and on the management of environmental contaminations are typical phenomena observed in the aftermath of accidental releases of radionuclides [14].

Following the accident in the FDNPP mechanisms were established to provide information to the public on the radiological status in the Fukushima Prefecture, on the planning and on the progress of decontamination activities. A wide range of topics were addressed to disseminate information and guidance on radiation safety [57], including implications for agriculture, fishing, food supply, environmental monitoring, lifting of restrictions, and the future development of the radiological situation.

For this purpose, the municipalities and the Fukushima Prefecture made use of different information channels as:

- The Commutan Fukushima (Fukushima Prefectural Centre for Environmental Creation) was established in 2016. Since then, this Centre been also one of the important information channels for the public.
- Local newspapers, radio stations and TV programmes
- Organisation of explanatory and consultation meetings for the people living in affected areas
- Providing basic and comprehensive information that helps people understanding radiological topics and the state of the region after decontamination
- Distributing pamphlets, comic books, and videos addressing radiation-related topics
- The Environmental Regeneration Plaza, set up by the Ministry of the Environment, is an information centre in Fukushima City with interactive exhibitions and workshops on radiation-related topics
- Visit of experts in municipalities, communities, and schools for discussing actual topics related to the radiological situation and future developments
- Establishing a website to share information on efforts toward restoration and reconstruction, including decommissioning, decontamination, and improvement of living environment, as well as activities to revitalize and revitalize the economy of the Fukushima Prefecture[10].

Over time, the focus of the information campaign shifted from the simple transmission of results from measurements and of scientific knowledge to a dialogue with the population on radiation-related issues. The intention of the dialogue with the people is to let people develop for themselves a sense for the safety of their municipalities.

Although after the termination of the decontamination work, the gamma dose rate declined steadily, concerns remained regarding radiation risk, storage of removed soils and wastes, and the possible implications for the daily life. In principle, there is a rational understanding of the

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[10] Available from: https://www.pref.fukushima.lg.jp/site/portal-english/

radiological circumstances; nevertheless, the perception of the situation is often characterized by anxieties and fears.

Efforts are still being undertaken to offer correct and easily understandable information for supporting the communication between the local governments and citizens. The aim is to increase the awareness of the enormous remediation efforts for remediation and the resulting improvement in environmental conditions among both, local and country-wide population.

8.2. INTERNATIONAL EXPERIENCE

The experience gained after nuclear and radiological accidents has shown that the interaction with the population in the affected areas is essential. This includes activities such as timely information of the public on the environmental contaminations, a dialogue on the radiological hazards arising from environmental contaminations, discussion about measures to mitigate radiological, social, and economic consequences, and fora to address any concerns raised by the public and specific groups.

The radiological incidence on Goiânia (Brazil) happened in 1987. A medical ^{137}Cs source with an activity of about 52 TBq was opened by scrap collectors. A large part of the ^{137}Cs dispersed in the environment and caused exposures to the local population. Comprehensive activities for monitoring people and the environment, for decontamination of the affected area, and for the management of the decontamination waste were initiated. Details including the experience made with the interaction with the public are summarized in Ref. [65].

Valuable insights were also achieved during the ICRIN programme (International Chernobyl Research and Information Network) [66]. This programme was launched in 2009 by four International Organisations (UNDP, UNICEF, IAEA, WHO)[11] in rural areas affected by the Chernobyl fallout of Belarus, Russia, and Ukraine. The aim of the program was to provide scientific correct information on radiation-related topics, to initiate a dialogue with the local population on agricultural practice, and to discuss individual habits that could reduce exposures. Additionally, initiatives started to foster the economic development of these areas.

During the cooperation of the Fukushima Prefecture with the IAEA, the global experience from interaction with the public in post-accidental situations were discussed in detail. The essential points of the discussion are summarized in Table 12.

The discussions underlined that the interaction with the public is a complex process. A special challenge is that — besides the official information sources — rumours will be around, and other information sources will become available as the contamination situation develops. Experience shows that not all information sources are reliable. So, conflicting information will be spread. It may be difficult for the people to clearly differentiate between reliable and non-reliable information sources, which undermines confidence in the official information channels. Therefore, according to the experience made after the Chernobyl and the Goiânia accidents, the development, and maintenance of trust is the most important factor for the successful dialogue and fruitful discussions with the local and nation-wide population.

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[11] UNDP: United Nations Development Programme; UNICEF: United Nations International Children’s Emergency Fund; IAEA: International Atomic Energy Agency; WHO: World Health Organization.

Table 12: Aspects on communication with the public identified as essential during management of post-accidental situations outside Japan [65, 66]

Item	Essential features
Information	— Transparency: Where does the information come from? — Credibility: Is the source of information trustworthy? — Completeness: What is known, what is uncertain? Are the knowledge gaps relevant? — Status of the radiological situation: What has happened, what is the current situation, what will be next? — Tailored information: Addressing concerns of specific groups as e.g. children, farmers, leisure facilities
Distribution of information	— Radio and TV — Internet and social media — Print media including brochures — Establishment of information centers — Involvement of respected and credible persons in the dissemination of scientifically correct information — Involve physicians and teachers in the dissemination of results
Direct contact to people	— Organisation of information events to allow dialogues and discussions with affected people — Availability of competent experts in the public, e.g. on marketplaces, cultural events, local festivals — Establishment contact points and information services for allowing immediate information, as necessary — Availability of competent and trustworthy contact persons — Monitoring for privately produced food — Face-to-face discussions on radiation issues and the resulting implications, providing advice to individuals on social and economic topics

9. SUMMARY

The report summarizes the results of the cooperation of the Fukushima Prefecture and the International Atomic Energy Agency in the field of decontamination and remediation of areas affected by the deposition of radionuclides during the accident in the Fukushima Daiichi Nuclear Power Station. The main findings of the discussions and findings of the work carried out from 2018 to 2022 are:

- Comprehensive monitoring and research programs were initiated in 2011 for studying the fate of radionuclides in freshwater systems of the Fukushima Prefecture. As expected, immediately after the deposition, the maximum level of ^{137}Cs in river water is observed. The concentrations of dissolved and particulate ^{137}Cs in river water declined steadily since 2011.

- The concentrations of suspended sediments in river water increase with rising water levels. Caesium-137 activity concentrations in suspended sediments tend to be higher during periods of low flow rates.

- In forested areas, forest soils and litter may significantly contribute to the concentrations of suspended sediments in rivers.

- The concentrations of dissolved and particulate ^{137}Cs in rivers of the Fukushima Prefecture were modelled by application of the TODAM model. For the cases investigated in detail, measurements and predictions agree reasonably well.

- Usually, the time-dependence of ^{137}Cs in river water can be described by exponential functions with one to three components representing different phases after the deposition:
    - Immediately after deposition, a decline of ^{137}Cs in European rivers according to a half-life of 5 days during a period of about 2–3 weeks was observed. However, many data sets do not include the initial phase with the fast decline.
    - Most data sets cover an observation period of 5–15 years starting several months after radionuclide deposition. For rivers of in the Fukushima Prefecture, the values for the half-life of ^{137}Cs for 48 data sets of river water range from 0.7–16 years. Only 3 values were below 1 year, and only three values were above 5 years. Forty-two values were in the range from 1.1–4.6 years.
    - If the observation period is long enough, in some cases a third phase can be identified. However, quantifying a third decline component requires observation times of at least 15 years. Such long observation periods cannot yet be available for Fukushima Prefecture.
    - In water of 25 rivers in Europe and West Asia, a long-term component with an effective half-life of 16 years was identified. The contribution to the overall decline of this component was only 0.5% and the relevance in practice is of minor importance.
    - In general, the time trends observed in the Fukushima Prefecture and in other parts of the world agree reasonably well. The general pattern of the decline is quite similar for both.

- The loss of ^{137}Cs due to run-off depends on the land-use. The loss of ^{137}Cs increases with increasing fractions of rice paddies, farmland, and residential areas.

- Decontamination activities in catchment areas cause a higher loss of ^{137}Cs with surface run-off. In a study carried out during ongoing decontamination work, a total loss of ^{137}Cs due to surface run-off of the order of 0.03% per month was found. The ^{137}Cs -reduction rate due to radioactive decay is 0.19% per month.

- Leaching of ^{137}Cs from forest and grassland litter can cause an increase of dissolved ^{137}Cs levels in the surface runoff water following rainfall.

- Remediation work was carried out in a part of a river channel of the Fukushima Prefecture, where a reduction in the gamma dose rate by approximately a factor of 2 was observed. This effect persisted also during the next years.

- International experience shows that decontamination works in rivers are challenging due to the dynamic nature of flowing waters. Engineering measures are costly and often difficult to implement, and the overall impact on public doses remains low. For reducing exposures to the populations, restrictions on the abstraction of drinking water and fishing were most effective.

- Following both accidents in Fukushima Daiichi and at Chernobyl, particles with enhanced levels of radionuclides were detected. The Chernobyl hot particles are fuel fragments, and they are different from the Caesium-Micro-Particles (CsMPs) which are found in the Fukushima fallout. CsMPs are smaller and contain much lower activities than those released from the Chornobyl reactor.

- The decontamination work in the Fukushima Prefecture was terminated in 2018 except for the Difficult-to-Return-Zone. In the Special Decontamination Area (SDA), the average gamma dose rate immediately after the decontamination work was reduced by 44–60%. Six to twelve months after the decontamination work, the gamma dose rate was 55–76% lower than before the decontamination. These reductions are consistent with the experience made after the Chornobyl accident.

- For reducing ^{137}Cs -levels is crops, a similar spectrum of techniques was applied as after the Chernobyl accident. The effectiveness of the countermeasures was — as far as being comparable — generally the same as that achieved after the Chernobyl accident.

- Interaction with the public during the management of post-accident situations is a complex process. The interests and concerns of numerous groups and individuals need to be addressed, which underlines the need for a tailored, situation-specific communication strategy to initiate and maintain a dialogue with the population in the affected areas.

- A matrix is suggested to define a structure for data reporting to enable a comprehensive and concise compilation of the results elaborated in the Fukushima Prefecture on the behaviour of radiocaesium in the environment and on decontamination of contaminated areas.

APPENDIX I. DYNAMICS OF CAESIUM-137 IN JAPANESE AND EUROPEAN RIVERS

Table I.1: Compilation of data to describe the dynamic of ^{137}Cs in rivers, half-lives are given for the short-term, the intermediate and the long-term component of the decline. If more than one component is given, the weighting factors for these components are given in brackets.

River or site name	**Observation period**	**Medium**	**Effective half-lives (Weighting factors, if available)**			**Reference number**
			$T_{eff,1}$ (short-term)	**$T_{eff,2}$ (intermediate)**	**$T_{eff,3}$ (long-term)**	
European rivers affected by the Chernobyl accident						
Pripyat (Ukraine)	May 1986, Week 1–3 after deposition	Dissolved	11 d			[67]
Dnieper (Ukraine)		Dissolved	9.0 d			
Glatt (Switzerland)		Dissolved	19 d			
Elbe (Germany)		Dissolved	18 d			
Po (Italy)	20 May–July 1986	Dissolved	35 d			[68]
European rivers	1–15 May 1986		5 d			[69]
9 Ukrainian rivers	1987–1991	Dissolved	–	1.0-2.1 y	–	[67]
5 Finnish rivers	1987–1991	Dissolved	–	1.7-4.3 y	–	
5 Belarussian rivers	1987–1991	Dissolved	–	1.0-1.4 y	–	
Dora Baltea (Italy)	1987–1991	Dissolved	–	1.9 y	–	
Rhine (Germany)	1987–1991	Dissolved	–	1.3 y	–	
Rhine (Germany)	1987–1991	Particulate	–	1.9 y	–	
Pripyat (Ukraine)	1987–1991	Dissolved	–	1.6 y	–	
Pripyat (Ukraine)	1995–1998	Dissolved	–	3.8 y	–	
Dnieper (Ukraine)	1995–1998	Dissolved	–	3.6 y	–	
Desna (Ukraine)	1995–1998	Dissolved	–	9.9 y	–	
5 Finnish rivers	1995–2002	Dissolved	–	5.2-7.5 y	–	
5 Belarussian rivers	1994–1998	Dissolved	–	2.1-4.5 y	–	
Pripyat (Ukraine)	1995–1998	Particulate	–	8.2 y	–	
Dnieper (Ukraine)	1995–1998	Particulate	–	7.5 y	–	
Desna (Ukraine)	1995–1998	Particulate	–	2.6 y	–	
Pripyat (Ukraine)	1987–2001	Unfiltered water	–	3.0 y (*)	14 y (*)	[70]
Pripyat (Chernobyl)	1987–2001	Unfiltered water	–	2.5 y (*)	15 y (*)	
Dnieper (Ukraine)	1987–2001	Unfiltered water	–	1.9 y (*)	8.3 y (*)	
Uzh (Ukraine)	1987–2001	Unfiltered water	–	2.6 y (*)	6.2 y (*)	
Teterev (Ukraine)	1987–2001	Unfiltered water	–	3.1 y	–	
Irpen (Ukraine)	1987–2001	Unfiltered water	–	2.8 y	–	
Braginka (Ukraine)	1987–2001	Unfiltered water	–	5.3 y (*)	6.0 y (*)	
Ilya (Ukraine)	1987–2001	Unfiltered water	–	3.2 y	–	
Sakhan (Ukraine)	1987–2001	Unfiltered water	–	2.7 y (*)	16 y (*)	
Glinitsa (Ukraine)	1987–2001	Unfiltered water	–	2.0 y (*)	21 y (*)	
Pripyat (Ukraine)	1988–2018	Particulate	–	1.1 y (*)	10 y (*)	[71]
Dnieper (Ukraine)	1989–2012	Particulate	–	3.6 y (*)	7.6 y (*)	
25 rivers in Asia and Europe	1987–2001	Unfiltered water	20 d (0.905)	1.6 y (0.09)	16 y (0.005)	[30]
Iput river (Russia)	1987–1991		–	1.3 y	–	[72]
Kymijoki (Finland)	1990–1996		–	6.0 y	–	[73]
Kokemäenjoki (Finland)	1990–1996		–	3.5 y	–	

Table I.1. (cont.)

River or site name	Observation period	Medium	Effective half-lives (Weighting factors, if available)			Reference number
			$T_{eff,1}$ (short-term)	$T_{eff,2}$ (intermediate)	$T_{eff,3}$ (long-term)	
Japanese rivers affected by the FDNPP accident						
Ukedo	2015–2018	Dissolved	–	3.7 y	–	[19]
		Particulate	–	2.3 y	–	
Ota	2015–2018	Dissolved	–	2.4 y	–	
		Particulate	–	1.6 y	–	
Koutaishi	2011–2013	Dissolved	–	0.69 y	–	[74]
Iboishi	2011–2013	Dissolved	–	0.69 y	–	
Ishidaira	2011–2013	Dissolved	–	1.5 y	–	
Fukushima rivers**	2012–2014	Dissolved	–	1.8±0.5 y	–	[75]
Odaka river	2012–2016	Sediment	–	4.7±1.3 y	–	[76]
		River water	–	3.7±0.6 y	–	
Ota	2012-2016	Sediment	–	1.5±0.4 y	–	
		River water	–	2.1±0.6 y	–	
Niida	2012-2016	Sediment	–	1.8±0.6 y	–	
		River water	–	1.0±0.2 y	–	
Mano	2012-2016	Sediment	–	2.1±0.2 y	–	
		River water	–	0.9±0.1 y	–	
Mizusakai	2011–2016	Particulate	1.6 y (0.64)	2.7 y (0.36)	–	[15]
Kuchibuto_Upper	2011–2016	Particulate	135 d (0.79)	2.0 y (0.21)	–	
Kuchibuto_Middle	2011–2016	Particulate	120 d (0.74)	1.6 y (0.26)	–	
Kuchibuto_Down	2011–2016	Particulate	274 d (0.64)	1.4 y (0.36)	–	
Fushiguro	2011–2016	Particulate	66 d (0.92)	1.8 y (0.08	–	
Iwanuma	2011–2016	Particulate	80 d (0.92)	1.5 y (0.08)	–	
Mano	2012–2016	Particulate	–	8.2 y	–	
Ojimadazeki	2012–2016	Particulate	–	4.6 y	–	
Matsubara	2012–2016	Particulate	–	3.7 y	–	
Onahama	2012–2016	Particulate	–	2.1 y	–	
Tsukidate	2012–2016	Particulate	–	1.1 y	–	
Nihonmatsu	2012–2016	Particulate	–	1.6 y	–	
Miyota	2012–2016	Particulate	–	2.9 y	–	
Nishikawa	2012–2016	Particulate	–	2.9 y	–	
Kitamachi	2012–2016	Particulate	–	1.5 y	–	[15]
Kawamata	2012–2016	Particulate	–	1.1 y	–	
Marumori	2012–2016	Particulate	–	1.8 y	–	
Senoue	2012–2016	Particulate	–	2.4 y	–	
Yagita	2012–2016	Particulate	–	16 y	–	
Kuroiwa	2012–2016	Particulate	–	1.3 y	–	
Tomita	2012–2016	Particulate	–	1.5 y	–	
Ota	2012–2016	Particulate	–	3.8 y	–	
Odaka	2012–2016	Particulate	–	11 y	–	
Asami	2012–2016	Particulate	–	2.1 y	–	
Tsushima	2012–2016	Particulate	–	1.7 y	–	
Ukedo	2012–2016	Particulate	–	2.8 y	–	
Takase	2012–2016	Particulate	–	1.7 y	–	
Haramachi	2012–2016	Particulate	–	3.0 y	–	
Akanuma	2012–2016	Particulate	–	2.0 y	–	

Table I.1. (cont.)

River or site name	**Observation period**	**Medium**	**Effective half-lives (Weighting factors, if available)**			**Reference**
			$T_{eff,1}$ (short-term)	**$T_{eff,2}$ (intermediate)**	**$T_{eff,3}$ (long-term)**	
Abukuma River	2011–2017	Particulate	0.14 y (0.96)	1.5 y (0.04)	–	[77]
Rivers coastal region of FP	2011–2017	Particulate	0.12 y (0.93)	2.6 y (0.07)	–	
Abukuma & rivers of coastal region	2011–2017	Dissolved	0.14 y (0.94)	2.6 y (0.06)	–	
Hiso River	2011–2021	Particulate	0.068 y (0.97)	1.7 y (0.03)	–	[21]
Hiso River	2011–2021	Dissolved	0.20 y (0.914)	1.8 y (0.086)	–	
Wariki River	2011–2021	Particulate	0.071 y (0.975)	1. 9y (0.025)	–	
Wariki River	2011–2021	Dissolved	0.24 y (0.82)	1.7 y 0.18)	–	

* The data indicate that the decrease of ^{137}Cs in these rivers follows an exponential function with two components. However, the weighting factors for the 2 components are not given by the authors, since the uncertainty of the long-term component is very high, and it was not considered reasonable to assign a specific value for the weighting factors. The values should therefore be considered as a first estimation of the long-term component. The high uncertainty of the long-term component is due to the short observation period compared to its ecological half-life.

** The effective half-lives were derived from measurements in the Uta, Mano, Niida, Ohta, Odaka, Ukedo, and Abukuma Rivers.

APPENDIX II. TIME-DEPENDENCE OF CAESIUM-137 IN SUSPENDED SEDIMENTS OF RIVERS OF THE FUKUSHIMA PREFECTURE

Table II.1: Underlying data for Figure 4a of the main text for the dynamics of ^{137}*Cs in suspended sediments of rivers within the 80 km-zone around the Fukushima Daiichi Nuclear Power Plant form 2011–2021 [15, 78].*

Sampling date	Site (river name)	Activity in suspended sediments (Bq/kg)	Standard deviation	Catchment area (km^2)	Mean deposition in the catchment (kBq/m^2)
2011-06-27	Mizusakai (Kuchibuto)	4.85E+04	1.45E+03	7.5	745.2
2011-07-12	Mizusakai (Kuchibuto)	3.85E+04	1.25E+03		
2011-07-20	Mizusakai (Kuchibuto)	9.28E+03	5.57E+02		
2011-07-25	Mizusakai (Kuchibuto)	2.42E+04	1.06E+02		
2011-08-01	Mizusakai (Kuchibuto)	5.54E+04	1.11E+03		
2011-08-09	Mizusakai (Kuchibuto)	2.57E+03	6.19E+02		
2011-08-16	Mizusakai (Kuchibuto)	3.39E+04	1.34E+03		
2011-08-24	Mizusakai (Kuchibuto)	3.42E+04	6.45E+02		
2011-08-30	Mizusakai (Kuchibuto)	1.15E+04	2.80E+02		
2011-09-10	Mizusakai (Kuchibuto)	2.75E+04	1.04E+03		
2011-09-17	Mizusakai (Kuchibuto)	3.50E+04	2.10E+03		
2011-12-08	Mizusakai (Kuchibuto)	1.31E+03	3.37E+02		
2011-12-22	Mizusakai (Kuchibuto)	1.21E+04	4.63E+02		
2012-01-14	Mizusakai (Kuchibuto)	2.65E+04	4.17E+02		
2012-01-28	Mizusakai (Kuchibuto)	2.46E+04	1.10E+03		
2012-02-11	Mizusakai (Kuchibuto)	2.53E+04	7.02E+02		
2012-02-21	Mizusakai (Kuchibuto)	2.55E+04	1.16E+03		
2012-02-25	Mizusakai (Kuchibuto)	2.54E+04	2.29E+02		
2012-03-09	Mizusakai (Kuchibuto)	2.00E+04	2.33E+02		
2012-03-20	Mizusakai (Kuchibuto)	1.52E+04	5.94E+02		
2012-03-29	Mizusakai (Kuchibuto)	1.32E+03	6.17E+02		
2012-04-17	Mizusakai (Kuchibuto)	1.73E+03	1.48E+02		
2012-04-25	Mizusakai (Kuchibuto)	1.63E+04	4.31E+02		
2012-05-15	Mizusakai (Kuchibuto)	7.99E+03	1.87E+02		
2012-05-30	Mizusakai (Kuchibuto)	1.73E+04	6.53E+02		
2012-06-21	Mizusakai (Kuchibuto)	1.15E+04	4.00E+02		
2012-06-29	Mizusakai (Kuchibuto)	1.63E+04	1.93E+02		
2012-12-05	Mizusakai (Kuchibuto)	6.29E+03	2.41E+02		
2012-12-19	Mizusakai (Kuchibuto)	8.45E+03	4.22E+02		
2013-01-11	Mizusakai (Kuchibuto)	1.45E+04	2.92E+02		
2013-01-23	Mizusakai (Kuchibuto)	9.49E+03	3.51E+02		
2013-02-27	Mizusakai (Kuchibuto)	1.07E+02	2.19E+02		
2013-04-18	Mizusakai (Kuchibuto)	8.65E+03	2.72E+02		
2013-05-21	Mizusakai (Kuchibuto)	4.53E+03	2.28E+02		
2013-06-18	Mizusakai (Kuchibuto)	9.76E+03	3.87E+02		
2013-07-26	Mizusakai (Kuchibuto)	1.42E+04	3.11E+02		
2013-08-09	Mizusakai (Kuchibuto)	9.80E+03	3.12E+02		
2013-08-23	Mizusakai (Kuchibuto)	1.43E+04	2.56E+02		
2013-09-12	Mizusakai (Kuchibuto)	1.93E+04	3.06E+02		
2013-09-26	Mizusakai (Kuchibuto)	9.62E+03	1.75E+02		
2013-10-30	Mizusakai (Kuchibuto)	4.32E+03	1.04E+02		
2013-11-21	Mizusakai (Kuchibuto)	1.30E+04	3.16E+02		
2013-12-24	Mizusakai (Kuchibuto)	1.26E+04	3.22E+02		
2014-01-17	Mizusakai (Kuchibuto)	9.49E+03	1.82E+02		
2014-02-26	Mizusakai (Kuchibuto)	1.61E+04	3.71E+02		
2014-08-05	Mizusakai (Kuchibuto)	4.83E+03	9.10E+01		

Table II.1. (cont.)

Sampling date	Site (river name)	Activity in suspended sediments (Bq/kg)	Standard deviation	Catchment area (km^2)	Mean deposition in the catchment (kBq/m^2)
2014-09-09	Mizusakai (Kuchibuto)	3.30E+03	9.60E+01		
2014-10-21	Mizusakai (Kuchibuto)	1.80E+03	5.30E+01		
2014-12-04	Mizusakai (Kuchibuto)	5.37E+03	1.18E+02		
2015-01-15	Mizusakai (Kuchibuto)	6.88E+03	1.66E+02		
2015-04-22	Mizusakai (Kuchibuto)	3.95E+3	4.70E+1		
2015-05-29	Mizusakai (Kuchibuto)	5.00E+3	9.50E+1		
2015-07-21	Mizusakai (Kuchibuto)	3.33E+3	4.10E+1		
2015-09-03	Mizusakai (Kuchibuto)	3.56E+3	8.10E+1		
2015-12-24	Mizusakai (Kuchibuto)	2.33E+3	4.60E+1		
2016-01-21	Mizusakai (Kuchibuto)	3.24E+3	1.05E+2		
2016-02-23	Mizusakai (Kuchibuto)	3.08E+3	6.60E+1		
2016-04-15	Mizusakai (Kuchibuto)	2.99E+3	9.50E+1		
2016-09-27	Mizusakai (Kuchibuto)	2.24E+3	7.50E+1		
2016-12-21	Mizusakai (Kuchibuto)	3.53E+3	9.00E+1		
2017-03-01	Mizusakai (Kuchibuto)	1.96E+3	1.03E+2		
2017-05-08	Mizusakai (Kuchibuto)	3.87E+3	1.69E+2		
2017-07-10	Mizusakai (Kuchibuto)	4.08E+3	9.40E+1		
2017-09-05	Mizusakai (Kuchibuto)	3.04E+3	3.30E+1		
2017-12-12	Mizusakai (Kuchibuto)	2.46E+3	2.80E+1		
2018-05-14	Mizusakai (Kuchibuto)	4.54E+3	1.20E+2		
2018-05-30	Mizusakai (Kuchibuto)	3.15E+3	3.60E+1		
2018-07-03	Mizusakai (Kuchibuto)	6.44E+3	1.75E+2		
2018-10-11	Mizusakai (Kuchibuto)	4.19E+3	5.40E+1		
2018-12-03	Mizusakai (Kuchibuto)	3.86E+3	9.00E+1		
2019-04-24	Mizusakai (Kuchibuto)	2.88E+3	1.52E+2		
2019-07-05	Mizusakai (Kuchibuto)	2.41E+3	7.30E+1		
2020-02-26	Mizusakai (Kuchibuto)	7.73E+2	2.90E+1		
2020-05-15	Mizusakai (Kuchibuto)	9.32E+2	2.70E+1		
2020-07-06	Mizusakai (Kuchibuto)	5.10E+2	2.70E+1		
2020-10-21	Mizusakai (Kuchibuto)	3.40E+2	1.10E+1		
2021-02-01	Mizusakai (Kuchibuto)	1.58E+3	6.10E+1		
2011-06-27	Kuchibuto-upper (Kuchibuto)	5.75E+04	2.50E+01	21.4	477.4
2011-07-06	Kuchibuto-upper (Kuchibuto)	3.32E+04	1.10E+03		
2011-07-12	Kuchibuto-upper (Kuchibuto)	3.45E+03	1.43E+03		
2011-07-20	Kuchibuto-upper (Kuchibuto)	3.58E+04	1.68E+03		
2011-07-25	Kuchibuto-upper (Kuchibuto)	4.13E+04	1.61E+03		
2011-08-01	Kuchibuto-upper (Kuchibuto)	3.41E+04	1.37E+03		
2011-08-09	Kuchibuto-upper (Kuchibuto)	2.92E+04	6.14E+02		
2011-08-16	Kuchibuto-upper (Kuchibuto)	3.68E+04	1.36E+03		
2011-08-24	Kuchibuto-upper (Kuchibuto)	2.02E+04	4.23E+02		
2011-08-30	Kuchibuto-upper (Kuchibuto)	2.90E+04	1.72E+02		
2011-09-10	Kuchibuto-upper (Kuchibuto)	3.09E+03	1.36E+03		
2011-09-17	Kuchibuto-upper (Kuchibuto)	3.28E+04	1.12E+03		
2011-12-08	Kuchibuto-upper (Kuchibuto)	7.40E+03	3.25E+02		
2011-12-22	Kuchibuto-upper (Kuchibuto)	9.63E+03	5.24E+02		
2012-01-14	Kuchibuto-upper (Kuchibuto)	6.84E+03	2.84E+02		
2012-01-27	Kuchibuto-upper (Kuchibuto)	1.07E+03	7.10E+01		
2012-02-11	Kuchibuto-upper (Kuchibuto)	8.46E+03	7.10E+01		
2012-02-21	Kuchibuto-upper (Kuchibuto)	2.32E+04	6.48E+02		
2012-02-25	Kuchibuto-upper (Kuchibuto)	2.94E+04	6.61E+02		
2012-03-09	Kuchibuto-upper (Kuchibuto)	1.44E+04	4.21E+02		
2012-03-20	Kuchibuto-upper (Kuchibuto)	1.32E+04	1.90E+02		

Table II.1. (cont.)

Sampling date	**Site (river name)**	**Activity in suspended sediments (Bq/kg)**	**Standard deviation**	**Catchment area (km²)**	**Mean deposition in the catchment (kBq/m²)**
2012-03-29	Kuchibuto-upper (Kuchibuto)	1.16E+04	3.94E+02		
2012-04-17	Kuchibuto-upper (Kuchibuto)	1.75E+04	1.07E+02		
2012-04-25	Kuchibuto-upper (Kuchibuto)	1.09E+04	1.53E+02		
2012-05-15	Kuchibuto-upper (Kuchibuto)	1.06E+04	3.15E+02		
2012-05-30	Kuchibuto-upper (Kuchibuto)	1.19E+04	4.58E+02		
2012-06-21	Kuchibuto-upper (Kuchibuto)	6.65E+03	8.70E+01		
2012-06-29	Kuchibuto-upper (Kuchibuto)	1.06E+04	1.43E+02		
2012-12-05	Kuchibuto-upper (Kuchibuto)	8.47E+03	2.29E+02		
2012-12-19	Kuchibuto-upper (Kuchibuto)	1.30E+04	2.80E+02		
2013-01-11	Kuchibuto-upper (Kuchibuto)	9.94E+03	1.88E+02		
2013-01-23	Kuchibuto-upper (Kuchibuto)	1.07E+04	3.26E+02		
2013-02-27	Kuchibuto-upper (Kuchibuto)	1.05E+04	3.45E+02		
2013-04-18	Kuchibuto-upper (Kuchibuto)	7.49E+03	2.72E+02		
2013-05-21	Kuchibuto-upper (Kuchibuto)	8.53E+02	2.91E+02		
2013-06-18	Kuchibuto-upper (Kuchibuto)	7.22E+03	9.70E+01		
2013-07-26	Kuchibuto-upper (Kuchibuto)	1.02E+04	2.34E+02		
2013-08-08	Kuchibuto-upper (Kuchibuto)	1.04E+04	4.00E+02		
2013-08-23	Kuchibuto-upper (Kuchibuto)	8.12E+03	2.38E+02		
2013-09-12	Kuchibuto-upper (Kuchibuto)	2.16E+03	4.70E+01		
2013-09-26	Kuchibuto-upper (Kuchibuto)	9.52E+03	1.40E+02		
2013-10-30	Kuchibuto-upper (Kuchibuto)	6.75E+03	7.00E+01		
2013-11-21	Kuchibuto-upper (Kuchibuto)	1.22E+04	2.76E+02		
2013-12-24	Kuchibuto-upper (Kuchibuto)	1.11E+04	3.14E+02		
2014-01-17	Kuchibuto-upper (Kuchibuto)	1.17E+04	2.04E+02		
2014-02-26	Kuchibuto-upper (Kuchibuto)	7.43E+03	1.46E+02		
2014-08-05	Kuchibuto-upper (Kuchibuto)	3.31E+03	7.30E+01		
2014-09-09	Kuchibuto-upper (Kuchibuto)	5.32E+03	1.43E+02		
2014-10-21	Kuchibuto-upper (Kuchibuto)	1.95E+03	4.10E+01		
2014-12-04	Kuchibuto-upper (Kuchibuto)	4.16E+02	1.15E+02		
2015-01-15	Kuchibuto-upper (Kuchibuto)	7.14E+03	1.59E+02		
2015-04-22	Kuchibuto-upper (Kuchibuto)	2.26E+3	3.70E+1		
2015-05-29	Kuchibuto-upper (Kuchibuto)	3.43E+3	9.00E+1		
2015-07-21	Kuchibuto-upper (Kuchibuto)	2.89E+3	4.30E+1		
2015-09-03	Kuchibuto-upper (Kuchibuto)	3.79E+3	6.80E+1		
2015-10-22	Kuchibuto-upper (Kuchibuto)	1.12E+3	2.40E+1		
2015-12-24	Kuchibuto-upper (Kuchibuto)	1.53E+3	3.10E+1		
2016-01-21	Kuchibuto-upper (Kuchibuto)	3.91E+2	1.80E+1		
2016-02-17	Kuchibuto-upper (Kuchibuto)	7.08E+2	2.40E+1		
2016-04-15	Kuchibuto-upper (Kuchibuto)	9.83E+2	3.10E+1		
2016-09-27	Kuchibuto-upper (Kuchibuto)	7.27E+2	2.40E+1		
2016-12-21	Kuchibuto-upper (Kuchibuto)	7.17E+2	2.50E+1		
2017-03-01	Kuchibuto-upper (Kuchibuto)	6.49E+2	3.40E+1		
2017-05-08	Kuchibuto-upper (Kuchibuto)	1.60E+3	4.70E+1		
2017-07-04	Kuchibuto-upper (Kuchibuto)	1.71E+3	4.00E+1		
2017-09-05	Kuchibuto-upper (Kuchibuto)	1.07E+3	1.60E+1		
2018-07-03	Kuchibuto-upper (Kuchibuto)	1.34E+3	5.20E+1		
2018-10-11	Kuchibuto-upper (Kuchibuto)	7.60E+2	1.60E+1		
2018-12-03	Kuchibuto-upper (Kuchibuto)	1.90E+3	9.90E+1		
2019-04-24	Kuchibuto-upper (Kuchibuto)	1.42E+3	4.80E+1		
2019-07-05	Kuchibuto-upper (Kuchibuto)	9.97E+2	6.10E+1		
2019-11-19	Kuchibuto-upper (Kuchibuto)	7.97E+2	1.70E+1		
2020-02-26	Kuchibuto-upper (Kuchibuto)	9.13E+2	2.50E+1		

Table II.1. (cont.)

Sampling date	Site (river name)	Activity in suspended sediments (Bq/kg)	Standard deviation	Catchment area (km^2)	Mean deposition in the catchment (kBq/m^2)
2020-05-15	Kuchibuto-upper (Kuchibuto)	7.09E+2	2.00E+1		
2020-07-06	Kuchibuto-upper (Kuchibuto)	8.14E+2	4.00E+1		
2020-10-21	Kuchibuto-upper (Kuchibuto)	4.65E+2	1.30E+1		
2021-02-01	Kuchibuto-upper (Kuchibuto)	1.67E+3	6.60E+1		
2011-06-27	Kuchibuto-middle (Kuchibuto)	3.27E+04	1.99E+03	62.8	357.2
2011-07-06	Kuchibuto-middle (Kuchibuto)	1.21E+04	5.60E+02		
2011-07-12	Kuchibuto-middle (Kuchibuto)	1.37E+04	6.64E+02		
2011-07-20	Kuchibuto-middle (Kuchibuto)	1.28E+04	6.61E+02		
2011-07-25	Kuchibuto-middle (Kuchibuto)	1.51E+04	5.88E+02		
2011-08-01	Kuchibuto-middle (Kuchibuto)	1.85E+04	7.68E+02		
2011-08-10	Kuchibuto-middle (Kuchibuto)	9.29E+03	2.68E+02		
2011-08-16	Kuchibuto-middle (Kuchibuto)	1.81E+04	8.27E+02		
2011-08-24	Kuchibuto-middle (Kuchibuto)	1.75E+04	7.64E+02		
2011-08-30	Kuchibuto-middle (Kuchibuto)	1.14E+04	3.20E+02		
2011-09-10	Kuchibuto-middle (Kuchibuto)	6.76E+03	2.50E+02		
2011-09-17	Kuchibuto-middle (Kuchibuto)	1.27E+04	6.02E+02		
2011-12-08	Kuchibuto-middle (Kuchibuto)	7.73E+03	4.65E+02		
2011-12-22	Kuchibuto-middle (Kuchibuto)	3.04E+03	1.38E+02		
2012-01-14	Kuchibuto-middle (Kuchibuto)	4.33E+03	2.51E+02		
2012-01-28	Kuchibuto-middle (Kuchibuto)	3.16E+03	1.40E+02		
2012-02-11	Kuchibuto-middle (Kuchibuto)	5.65E+03	1.91E+02		
2012-02-21	Kuchibuto-middle (Kuchibuto)	3.31E+03	1.85E+02		
2012-02-25	Kuchibuto-middle (Kuchibuto)	1.20E+04	7.94E+02		
2012-03-10	Kuchibuto-middle (Kuchibuto)	1.19E+04	3.09E+02		
2012-03-20	Kuchibuto-middle (Kuchibuto)	6.65E+03	2.43E+02		
2012-03-29	Kuchibuto-middle (Kuchibuto)	7.13E+03	1.61E+02		
2012-04-17	Kuchibuto-middle (Kuchibuto)	8.27E+03	2.43E+02		
2012-04-26	Kuchibuto-middle (Kuchibuto)	5.58E+03	1.69E+02		
2012-05-15	Kuchibuto-middle (Kuchibuto)	6.58E+03	1.74E+02		
2012-05-30	Kuchibuto-middle (Kuchibuto)	6.63E+03	3.38E+02		
2012-06-22	Kuchibuto-middle (Kuchibuto)	3.66E+03	5.20E+01		
2012-06-29	Kuchibuto-middle (Kuchibuto)	5.96E+03	1.14E+02		
2012-12-05	Kuchibuto-middle (Kuchibuto)	6.82E+03	2.45E+02		
2012-12-18	Kuchibuto-middle (Kuchibuto)	2.50E+03	1.95E+02		
2013-01-10	Kuchibuto-middle (Kuchibuto)	5.69E+03	1.42E+02		
2013-01-22	Kuchibuto-middle (Kuchibuto)	1.05E+04	2.77E+02		
2013-02-26	Kuchibuto-middle (Kuchibuto)	1.28E+04	4.38E+02		
2013-04-18	Kuchibuto-middle (Kuchibuto)	5.04E+03	1.63E+02		
2013-05-21	Kuchibuto-middle (Kuchibuto)	3.26E+03	1.72E+02		
2013-06-18	Kuchibuto-middle (Kuchibuto)	4.32E+03	8.60E+01		
2013-07-26	Kuchibuto-middle (Kuchibuto)	3.85E+02	7.70E+01		
2013-08-09	Kuchibuto-middle (Kuchibuto)	3.40E+03	2.25E+02		
2013-08-23	Kuchibuto-middle (Kuchibuto)	1.34E+03	4.50E+01		
2013-09-12	Kuchibuto-middle (Kuchibuto)	5.56E+03	1.62E+02		
2013-09-26	Kuchibuto-middle (Kuchibuto)	3.28E+03	8.40E+01		
2013-10-30	Kuchibuto-middle (Kuchibuto)	1.84E+03	4.60E+01		
2013-11-20	Kuchibuto-middle (Kuchibuto)	4.16E+03	6.40E+01		
2013-12-24	Kuchibuto-middle (Kuchibuto)	3.88E+03	1.02E+02		
2014-01-16	Kuchibuto-middle (Kuchibuto)	7.33E+03	9.60E+01		
2014-02-25	Kuchibuto-middle (Kuchibuto)	4.72E+03	5.70E+01		
2014-08-07	Kuchibuto-middle (Kuchibuto)	2.10E+03	5.40E+01		
2014-09-09	Kuchibuto-middle (Kuchibuto)	1.73E+03	5.70E+01		

Table II.1. (cont.)

Sampling date	Site (river name)	Activity in suspended sediments (Bq/kg)	Standard deviation	Catchment area (km²)	Mean deposition in the catchment (kBq/m²)
2014-10-21	Kuchibuto-middle (Kuchibuto)	1.06E+03	4.10E+01		
2014-12-04	Kuchibuto-middle (Kuchibuto)	1.86E+02	5.30E+01		
2015-01-15	Kuchibuto-middle (Kuchibuto)	2.99E+03	7.30E+01		
2015-04-23	Kuchibuto-middle (Kuchibuto)	2.65E+3	4.40E+1		
2015-05-29	Kuchibuto-middle (Kuchibuto)	1.94E+3	3.80E+1		
2015-07-21	Kuchibuto-middle (Kuchibuto)	2.46E+3	3.30E+1		
2015-09-03	Kuchibuto-middle (Kuchibuto)	2.35E+3	4.20E+1		
2015-12-24	Kuchibuto-middle (Kuchibuto)	7.40E+2	2.00E+1		
2016-01-21	Kuchibuto-middle (Kuchibuto)	1.19E+3	4.50E+1		
2016-02-17	Kuchibuto-middle (Kuchibuto)	8.87E+2	2.50E+1		
2016-04-15	Kuchibuto-middle (Kuchibuto)	7.15E+2	2.50E+1		
2016-09-27	Kuchibuto-middle (Kuchibuto)	7.96E+2	2.70E+1		
2016-12-21	Kuchibuto-middle (Kuchibuto)	1.19E+3	3.50E+1		
2017-03-01	Kuchibuto-middle (Kuchibuto)	7.37E+2	2.50E+1		
2017-05-08	Kuchibuto-middle (Kuchibuto)	7.60E+2	3.50E+1		
2017-07-07	Kuchibuto-middle (Kuchibuto)	1.29E+3	3.70E+1		
2017-09-05	Kuchibuto-middle (Kuchibuto)	1.08E+3	2.50E+1		
2017-12-08	Kuchibuto-middle (Kuchibuto)	1.55E+3	4.50E+1		
2018-05-11	Kuchibuto-middle (Kuchibuto)	6.68E+2	1.60E+1		
2018-07-03	Kuchibuto-middle (Kuchibuto)	1.28E+3	3.30E+1		
2018-10-11	Kuchibuto-middle (Kuchibuto)	1.37E+3	3.60E+1		
2018-12-03	Kuchibuto-middle (Kuchibuto)	8.24E+2	7.30E+1		
2019-04-24	Kuchibuto-middle (Kuchibuto)	3.74E+2	4.20E+1		
2019-07-08	Kuchibuto-middle (Kuchibuto)	1.06E+3	1.04E+2		
2019-07-17	Kuchibuto-middle (Kuchibuto)	9.74E+2	3.60E+1		
2019-11-19	Kuchibuto-middle (Kuchibuto)	7.29E+2	2.20E+1		
2020-01-21	Kuchibuto-middle (Kuchibuto)	2.31E+2	8.00E+0		
2020-07-10	Kuchibuto-middle (Kuchibuto)	4.06E+2	9.00E+0		
2020-10-21	Kuchibuto-middle (Kuchibuto)	2.43E+2	9.00E+0		
2021-02-05	Kuchibuto-middle (Kuchibuto)	9.84E+2	3.90E+1		
2011-06-27	Kuchibuto-down (Kuchibuto)	4.56E+04	1.98E+03	135.2	269.1
2011-07-06	Kuchibuto-down (Kuchibuto)	2.92E+04	1.52E+03		
2011-07-12	Kuchibuto-down (Kuchibuto)	2.41E+04	6.38E+02		
2011-07-19	Kuchibuto-down (Kuchibuto)	2.33E+04	1.11E+03		
2011-07-25	Kuchibuto-down (Kuchibuto)	1.98E+04	5.48E+02		
2011-08-01	Kuchibuto-down (Kuchibuto)	2.44E+04	8.51E+02		
2011-08-10	Kuchibuto-down (Kuchibuto)	1.82E+04	9.60E+02		
2011-08-16	Kuchibuto-down (Kuchibuto)	2.05E+04	5.66E+02		
2011-08-24	Kuchibuto-down (Kuchibuto)	1.30E+04	6.98E+02		
2011-08-30	Kuchibuto-down (Kuchibuto)	9.21E+03	1.09E+02		
2011-09-10	Kuchibuto-down (Kuchibuto)	1.73E+04	6.48E+02		
2011-09-17	Kuchibuto-down (Kuchibuto)	1.68E+04	1.01E+03		
2011-12-08	Kuchibuto-down (Kuchibuto)	3.94E+03	1.65E+02		
2011-12-22	Kuchibuto-down (Kuchibuto)	1.04E+04	4.80E+01		
2012-01-14	Kuchibuto-down (Kuchibuto)	1.17E+04	6.34E+02		
2012-01-28	Kuchibuto-down (Kuchibuto)	1.04E+04	3.56E+02		
2012-02-11	Kuchibuto-down (Kuchibuto)	1.85E+04	1.18E+02		
2012-02-21	Kuchibuto-down (Kuchibuto)	1.36E+04	2.77E+02		
2012-02-25	Kuchibuto-down (Kuchibuto)	2.55E+04	3.26E+02		
2012-03-10	Kuchibuto-down (Kuchibuto)	1.13E+04	4.19E+02		
2012-03-20	Kuchibuto-down (Kuchibuto)	1.21E+04	2.10E+02		
2012-03-29	Kuchibuto-down (Kuchibuto)	7.77E+03	2.94E+02		

Table II.1. (cont.)

Sampling date	**Site (river name)**	**Activity in suspended sediments (Bq/kg)**	**Standard deviation**	**Catchment area (km²)**	**Mean deposition in the catchment (kBq/m²)**
2012-04-17	Kuchibuto-down (Kuchibuto)	9.54E+03	2.72E+02		
2012-04-26	Kuchibuto-down (Kuchibuto)	6.82E+03	1.47E+02		
2012-05-15	Kuchibuto-down (Kuchibuto)	8.67E+03	2.79E+02		
2012-05-30	Kuchibuto-down (Kuchibuto)	8.87E+03	5.61E+02		
2012-06-22	Kuchibuto-down (Kuchibuto)	8.21E+02	1.72E+02		
2012-06-29	Kuchibuto-down (Kuchibuto)	7.40E+03	3.34E+02		
2012-12-05	Kuchibuto-down (Kuchibuto)	7.98E+02	3.10E+02		
2012-12-18	Kuchibuto-down (Kuchibuto)	9.38E+03	3.05E+02		
2013-01-10	Kuchibuto-down (Kuchibuto)	4.29E+03	1.32E+02		
2013-01-22	Kuchibuto-down (Kuchibuto)	7.86E+03	2.96E+02		
2013-02-26	Kuchibuto-down (Kuchibuto)	7.09E+03	1.43E+02		
2013-04-18	Kuchibuto-down (Kuchibuto)	5.48E+03	9.30E+01		
2013-05-21	Kuchibuto-down (Kuchibuto)	5.86E+03	2.99E+02		
2013-06-18	Kuchibuto-down (Kuchibuto)	1.44E+04	5.11E+02		
2013-07-26	Kuchibuto-down (Kuchibuto)	8.36E+03	2.35E+02		
2013-08-09	Kuchibuto-down (Kuchibuto)	5.18E+02	9.70E+01		
2013-08-23	Kuchibuto-down (Kuchibuto)	2.30E+03	8.80E+01		
2013-09-12	Kuchibuto-down (Kuchibuto)	4.51E+03	1.54E+02		
2013-09-26	Kuchibuto-down (Kuchibuto)	3.92E+03	1.21E+02		
2013-10-30	Kuchibuto-down (Kuchibuto)	2.48E+03	5.30E+01		
2013-11-20	Kuchibuto-down (Kuchibuto)	3.89E+03	1.06E+02		
2013-12-24	Kuchibuto-down (Kuchibuto)	1.42E+02	2.60E+01		
2014-01-16	Kuchibuto-down (Kuchibuto)	4.52E+02	1.03E+02		
2014-02-25	Kuchibuto-down (Kuchibuto)	3.39E+03	7.40E+01		
2014-08-05	Kuchibuto-down (Kuchibuto)	1.86E+03	5.10E+01		
2014-09-09	Kuchibuto-down (Kuchibuto)	2.09E+03	5.80E+01		
2014-12-04	Kuchibuto-down (Kuchibuto)	1.70E+03	6.40E+01		
2015-01-15	Kuchibuto-down (Kuchibuto)	2.99E+03	1.00E+02		
2015-04-23	Kuchibuto-down (Kuchibuto)	3.00E+3	6.50E+1		
2015-05-29	Kuchibuto-down (Kuchibuto)	2.48E+3	6.90E+1		
2015-07-21	Kuchibuto-down (Kuchibuto)	2.79E+3	5.00E+1		
2015-09-03	Kuchibuto-down (Kuchibuto)	2.77E+3	4.60E+1		
2015-12-24	Kuchibuto-down (Kuchibuto)	1.23E+3	1.03E+2		
2016-01-21	Kuchibuto-down (Kuchibuto)	1.19E+3	4.30E+1		
2016-02-17	Kuchibuto-down (Kuchibuto)	1.76E+3	6.10E+1		
2016-04-15	Kuchibuto-down (Kuchibuto)	1.63E+3	9.00E+1		
2016-10-24	Kuchibuto-down (Kuchibuto)	1.98E+3	5.50E+1		
2016-12-21	Kuchibuto-down (Kuchibuto)	1.48E+3	6.40E+1		
2017-03-01	Kuchibuto-down (Kuchibuto)	9.16E+2	3.20E+1		
2017-05-08	Kuchibuto-down (Kuchibuto)	7.77E+2	3.70E+1		
2017-07-07	Kuchibuto-down (Kuchibuto)	1.87E+3	5.50E+1		
2017-09-04	Kuchibuto-down (Kuchibuto)	1.60E+3	2.30E+1		
2017-12-08	Kuchibuto-down (Kuchibuto)	1.83E+3	5.20E+1		
2018-05-30	Kuchibuto-down (Kuchibuto)	8.66E+2	4.40E+1		
2018-07-03	Kuchibuto-down (Kuchibuto)	1.63E+3	5.30E+1		
2018-10-11	Kuchibuto-down (Kuchibuto)	1.52E+3	3.30E+1		
2018-12-03	Kuchibuto-down (Kuchibuto)	8.00E+2	1.05E+2		
2019-04-24	Kuchibuto-down (Kuchibuto)	7.41E+2	9.70E+1		
2019-07-26	Kuchibuto-down (Kuchibuto)	1.45E+3	5.90E+1		
2021-02-05	Kuchibuto-down (Kuchibuto)	4.20E+2	1.70E+1		
2011-07-11	Fushiguro (Abukuma)	5.53E+04	1.80E+03	3645	95.9
2011-07-19	Fushiguro (Abukuma)	3.02E+04	1.85E+03		

Table II.1. (cont.)

Sampling date	Site (river name)	Activity in suspended sediments (Bq/kg)	Standard deviation	Catchment area (km²)	Mean deposition in the catchment (kBq/m²)
2011-07-25	Fushiguro (Abukuma)	4.10E+04	9.71E+02		
2011-08-09	Fushiguro (Abukuma)	3.23E+03	4.27E+02		
2011-08-16	Fushiguro (Abukuma)	3.88E+04	9.80E+02		
2011-08-24	Fushiguro (Abukuma)	3.25E+04	8.29E+02		
2011-08-31	Fushiguro (Abukuma)	2.18E+03	4.18E+02		
2011-09-10	Fushiguro (Abukuma)	3.09E+04	1.29E+03		
2011-09-17	Fushiguro (Abukuma)	3.37E+04	1.24E+03		
2011-12-09	Fushiguro (Abukuma)	5.16E+03	1.41E+02		
2011-12-21	Fushiguro (Abukuma)	6.58E+03	2.64E+02		
2012-01-13	Fushiguro (Abukuma)	1.34E+04	7.05E+02		
2012-01-27	Fushiguro (Abukuma)	4.91E+03	1.84E+02		
2012-02-10	Fushiguro (Abukuma)	3.77E+03	3.48E+02		
2012-02-20	Fushiguro (Abukuma)	5.13E+03	3.98E+02		
2012-02-26	Fushiguro (Abukuma)	1.01E+04	4.99E+02		
2012-03-21	Fushiguro (Abukuma)	1.26E+04	4.49E+02		
2012-03-30	Fushiguro (Abukuma)	1.61E+03	9.50E+01		
2012-05-30	Fushiguro (Abukuma)	3.93E+03	2.32E+02		
2012-06-28	Fushiguro (Abukuma)	1.53E+03	4.50E+01		
2012-12-07	Fushiguro (Abukuma)	2.71E+03	1.36E+02		
2012-12-17	Fushiguro (Abukuma)	2.62E+03			
2013-01-09	Fushiguro (Abukuma)	2.09E+03	2.38E+02		
2013-01-21	Fushiguro (Abukuma)	2.54E+03	4.90E+01		
2013-02-25	Fushiguro (Abukuma)	8.84E+03	2.87E+02		
2013-04-17	Fushiguro (Abukuma)	4.51E+03	1.72E+02		
2013-05-20	Fushiguro (Abukuma)	1.58E+03	2.80E+01		
2013-06-17	Fushiguro (Abukuma)	4.99E+03	1.25E+02		
2013-09-12	Fushiguro (Abukuma)	2.40E+03	6.00E+01		
2013-09-25	Fushiguro (Abukuma)	1.75E+03	6.00E+01		
2013-11-19	Fushiguro (Abukuma)	2.30E+03	8.10E+01		
2013-12-24	Fushiguro (Abukuma)	2.49E+03	8.40E+01		
2014-01-16	Fushiguro (Abukuma)	2.53E+02			
2014-02-25	Fushiguro (Abukuma)	2.82E+03	5.80E+01		
2014-08-04	Fushiguro (Abukuma)	2.34E+03	5.70E+01		
2014-09-11	Fushiguro (Abukuma)	2.55E+03	7.00E+01		
2014-10-20	Fushiguro (Abukuma)	1.02E+02	8.00E+00		
2014-12-03	Fushiguro (Abukuma)	2.17E+02	4.50E+01		
2015-01-13	Fushiguro (Abukuma)	1.51E+03	8.60E+01		
2015-05-27	Fushiguro (Abukuma)	2.35E+3	8.50E+1		
2015-07-15	Fushiguro (Abukuma)	3.82E+3	1.29E+2		
2015-08-24	Fushiguro (Abukuma)	2.05E+3	3.90E+1		
2015-10-08	Fushiguro (Abukuma)	9.75E+2	2.00E+1		
2016-01-26	Fushiguro (Abukuma)	1.32E+3	7.50E+1		
2016-02-16	Fushiguro (Abukuma)	4.32E+2	3.40E+1		
2016-04-13	Fushiguro (Abukuma)	7.61E+2	2.20E+1		
2016-10-24	Fushiguro (Abukuma)	9.61E+2	3.20E+1		
2016-12-21	Fushiguro (Abukuma)	4.34E+2	1.90E+1		
2017-03-01	Fushiguro (Abukuma)	6.90E+2	3.90E+1		
2017-05-09	Fushiguro (Abukuma)	4.27E+3	1.49E+2		
2017-07-07	Fushiguro (Abukuma)	1.84E+3	3.10E+1		
2017-09-25	Fushiguro (Abukuma)	2.76E+3	3.00E+1		
2017-11-10	Fushiguro (Abukuma)	8.44E+2	1.90E+1		
2017-12-08	Fushiguro (Abukuma)	9.09E+2	2.04E+2		

Table II.1. (cont.)

Sampling date	Site (river name)	Activity in suspended sediments (Bq/kg)	Standard deviation	Catchment area (km²)	Mean deposition in the catchment (kBq/m²)
2018-05-30	Fushiguro (Abukuma)	6.86E+2	1.10E+1		
2018-07-03	Fushiguro (Abukuma)	5.81E+2	9.70E+1		
2018-10-17	Fushiguro (Abukuma)	1.21E+3	2.80E+1		
2018-12-05	Fushiguro (Abukuma)	1.06E+3	3.30E+1		
2019-04-09	Fushiguro (Abukuma)	1.52E+3	5.20E+1		
2019-08-06	Fushiguro (Abukuma)	1.12E+3	4.00E+1		
2020-09-04	Fushiguro (Abukuma)	6.37E+2	1.70E+1		
2020-11-11	Fushiguro (Abukuma)	7.67E+2	2.10E+1		
2021-02-05	Fushiguro (Abukuma)	4.51E+2	9.30E+1		
2011-07-12	Iwanuma (Abukuma)	3.09E+04	1.61E+03	5313	88.4
2011-07-19	Iwanuma (Abukuma)	3.45E+03	1.71E+03		
2011-07-26	Iwanuma (Abukuma)	2.83E+04	1.01E+03		
2011-08-10	Iwanuma (Abukuma)	2.02E+04	6.29E+02		
2011-08-17	Iwanuma (Abukuma)	4.44E+04	2.00E+03		
2011-08-25	Iwanuma (Abukuma)	1.62E+04	9.31E+02		
2011-08-31	Iwanuma (Abukuma)	2.01E+04	6.86E+02		
2011-09-10	Iwanuma (Abukuma)	2.72E+04	3.45E+02		
2011-09-17	Iwanuma (Abukuma)	2.81E+04	1.64E+03		
2011-12-09	Iwanuma (Abukuma)	8.02E+03	4.31E+02		
2011-12-21	Iwanuma (Abukuma)	6.44E+03	1.99E+02		
2012-01-13	Iwanuma (Abukuma)	4.22E+02	9.80E+01		
2012-01-27	Iwanuma (Abukuma)	7.45E+03	2.23E+02		
2012-02-10	Iwanuma (Abukuma)	8.48E+03	3.16E+02		
2012-02-20	Iwanuma (Abukuma)	8.34E+03	3.54E+02		
2012-02-27	Iwanuma (Abukuma)	3.82E+03	1.63E+02		
2012-03-21	Iwanuma (Abukuma)	1.46E+04	7.21E+02		
2012-03-30	Iwanuma (Abukuma)	2.48E+04	1.02E+03		
2012-04-25	Iwanuma (Abukuma)	4.57E+02	2.25E+02		
2012-05-15	Iwanuma (Abukuma)	1.82E+03	1.00E+02		
2012-05-29	Iwanuma (Abukuma)	3.08E+03	5.30E+01		
2012-06-28	Iwanuma (Abukuma)	1.89E+03	8.20E+01		
2012-12-19	Iwanuma (Abukuma)	3.18E+03	1.71E+02		
2013-01-09	Iwanuma (Abukuma)	7.01E+03	2.12E+02		
2013-01-21	Iwanuma (Abukuma)	2.91E+03	1.08E+02		
2013-02-27	Iwanuma (Abukuma)	4.37E+03	1.39E+02		
2013-04-18	Iwanuma (Abukuma)	4.54E+03	3.30E+01		
2013-05-20	Iwanuma (Abukuma)	2.16E+03	7.90E+01		
2013-06-17	Iwanuma (Abukuma)	2.05E+03	8.50E+01		
2013-07-26	Iwanuma (Abukuma)	2.51E+03	7.90E+01		
2013-08-08	Iwanuma (Abukuma)	6.69E+03	1.03E+02		
2013-08-23	Iwanuma (Abukuma)	2.54E+03	9.60E+01		
2013-09-12	Iwanuma (Abukuma)	2.95E+03	8.70E+01		
2013-09-25	Iwanuma (Abukuma)	2.72E+03	8.40E+01		
2013-10-31	Iwanuma (Abukuma)	2.23E+03	5.50E+01		
2013-11-19	Iwanuma (Abukuma)	1.21E+03	3.80E+01		
2013-12-24	Iwanuma (Abukuma)	1.14E+03	3.80E+01		
2014-01-16	Iwanuma (Abukuma)	1.09E+03	2.10E+01		
2014-02-25	Iwanuma (Abukuma)	1.31E+02	3.40E+01		
2014-08-04	Iwanuma (Abukuma)	1.25E+03	3.70E+01		
2014-08-04	Iwanuma (Abukuma)	2.35E+03	6.00E+01		
2014-09-11	Iwanuma (Abukuma)	1.16E+03	4.70E+01		
2014-09-11	Iwanuma (Abukuma)	2.29E+03	6.40E+01		

Table II.1. (cont.)

Sampling date	Site (river name)	Activity in suspended sediments (Bq/kg)	Standard deviation	Catchment area (km²)	Mean deposition in the catchment (kBq/m²)
2014-10-20	Iwanuma (Abukuma)	1.39E+03	3.40E+01		
2014-10-20	Iwanuma (Abukuma)	1.47E+02	4.50E+01		
2014-12-03	Iwanuma (Abukuma)	2.10E+03	6.20E+01		
2015-01-13	Iwanuma (Abukuma)	2.93E+03	8.60E+01		
2015-01-13	Iwanuma (Abukuma)	2.93E+02	5.40E+01		
2015-06-02	Iwanuma (Abukuma)	2.15E+3	9.40E+1		
2015-08-03	Iwanuma (Abukuma)	1.81E+3	1.09E+2		
2015-08-28	Iwanuma (Abukuma)	1.35E+3	7.50E+1		
2015-10-14	Iwanuma (Abukuma)	6.96E+2	2.10E+1		
2016-01-15	Iwanuma (Abukuma)	1.10E+3	1.90E+1		
2016-04-11	Iwanuma (Abukuma)	7.24E+2	4.30E+1		
2016-05-30	Iwanuma (Abukuma)	7.79E+2	3.80E+1		
2016-08-02	Iwanuma (Abukuma)	1.13E+3	1.80E+1		
2016-10-17	Iwanuma (Abukuma)	5.26E+2	9.00E+0		
2017-01-06	Iwanuma (Abukuma)	6.41E+2	2.80E+1		
2017-02-27	Iwanuma (Abukuma)	4.87E+2	3.60E+1		
2017-05-11	Iwanuma (Abukuma)	6.38E+2	2.10E+1		
2017-07-06	Iwanuma (Abukuma)	1.21E+3	5.00E+1		
2017-12-04	Iwanuma (Abukuma)	7.15E+2	1.80E+1		
2018-05-30	Iwanuma (Abukuma)	9.40E+2	1.20E+1		
2018-07-03	Iwanuma (Abukuma)	7.52E+2	2.40E+1		
2018-10-11	Iwanuma (Abukuma)	1.01E+3	2.90E+1		
2018-12-05	Iwanuma (Abukuma)	7.34E+2	8.10E+1		
2019-04-09	Iwanuma (Abukuma)	8.43E+2	5.10E+1		
2019-08-05	Iwanuma (Abukuma)	8.05E+2	6.90E+1		
2019-12-13	Iwanuma (Abukuma)	4.11E+2	1.40E+1		
2019-12-13	Iwanuma (Abukuma)	4.69E+2	1.30E+1		
2020-05-11	Iwanuma (Abukuma)	3.00E+2	9.00E+0		
2020-07-07	Iwanuma (Abukuma)	8.59E+2	2.60E+1		
2020-11-11	Iwanuma (Abukuma)	5.48E+2	2.60E+1		
2021-02-24	Iwanuma (Abukuma)	9.05E+2	3.70E+1		
2012-12-06	Mano (Mano)	2.98E+04	8.30E+02	75.6	498.7
2012-12-18	Mano (Mano)	3.09E+04	7.61E+02		
2013-01-10	Mano (Mano)	1.26E+04	1.90E+02		
2013-01-22	Mano (Mano)	1.83E+04	2.00E+02		
2013-02-26	Mano (Mano)	2.09E+04	5.34E+02		
2013-04-18	Mano (Mano)	2.14E+04	5.62E+02		
2013-05-21	Mano (Mano)	1.67E+04	3.96E+02		
2013-06-18	Mano (Mano)	3.90E+03	1.77E+02		
2013-07-25	Mano (Mano)	3.47E+04	2.84E+02		
2013-08-08	Mano (Mano)	3.28E+04	1.04E+03		
2013-08-22	Mano (Mano)	2.38E+03	7.33E+02		
2013-09-11	Mano (Mano)	3.39E+04	9.84E+02		
2013-09-26	Mano (Mano)	2.53E+04	5.46E+02		
2013-10-30	Mano (Mano)	2.28E+04	4.14E+02		
2013-11-20	Mano (Mano)	2.48E+04	5.50E+02		
2013-12-23	Mano (Mano)	2.25E+04	5.48E+02		
2014-01-17	Mano (Mano)	9.29E+03	2.62E+02		
2014-02-26	Mano (Mano)	1.48E+04	5.07E+02		
2014-08-05	Mano (Mano)	1.43E+04	2.85E+02		
2014-09-08	Mano (Mano)	2.04E+03	2.75E+02		
2014-10-21	Mano (Mano)	1.80E+04	3.52E+02		

Table II.1. (cont.)

Sampling date	**Site (river name)**	**Activity in suspended sediments (Bq/kg)**	**Standard deviation**	**Catchment area (km²)**	**Mean deposition in the catchment (kBq/m²)**
2014-12-04	Mano (Mano)	1.37E+03	3.46E+02		
2015-01-14	Mano (Mano)	1.10E+03	2.40E+02		
2015-04-17	Mano (Mano)	1.83E+4	2.77E+2		
2015-06-02	Mano (Mano)	1.33E+4	4.11E+2		
2015-07-22	Mano (Mano)	1.50E+4	2.56E+2		
2015-08-25	Mano (Mano)	1.76E+4	2.04E+2		
2016-02-16	Mano (Mano)	2.69E+3	6.18E+2		
2016-04-08	Mano (Mano)	3.11E+3	1.37E+2		
2016-06-21	Mano (Mano)	7.41E+3	1.32E+2		
2016-07-28	Mano (Mano)	6.62E+3	3.22E+2		
2016-10-17	Mano (Mano)	6.39E+3	1.06E+2		
2016-12-20	Mano (Mano)	3.89E+3	1.01E+2		
2017-02-27	Mano (Mano)	1.01E+3			
2017-05-11	Mano (Mano)	3.50E+3	2.74E+2		
2017-07-06	Mano (Mano)	8.78E+3	1.39E+3		
2017-12-04	Mano (Mano)	7.83E+3	2.70E+1		
2018-05-31	Mano (Mano)	7.37E+3	2.00E+2		
2018-07-02	Mano (Mano)	1.99E+2	6.40E+1		
2018-10-11	Mano (Mano)	7.99E+3	5.50E+1		
2018-12-04	Mano (Mano)	8.50E+3	4.62E+2		
2019-04-25	Mano (Mano)	1.29E+4	8.24E+2		
2019-07-05	Mano (Mano)	7.07E+3	1.57E+2		
2020-02-17	Mano (Mano)	4.67E+3	6.70E+1		
2020-05-14	Mano (Mano)	3.62E+3	6.30E+1		
2020-07-07	Mano (Mano)	3.76E+3	6.10E+1		
2020-10-14	Mano (Mano)	3.88E+3	6.10E+1		
2021-02-02	Mano (Mano)	2.84E+3	1.00E+2		
2011-09-26	Ojimadazeki (Mano)	2.81E+04	4.34E+02	110.8	405.5
2012-12-06	Ojimadazeki (Mano)	7.78E+03	2.88E+02		
2012-12-18	Ojimadazeki (Mano)	6.30E+03	2.38E+02		
2013-01-10	Ojimadazeki (Mano)	7.07E+03	2.40E+02		
2013-01-22	Ojimadazeki (Mano)	6.71E+03	2.26E+02		
2013-02-26	Ojimadazeki (Mano)	6.13E+03	1.09E+02		
2013-04-18	Ojimadazeki (Mano)	6.51E+03	1.29E+02		
2013-05-22	Ojimadazeki (Mano)	5.85E+03	7.80E+01		
2013-06-18	Ojimadazeki (Mano)	6.30E+03	3.41E+02		
2013-07-25	Ojimadazeki (Mano)	6.18E+03	8.70E+01		
2013-08-08	Ojimadazeki (Mano)	7.67E+03	2.69E+02		
2013-08-22	Ojimadazeki (Mano)	7.32E+03	1.54E+02		
2013-09-11	Ojimadazeki (Mano)	5.64E+03	2.29E+02		
2013-09-26	Ojimadazeki (Mano)	8.42E+03	2.34E+02		
2013-10-30	Ojimadazeki (Mano)	7.20E+03	1.64E+02		
2013-11-20	Ojimadazeki (Mano)	7.08E+03	1.81E+02		
2013-12-23	Ojimadazeki (Mano)	5.41E+03	1.63E+02		
2014-01-17	Ojimadazeki (Mano)	1.35E+03	1.30E+01		
2014-02-26	Ojimadazeki (Mano)	4.69E+03	1.11E+02		
2014-08-05	Ojimadazeki (Mano)	6.26E+03	9.20E+01		
2014-09-08	Ojimadazeki (Mano)	5.69E+03	1.70E+02		
2014-10-21	Ojimadazeki (Mano)	4.89E+03	1.37E+02		
2014-12-04	Ojimadazeki (Mano)	4.81E+03	1.01E+02		
2015-01-14	Ojimadazeki (Mano)	9.10E+01	3.36E+02		
2015-04-17	Ojimadazeki (Mano)	4.25E+3	1.25E+2		

Table II.1. (cont.)

Sampling date	Site (river name)	Activity in suspended sediments (Bq/kg)	Standard deviation	Catchment area (km²)	Mean deposition in the catchment (kBq/m²)
2015-06-17	Ojimadazeki (Mano)	3.88E+3	1.37E+2		
2015-07-22	Ojimadazeki (Mano)	4.18E+3	7.40E+1		
2015-08-25	Ojimadazeki (Mano)	3.66E+3	9.40E+1		
2015-11-05	Ojimadazeki (Mano)	4.96E+3	5.90E+1		
2015-11-24	Ojimadazeki (Mano)	3.06E+3	2.40E+1		
2016-02-16	Ojimadazeki (Mano)	3.10E+3	8.10E+1		
2016-04-11	Ojimadazeki (Mano)	8.21E+2	8.50E+1		
2016-06-21	Ojimadazeki (Mano)	2.08E+3	1.85E+2		
2016-07-28	Ojimadazeki (Mano)	2.56E+3	1.07E+2		
2016-10-17	Ojimadazeki (Mano)	2.15E+3	5.30E+1		
2016-12-20	Ojimadazeki (Mano)	2.62E+3	1.25E+2		
2017-02-27	Ojimadazeki (Mano)	2.06E+3	1.66E+2		
2017-05-11	Ojimadazeki (Mano)	2.62E+3	6.90E+1		
2017-07-06	Ojimadazeki (Mano)	2.17E+3	2.60E+1		
2017-12-04	Ojimadazeki (Mano)	2.68E+3	2.00E+1		
2018-05-31	Ojimadazeki (Mano)	1.35E+3	2.20E+1		
2018-07-02	Ojimadazeki (Mano)	1.33E+3	2.30E+1		
2018-10-11	Ojimadazeki (Mano)	1.75E+3	1.90E+1		
2018-12-04	Ojimadazeki (Mano)	2.11E+3	1.21E+2		
2019-04-25	Ojimadazeki (Mano)	1.49E+3	1.38E+2		
2019-07-05	Ojimadazeki (Mano)	1.51E+3	1.06E+2		
2019-12-19	Ojimadazeki (Mano)	1.12E+3	2.30E+1		
2020-02-17	Ojimadazeki (Mano)	7.29E+2	2.20E+1		
2020-05-14	Ojimadazeki (Mano)	4.10E+2	8.00E+0		
2020-07-07	Ojimadazeki (Mano)	1.25E+3	7.80E+1		
2020-10-14	Ojimadazeki (Mano)	6.21E+2	1.50E+1		
2021-02-02	Ojimadazeki (Mano)	1.22E+3	7.00E+1		
2011-09-27	Matsubara (Same)	1.61E+03	7.00E+01	570.9	40.0
2012-12-08	Matsubara (Same)	1.12E+03	5.30E+01		
2012-12-17	Matsubara (Same)	2.06E+02	1.10E+01		
2013-01-09	Matsubara (Same)	4.30E+02	1.90E+01		
2013-01-21	Matsubara (Same)	3.69E+02	1.80E+01		
2013-02-25	Matsubara (Same)	3.66E+02	7.00E+00		
2013-04-17	Matsubara (Same)	9.00E+02	5.00E+00		
2013-05-20	Matsubara (Same)	3.53E+02	5.00E+00		
2013-06-17	Matsubara (Same)	9.23E+02	4.20E+01		
2013-08-08	Matsubara (Same)	1.04E+03	2.20E+01		
2013-08-22	Matsubara (Same)	4.57E+02	1.50E+01		
2013-09-11	Matsubara (Same)	8.47E+02	2.10E+01		
2013-09-25	Matsubara (Same)	4.33E+02	1.20E+01		
2013-10-29	Matsubara (Same)	7.47E+02	2.30E+01		
2013-12-23	Matsubara (Same)	2.29E+02	1.40E+01		
2014-01-15	Matsubara (Same)	2.59E+03	5.10E+01		
2014-02-24	Matsubara (Same)	3.99E+02	1.10E+01		
2014-09-08	Matsubara (Same)	8.12E+02	4.00E+01		
2014-10-20	Matsubara (Same)	5.87E+02	1.70E+01		
2014-12-03	Matsubara (Same)	5.93E+02	2.00E+01		
2015-01-13	Matsubara (Same)	2.57E+02	9.00E+00		
2015-05-01	Matsubara (Same)	6.33E+2	2.60E+1		
2015-06-03	Matsubara (Same)	2.19E+2	1.00E+1		
2015-08-04	Matsubara (Same)	9.61E+2	7.90E+1		
2015-09-01	Matsubara (Same)	2.78E+2	2.30E+1		

Table II.1. (cont.)

Sampling date	**Site (river name)**	**Activity in suspended sediments (Bq/kg)**	**Standard deviation**	**Catchment area (km²)**	**Mean deposition in the catchment (kBq/m²)**
2015-10-13	Matsubara (Same)	4.07E+2	1.70E+1		
2015-11-25	Matsubara (Same)	1.18E+2	1.20E+1		
2016-01-14	Matsubara (Same)	2.92E+2	2.10E+1		
2016-02-22	Matsubara (Same)	3.45E+2	1.90E+1		
2016-04-07	Matsubara (Same)	2.12E+2	5.40E+1		
2016-06-07	Matsubara (Same)	2.04E+2	4.60E+1		
2016-08-02	Matsubara (Same)	1.81E+2	2.10E+1		
2016-09-30	Matsubara (Same)	3.36E+2	3.00E+1		
2017-01-19	Matsubara (Same)	4.29E+2	3.90E+1		
2017-02-27	Matsubara (Same)	1.40E+2	4.40E+1		
2017-05-11	Matsubara (Same)	3.53E+2	2.70E+1		
2017-07-10	Matsubara (Same)	5.98E+2	2.80E+1		
2017-09-20	Matsubara (Same)	4.90E+2	1.90E+1		
2017-12-11	Matsubara (Same)	4.87E+2	1.90E+1		
2018-05-28	Matsubara (Same)	1.85E+2	2.00E+1		
2018-07-02	Matsubara (Same)	2.37E+2	1.20E+1		
2018-10-12	Matsubara (Same)	1.99E+2	1.60E+1		
2018-12-04	Matsubara (Same)	1.43E+2	5.90E+1		
2019-04-23	Matsubara (Same)	1.45E+2	2.60E+1		
2019-07-03	Matsubara (Same)	1.86E+2	2.90E+1		
2020-05-13	Matsubara (Same)	1.20E+2	2.00E+0		
2020-07-09	Matsubara (Same)	1.79E+2	4.00E+0		
2020-10-15	Matsubara (Same)	2.90E+2	7.00E+0		
2021-02-04	Matsubara (Same)	1.74E+2	6.00E+0		
2012-12-08	Onahama (Fujiwara)	2.38E+03	9.90E+01	70.1	38.8
2012-12-17	Onahama (Fujiwara)	1.33E+03	2.80E+01		
2013-01-09	Onahama (Fujiwara)	1.35E+03	4.80E+01		
2013-01-21	Onahama (Fujiwara)	1.29E+03	2.70E+01		
2013-02-25	Onahama (Fujiwara)	1.44E+03	1.80E+01		
2013-04-17	Onahama (Fujiwara)	1.19E+03	4.20E+01		
2013-05-20	Onahama (Fujiwara)	1.33E+03	3.80E+01		
2013-06-17	Onahama (Fujiwara)	2.12E+03	1.03E+02		
2013-07-25	Onahama (Fujiwara)	7.51E+02	3.10E+01		
2013-08-08	Onahama (Fujiwara)	7.23E+02	7.00E+00		
2013-08-22	Onahama (Fujiwara)	9.90E+02	3.20E+01		
2013-10-29	Onahama (Fujiwara)	1.28E+03	3.60E+01		
2013-12-23	Onahama (Fujiwara)	7.98E+02	1.90E+01		
2014-01-15	Onahama (Fujiwara)	4.40E+02	1.30E+01		
2014-02-24	Onahama (Fujiwara)	1.10E+03	2.50E+01		
2014-08-08	Onahama (Fujiwara)	7.59E+02	2.90E+01		
2014-09-08	Onahama (Fujiwara)	6.96E+02	2.60E+01		
2014-10-20	Onahama (Fujiwara)	7.11E+02	2.60E+01		
2014-12-03	Onahama (Fujiwara)	8.33E+02	2.60E+01		
2015-01-13	Onahama (Fujiwara)	5.73E+02	1.60E+01		
2015-05-01	Onahama (Fujiwara)	9.80E+2	2.50E+1		
2015-06-03	Onahama (Fujiwara)	5.71E+2	3.80E+1		
2015-08-04	Onahama (Fujiwara)	6.68E+2	3.70E+1		
2015-09-01	Onahama (Fujiwara)	9.86E+2	5.20E+1		
2015-10-13	Onahama (Fujiwara)	7.05E+2	3.00E+1		
2015-11-25	Onahama (Fujiwara)	3.73E+2	2.60E+1		
2016-01-14	Onahama (Fujiwara)	4.44E+2	1.10E+1		
2016-02-22	Onahama (Fujiwara)	2.32E+2	1.60E+1		

Table II.1. (cont.)

Sampling date	Site (river name)	Activity in suspended sediments (Bq/kg)	Standard deviation	Catchment area (km²)	Mean deposition in the catchment (kBq/m²)
2016-04-07	Onahama (Fujiwara)	2.48E+2	2.10E+1		
2016-06-07	Onahama (Fujiwara)	6.88E+2	4.00E+1		
2016-08-02	Onahama (Fujiwara)	4.68E+2	3.20E+1		
2016-09-30	Onahama (Fujiwara)	5.85E+2	4.00E+1		
2017-01-19	Onahama (Fujiwara)	7.42E+2	4.40E+1		
2017-02-27	Onahama (Fujiwara)	4.45E+2	3.30E+1		
2017-05-11	Onahama (Fujiwara)	5.23E+2	2.50E+1		
2017-07-10	Onahama (Fujiwara)	5.22E+2	2.80E+1		
2017-09-20	Onahama (Fujiwara)	4.78E+2	2.40E+1		
2017-12-11	Onahama (Fujiwara)	5.99E+2	1.60E+1		
2018-05-28	Onahama (Fujiwara)	4.75E+2	1.30E+1		
2018-07-02	Onahama (Fujiwara)	4.90E+2	2.00E+1		
2018-10-12	Onahama (Fujiwara)	4.70E+2	2.10E+1		
2019-04-23	Onahama (Fujiwara)	3.68E+2	4.30E+1		
2019-07-03	Onahama (Fujiwara)	1.05E+3	7.00E+1		
2020-05-13	Onahama (Fujiwara)	7.66E+2	6.80E+1		
2020-07-09	Onahama (Fujiwara)	4.55E+2	1.70E+1		
2020-10-15	Onahama (Fujiwara)	5.90E+2	1.80E+1		
2021-02-04	Onahama (Fujiwara)	4.02E+2	2.30E+1		
2011-08-31	Tsukidate (Hirose)	2.07E+04	2.00E+02	83.6	222.8
2011-09-26	Tsukidate (Hirose)	7.37E+03	1.68E+02		
2012-12-19	Tsukidate (Hirose)	8.60E+03	9.30E+01		
2013-01-11	Tsukidate (Hirose)	9.11E+03	9.10E+01		
2013-01-23	Tsukidate (Hirose)	1.01E+04	2.52E+02		
2013-02-27	Tsukidate (Hirose)	6.36E+03	1.53E+02		
2013-04-18	Tsukidate (Hirose)	6.69E+03	1.62E+02		
2013-05-21	Tsukidate (Hirose)	4.82E+03	1.67E+02		
2013-06-18	Tsukidate (Hirose)	8.75E+03	3.62E+02		
2013-08-09	Tsukidate (Hirose)	5.20E+03	1.93E+02		
2013-08-23	Tsukidate (Hirose)	6.60E+03	1.32E+02		
2013-09-13	Tsukidate (Hirose)	8.82E+03	2.99E+02		
2013-09-27	Tsukidate (Hirose)	4.17E+03	1.02E+02		
2013-10-31	Tsukidate (Hirose)	1.69E+03	5.70E+01		
2013-11-21	Tsukidate (Hirose)	2.18E+03	6.90E+01		
2013-12-25	Tsukidate (Hirose)	1.26E+04	3.22E+02		
2014-01-15	Tsukidate (Hirose)	3.53E+03	1.24E+02		
2014-02-25	Tsukidate (Hirose)	3.26E+03	8.50E+01		
2014-08-07	Tsukidate (Hirose)	1.57E+03	3.90E+01		
2014-09-10	Tsukidate (Hirose)	4.43E+02	6.50E+01		
2014-10-21	Tsukidate (Hirose)	2.51E+03	6.50E+01		
2014-12-04	Tsukidate (Hirose)	3.07E+03	6.00E+01		
2015-01-14	Tsukidate (Hirose)	2.13E+03	5.30E+01		
2015-04-23	Tsukidate (Hirose)	1.84E+3	3.50E+1		
2015-05-27	Tsukidate (Hirose)	8.69E+2	3.70E+1		
2015-07-22	Tsukidate (Hirose)	1.63E+3	4.20E+1		
2015-08-25	Tsukidate (Hirose)	1.90E+3	9.10E+1		
2015-10-09	Tsukidate (Hirose)	3.37E+3	7.00E+1		
2016-01-20	Tsukidate (Hirose)	9.11E+2	3.20E+1		
2016-02-15	Tsukidate (Hirose)	3.12E+2	2.50E+1		
2016-02-15	Tsukidate (Hirose)	4.74E+2	1.50E+1		
2016-04-19	Tsukidate (Hirose)	4.94E+2	2.60E+1		
2016-04-19	Tsukidate (Hirose)	3.21E+2	1.50E+1		

Table II.1. (cont.)

Sampling date	Site (river name)	Activity in suspended sediments (Bq/kg)	Standard deviation	Catchment area (km²)	Mean deposition in the catchment (kBq/m²)
2016-05-31	Tsukidate (Hirose)	9.35E+2	2.90E+1		
2016-05-31	Tsukidate (Hirose)	1.25E+3	4.20E+1		
2016-08-09	Tsukidate (Hirose)	3.01E+2	1.40E+1		
2016-08-09	Tsukidate (Hirose)	2.57E+3	7.10E+1		
2017-05-08	Tsukidate (Hirose)	1.16E+3	3.80E+1		
2017-05-22	Tsukidate (Hirose)	1.14E+3	4.00E+1		
2017-12-07	Tsukidate (Hirose)	2.27E+3	3.80E+1		
2018-05-28	Tsukidate (Hirose)	1.52E+3	2.30E+1		
2018-06-01	Tsukidate (Hirose)	2.47E+3	2.10E+1		
2018-12-05	Tsukidate (Hirose)	1.78E+3	5.20E+1		
2019-04-23	Tsukidate (Hirose)	1.88E+3	6.70E+1		
2019-07-03	Tsukidate (Hirose)	4.20E+3	2.43E+2		
2020-07-08	Tsukidate (Hirose)	8.51E+2	1.80E+1		
2011-08-31	Nihonmatsu (Abukuma)	3.05E+04	2.36E+02	2380	81.8
2011-10-18	Nihonmatsu (Abukuma)	2.09E+04	1.84E+02		
2012-12-07	Nihonmatsu (Abukuma)	5.42E+03	2.40E+02		
2012-12-17	Nihonmatsu (Abukuma)	5.34E+03	2.77E+02		
2013-01-09	Nihonmatsu (Abukuma)	7.75E+02	2.39E+02		
2013-01-21	Nihonmatsu (Abukuma)	3.66E+03	7.60E+01		
2013-02-25	Nihonmatsu (Abukuma)	7.19E+03	1.92E+02		
2013-04-18	Nihonmatsu (Abukuma)	3.60E+03	1.52E+02		
2013-05-21	Nihonmatsu (Abukuma)	7.48E+03	2.22E+02		
2013-06-18	Nihonmatsu (Abukuma)	5.48E+03	2.09E+02		
2013-09-13	Nihonmatsu (Abukuma)	2.46E+03	1.14E+02		
2013-09-27	Nihonmatsu (Abukuma)	1.64E+03	5.60E+01		
2013-11-20	Nihonmatsu (Abukuma)	1.12E+02	4.20E+01		
2013-12-24	Nihonmatsu (Abukuma)	4.02E+03	9.80E+01		
2014-01-16	Nihonmatsu (Abukuma)	2.67E+02	9.30E+01		
2014-02-25	Nihonmatsu (Abukuma)	1.66E+03	6.00E+01		
2014-08-05	Nihonmatsu (Abukuma)	2.03E+03	4.40E+01		
2015-01-14	Nihonmatsu (Abukuma)	2.25E+03	7.40E+01		
2015-05-28	Nihonmatsu (Abukuma)	1.93E+3	4.00E+1		
2015-07-23	Nihonmatsu (Abukuma)	1.74E+3	6.90E+1		
2015-10-08	Nihonmatsu (Abukuma)	1.65E+3	3.40E+1		
2015-12-04	Nihonmatsu (Abukuma)	9.15E+2	5.60E+1		
2016-01-26	Nihonmatsu (Abukuma)	1.71E+3	5.30E+1		
2016-02-26	Nihonmatsu (Abukuma)	2.70E+3	7.40E+1		
2016-04-13	Nihonmatsu (Abukuma)	3.32E+3	2.81E+2		
2016-06-10	Nihonmatsu (Abukuma)	2.88E+3	1.02E+2		
2016-10-24	Nihonmatsu (Abukuma)	1.54E+3	4.10E+1		
2016-12-21	Nihonmatsu (Abukuma)	2.06E+3	7.20E+1		
2017-03-02	Nihonmatsu (Abukuma)	1.95E+3	1.23E+2		
2017-05-09	Nihonmatsu (Abukuma)	6.85E+2	3.00E+1		
2017-07-07	Nihonmatsu (Abukuma)	1.92E+3	3.20E+1		
2017-09-25	Nihonmatsu (Abukuma)	2.54E+3	3.80E+1		
2017-12-08	Nihonmatsu (Abukuma)	6.63E+2	2.00E+1		
2018-05-31	Nihonmatsu (Abukuma)	7.56E+2	2.10E+1		
2018-07-03	Nihonmatsu (Abukuma)	2.49E+3	4.50E+1		
2018-10-17	Nihonmatsu (Abukuma)	1.05E+3	2.80E+1		
2018-12-03	Nihonmatsu (Abukuma)	6.19E+2	8.20E+1		
2019-04-24	Nihonmatsu (Abukuma)	2.14E+3	2.00E+2		
2019-08-06	Nihonmatsu (Abukuma)	1.77E+3	9.40E+1		

Table II.1. (cont.)

Sampling date	Site (river name)	Activity in suspended sediments (Bq/kg)	Standard deviation	Catchment area (km^2)	Mean deposition in the catchment (kBq/m^2)
2019-12-13	Nihonmatsu (Abukuma)	3.32E+2	1.10E+1		
2020-02-19	Nihonmatsu (Abukuma)	6.91E+2	4.00E+1		
2020-05-12	Nihonmatsu (Abukuma)	7.54E+2	4.20E+1		
2020-07-10	Nihonmatsu (Abukuma)	6.70E+2	2.20E+1		
2020-08-17	Nihonmatsu (Abukuma)	3.61E+2	9.00E+0		
2020-11-11	Nihonmatsu (Abukuma)	1.06E+3	7.30E+1		
2021-02-05	Nihonmatsu (Abukuma)	8.38E+2	8.70E+1		
2011-09-01	Miyota (Abukuma)	1.48E+02	3.28E+02	1287	74.1
2011-09-27	Miyota (Abukuma)	3.75E+03	9.80E+01		
2012-12-07	Miyota (Abukuma)	1.92E+03	8.70E+01		
2012-12-18	Miyota (Abukuma)	2.60E+03	2.27E+02		
2013-01-10	Miyota (Abukuma)	2.78E+03	4.70E+01		
2013-01-22	Miyota (Abukuma)	6.27E+02	2.90E+01		
2013-02-26	Miyota (Abukuma)	3.23E+02	9.20E+01		
2013-04-17	Miyota (Abukuma)	3.05E+03	7.80E+01		
2013-05-20	Miyota (Abukuma)	2.76E+03	1.00E+02		
2013-06-17	Miyota (Abukuma)	1.68E+03	6.10E+01		
2013-07-25	Miyota (Abukuma)	8.15E+02	1.36E+02		
2013-08-22	Miyota (Abukuma)	1.94E+03	7.50E+01		
2013-09-13	Miyota (Abukuma)	2.97E+02	1.04E+02		
2013-09-25	Miyota (Abukuma)	4.07E+02	1.10E+01		
2013-11-20	Miyota (Abukuma)	3.93E+02	1.10E+01		
2013-12-23	Miyota (Abukuma)	8.78E+02	1.00E+01		
2014-01-16	Miyota (Abukuma)	9.27E+02	1.40E+01		
2014-02-25	Miyota (Abukuma)	9.92E+02	3.90E+01		
2014-08-06	Miyota (Abukuma)	9.13E+02	3.00E+01		
2014-12-05	Miyota (Abukuma)	1.59E+03	5.00E+01		
2015-01-14	Miyota (Abukuma)	4.69E+03	1.73E+02		
2015-05-01	Miyota (Abukuma)	1.36E+3	4.40E+1		
2015-05-28	Miyota (Abukuma)	3.14E+3	1.49E+2		
2015-07-23	Miyota (Abukuma)	6.29E+2	2.00E+1		
2015-08-27	Miyota (Abukuma)	2.48E+3	1.23E+2		
2015-10-06	Miyota (Abukuma)	4.97E+2	1.70E+1		
2015-12-04	Miyota (Abukuma)	6.70E+2	1.30E+1		
2016-01-28	Miyota (Abukuma)	1.21E+3	4.30E+1		
2016-02-22	Miyota (Abukuma)	3.27E+2	2.20E+1		
2016-04-13	Miyota (Abukuma)	2.85E+3	1.62E+2		
2016-06-10	Miyota (Abukuma)	6.46E+2	1.40E+1		
2016-08-05	Miyota (Abukuma)	1.48E+3	6.60E+1		
2017-05-15	Miyota (Abukuma)	9.90E+2	4.30E+1		
2017-07-10	Miyota (Abukuma)	2.40E+3	7.40E+1		
2017-09-06	Miyota (Abukuma)	1.30E+3	2.60E+1		
2017-12-12	Miyota (Abukuma)	7.34E+2	1.60E+1		
2018-05-31	Miyota (Abukuma)	3.09E+2	9.00E+0		
2018-07-04	Miyota (Abukuma)	8.08E+2	3.20E+1		
2018-10-17	Miyota (Abukuma)	6.67E+2	1.70E+1		
2018-12-03	Miyota (Abukuma)	1.69E+3	9.20E+1		
2019-04-25	Miyota (Abukuma)	1.65E+3	4.30E+1		
2019-08-06	Miyota (Abukuma)	7.87E+2	3.80E+1		
2020-11-11	Miyota (Abukuma)	6.82E+2	2.70E+1		
2021-02-01	Miyota (Abukuma)	4.80E+2	4.20E+1		
2012-12-18	Nishikawa (Shakado)	3.29E+03	1.77E+02	289.4	132.0

Table II.1. (cont.)

Sampling date	**Site (river name)**	**Activity in suspended sediments (Bq/kg)**	**Standard deviation**	**Catchment area (km^2)**	**Mean deposition in the catchment (kBq/m^2)**
2013-01-10	Nishikawa (Shakado)	3.68E+03	1.29E+02		
2013-01-22	Nishikawa (Shakado)	3.47E+03	1.47E+02		
2013-02-26	Nishikawa (Shakado)	4.37E+03	1.39E+02		
2013-04-17	Nishikawa (Shakado)	2.92E+03	7.00E+01		
2013-05-20	Nishikawa (Shakado)	1.57E+03	4.30E+01		
2013-06-17	Nishikawa (Shakado)	2.96E+03	1.46E+02		
2013-07-25	Nishikawa (Shakado)	4.11E+03	1.14E+02		
2013-08-08	Nishikawa (Shakado)	1.98E+03	5.00E+01		
2013-08-22	Nishikawa (Shakado)	3.49E+03	9.90E+01		
2013-09-12	Nishikawa (Shakado)	2.16E+03	4.70E+01		
2013-09-26	Nishikawa (Shakado)	7.16E+02	2.20E+01		
2013-10-29	Nishikawa (Shakado)	3.16E+02	1.00E+01		
2013-11-20	Nishikawa (Shakado)	3.25E+03	8.50E+01		
2013-12-23	Nishikawa (Shakado)	4.55E+03	1.07E+02		
2014-01-16	Nishikawa (Shakado)	1.46E+02	4.90E+01		
2014-02-25	Nishikawa (Shakado)	3.78E+03	9.00E+01		
2014-08-07	Nishikawa (Shakado)	4.96E+02	1.50E+01		
2014-09-08	Nishikawa (Shakado)	1.30E+01	3.30E+01		
2014-10-20	Nishikawa (Shakado)	3.14E+02	9.00E+00		
2014-12-03	Nishikawa (Shakado)	1.93E+03	4.80E+01		
2015-01-14	Nishikawa (Shakado)	2.08E+03	6.90E+01		
2015-05-01	Nishikawa (Shakado)	1.49E+3	4.20E+1		
2015-05-28	Nishikawa (Shakado)	9.84E+2	2.90E+1		
2015-07-23	Nishikawa (Shakado)	1.03E+3	2.80E+1		
2015-08-27	Nishikawa (Shakado)	2.86E+3	1.31E+2		
2015-10-06	Nishikawa (Shakado)	1.42E+3	3.70E+1		
2015-12-04	Nishikawa (Shakado)	1.94E+3	1.03E+2		
2016-01-28	Nishikawa (Shakado)	1.46E+3	8.00E+1		
2016-02-22	Nishikawa (Shakado)	1.18E+3	1.80E+2		
2016-04-07	Nishikawa (Shakado)	9.86E+2	7.30E+1		
2016-05-27	Nishikawa (Shakado)	2.84E+3	1.79E+2		
2016-12-20	Nishikawa (Shakado)	1.54E+3	3.10E+1		
2017-02-27	Nishikawa (Shakado)	2.46E+2	1.80E+1		
2017-05-11	Nishikawa (Shakado)	2.04E+3	1.04E+2		
2017-09-06	Nishikawa (Shakado)	2.11E+3	2.60E+1		
2019-04-25	Nishikawa (Shakado)	7.45E+2	6.20E+1		
2019-08-06	Nishikawa (Shakado)	1.31E+3	5.10E+1		
2020-11-11	Nishikawa (Shakado)	6.25E+2	4.20E+1		
2021-02-01	Nishikawa (Shakado)	9.07E+2	3.90E+1		
2011-09-26	Kitamachi (Mizunashi)	4.22E+04	8.99E+02	35.8	565.0
2012-12-06	Kitamachi (Mizunashi)	2.67E+04	9.45E+02		
2012-12-18	Kitamachi (Mizunashi)	2.11E+04	3.01E+02		
2013-01-10	Kitamachi (Mizunashi)	2.28E+04	7.73E+02		
2013-01-22	Kitamachi (Mizunashi)	2.73E+04	3.76E+02		
2013-02-26	Kitamachi (Mizunashi)	2.24E+04	3.64E+02		
2013-04-18	Kitamachi (Mizunashi)	2.75E+04	4.37E+02		
2013-05-21	Kitamachi (Mizunashi)	2.55E+04	1.22E+02		
2013-06-18	Kitamachi (Mizunashi)	2.46E+04	7.50E+02		
2013-07-25	Kitamachi (Mizunashi)	2.49E+04	8.59E+02		
2013-08-08	Kitamachi (Mizunashi)	2.64E+04	5.18E+02		
2013-08-22	Kitamachi (Mizunashi)	2.32E+04	2.84E+02		
2013-09-11	Kitamachi (Mizunashi)	2.24E+04	5.63E+02		

Table II.1. (cont.)

Sampling date	**Site (river name)**	**Activity in suspended sediments (Bq/kg)**	**Standard deviation**	**Catchment area (km²)**	**Mean deposition in the catchment (kBq/m²)**
2013-09-26	Kitamachi (Mizunashi)	1.80E+04	3.50E+02		
2013-10-30	Kitamachi (Mizunashi)	2.05E+04	1.95E+02		
2013-11-20	Kitamachi (Mizunashi)	2.94E+04	7.51E+02		
2013-12-23	Kitamachi (Mizunashi)	2.13E+04	4.81E+02		
2014-01-17	Kitamachi (Mizunashi)	2.56E+04	5.03E+02		
2014-02-26	Kitamachi (Mizunashi)	1.96E+04	3.43E+02		
2014-08-06	Kitamachi (Mizunashi)	1.44E+04	2.82E+02		
2014-09-09	Kitamachi (Mizunashi)	1.32E+04	1.70E+02		
2014-10-21	Kitamachi (Mizunashi)	9.03E+03	1.67E+02		
2014-12-04	Kitamachi (Mizunashi)	1.60E+04	3.73E+02		
2015-01-14	Kitamachi (Mizunashi)	1.38E+04	4.42E+02		
2015-04-17	Kitamachi (Mizunashi)	8.28E+3	6.40E+1		
2015-06-17	Kitamachi (Mizunashi)	1.34E+4	9.90E+1		
2015-07-28	Kitamachi (Mizunashi)	7.25E+3	7.80E+1		
2015-08-28	Kitamachi (Mizunashi)	9.52E+3	9.10E+1		
2015-10-23	Kitamachi (Mizunashi)	1.89E+3	2.90E+1		
2015-12-21	Kitamachi (Mizunashi)	6.06E+3	1.09E+2		
2016-02-16	Kitamachi (Mizunashi)	6.44E+3	1.34E+2		
2016-04-08	Kitamachi (Mizunashi)	6.15E+3	2.59E+2		
2016-06-10	Kitamachi (Mizunashi)	6.05E+3	1.90E+2		
2016-08-19	Kitamachi (Mizunashi)	7.92E+3	1.53E+2		
2016-12-20	Kitamachi (Mizunashi)	7.03E+3	2.65E+2		
2017-03-02	Kitamachi (Mizunashi)	5.62E+3	2.78E+2		
2017-05-09	Kitamachi (Mizunashi)	4.11E+3	1.33E+2		
2017-07-07	Kitamachi (Mizunashi)	5.76E+3	8.50E+1		
2017-09-06	Kitamachi (Mizunashi)	6.58E+3	6.70E+1		
2018-05-31	Kitamachi (Mizunashi)	4.78E+3	6.00E+1		
2018-07-02	Kitamachi (Mizunashi)	4.28E+3	4.00E+1		
2018-10-11	Kitamachi (Mizunashi)	5.11E+3	4.70E+1		
2018-12-04	Kitamachi (Mizunashi)	5.56E+3	8.90E+1		
2019-04-25	Kitamachi (Mizunashi)	5.00E+3	1.26E+2		
2019-07-03	Kitamachi (Mizunashi)	4.95E+3	1.17E+2		
2020-10-14	Kitamachi (Mizunashi)	1.56E+3	5.40E+1		
2021-02-02	Kitamachi (Mizunashi)	1.13E+3	2.40E+1		
2011-08-31	Kawamata (Hirose)	2.52E+04	3.37E+02	56.6	229.1
2011-09-26	Kawamata (Hirose)	1.30E+03	3.41E+02		
2012-02-24	Kawamata (Hirose)	2.26E+04	4.70E+02		
2012-12-05	Kawamata (Hirose)	7.41E+03	3.15E+02		
2012-12-19	Kawamata (Hirose)	1.27E+04	1.67E+02		
2013-01-10	Kawamata (Hirose)	6.47E+03	2.55E+02		
2013-01-22	Kawamata (Hirose)	6.76E+03	3.08E+02		
2013-02-26	Kawamata (Hirose)	1.10E+04	4.21E+02		
2013-04-18	Kawamata (Hirose)	8.75E+03	3.03E+02		
2013-05-21	Kawamata (Hirose)	5.90E+03	1.80E+02		
2013-06-18	Kawamata (Hirose)	1.11E+04	5.00E+02		
2013-08-09	Kawamata (Hirose)	1.03E+04	3.66E+02		
2013-08-23	Kawamata (Hirose)	6.37E+03	1.75E+02		
2013-09-13	Kawamata (Hirose)	6.45E+03	2.50E+02		
2013-09-27	Kawamata (Hirose)	2.00E+00	7.10E+01		
2013-10-31	Kawamata (Hirose)	4.35E+03	9.20E+01		
2013-11-21	Kawamata (Hirose)	4.42E+03	1.14E+02		
2013-12-25	Kawamata (Hirose)	4.89E+03	5.40E+01		

Table II.1. (cont.)

Sampling date	Site (river name)	Activity in suspended sediments (Bq/kg)	Standard deviation	Catchment area (km²)	Mean deposition in the catchment (kBq/m²)
2014-01-15	Kawamata (Hirose)	1.51E+03	2.70E+01		
2014-02-25	Kawamata (Hirose)	3.00E+03	7.50E+01		
2014-08-07	Kawamata (Hirose)	1.26E+02	3.70E+01		
2014-09-10	Kawamata (Hirose)	2.60E+01	6.30E+01		
2014-10-21	Kawamata (Hirose)	1.33E+03	2.90E+01		
2014-12-04	Kawamata (Hirose)	3.58E+03	9.70E+01		
2015-01-15	Kawamata (Hirose)	4.49E+03	8.40E+01		
2015-04-23	Kawamata (Hirose)	2.91E+3	4.30E+1		
2015-05-27	Kawamata (Hirose)	3.40E+3	6.30E+1		
2015-07-24	Kawamata (Hirose)	3.23E+3	4.80E+1		
2015-08-28	Kawamata (Hirose)	3.69E+3	4.80E+1		
2015-10-09	Kawamata (Hirose)	8.37E+2	1.60E+1		
2016-02-15	Kawamata (Hirose)	6.39E+2	4.30E+1		
2016-04-19	Kawamata (Hirose)	7.73E+2	5.80E+1		
2016-05-31	Kawamata (Hirose)	2.31E+3	7.10E+1		
2016-08-09	Kawamata (Hirose)	1.59E+3	4.80E+1		
2016-10-03	Kawamata (Hirose)	8.93E+2	2.50E+1		
2016-12-21	Kawamata (Hirose)	1.53E+3	3.90E+1		
2017-03-01	Kawamata (Hirose)	1.20E+3	5.90E+1		
2017-05-08	Kawamata (Hirose)	1.09E+3	4.40E+1		
2017-07-04	Kawamata (Hirose)	9.24E+2	5.70E+1		
2017-09-04	Kawamata (Hirose)	1.28E+3	2.90E+1		
2017-12-07	Kawamata (Hirose)	2.71E+3	5.40E+1		
2018-05-28	Kawamata (Hirose)	5.85E+2	1.50E+1		
2018-07-04	Kawamata (Hirose)	1.52E+3	3.30E+1		
2018-10-11	Kawamata (Hirose)	1.72E+3	3.40E+1		
2018-12-03	Kawamata (Hirose)	1.58E+3	6.40E+1		
2019-04-23	Kawamata (Hirose)	1.59E+3	7.40E+1		
2019-07-03	Kawamata (Hirose)	1.76E+3	6.60E+1		
2012-12-07	Marumori (Abukuma)	5.30E+01	2.31E+02	4123	105.1
2012-12-17	Marumori (Abukuma)	4.91E+03	1.42E+02		
2013-01-09	Marumori (Abukuma)	3.23E+03	1.56E+02		
2013-01-21	Marumori (Abukuma)	2.66E+03	5.00E+01		
2013-02-25	Marumori (Abukuma)	4.17E+03	1.07E+02		
2013-04-17	Marumori (Abukuma)	4.43E+03	1.33E+02		
2013-05-20	Marumori (Abukuma)	3.11E+03	1.07E+02		
2013-06-17	Marumori (Abukuma)	2.54E+03	1.14E+02		
2013-09-12	Marumori (Abukuma)	4.11E+03	9.00E+01		
2013-09-25	Marumori (Abukuma)	1.36E+03	3.50E+01		
2013-11-19	Marumori (Abukuma)	1.26E+03	3.50E+01		
2013-12-24	Marumori (Abukuma)	8.83E+02	2.40E+01		
2014-01-16	Marumori (Abukuma)	9.51E+02	2.30E+01		
2014-02-25	Marumori (Abukuma)	2.96E+02	7.90E+01		
2014-08-04	Marumori (Abukuma)	2.06E+03	6.50E+01		
2014-10-20	Marumori (Abukuma)	2.03E+03	5.80E+01		
2014-12-03	Marumori (Abukuma)	1.43E+03	1.80E+01		
2015-01-13	Marumori (Abukuma)	5.64E+03	1.90E+02		
2015-06-02	Marumori (Abukuma)	1.56E+3	4.30E+1		
2015-07-15	Marumori (Abukuma)	1.26E+3	4.60E+1		
2015-08-24	Marumori (Abukuma)	1.21E+3	2.30E+1		
2015-10-14	Marumori (Abukuma)	1.22E+3	3.40E+1		
2016-01-15	Marumori (Abukuma)	7.91E+2	3.00E+1		

Table II.1. (cont.)

Sampling date	Site (river name)	Activity in suspended sediments (Bq/kg)	Standard deviation	Catchment area (km²)	Mean deposition in the catchment (kBq/m²)
2016-04-11	Marumori (Abukuma)	7.17E+2	6.30E+1		
2016-05-30	Marumori (Abukuma)	1.58E+3	5.50E+1		
2016-07-28	Marumori (Abukuma)	1.08E+3	4.30E+1		
2016-10-17	Marumori (Abukuma)	1.03E+3	2.00E+1		
2017-01-06	Marumori (Abukuma)	5.83E+2	2.20E+1		
2017-02-27	Marumori (Abukuma)	3.09E+2	3.60E+1		
2017-05-11	Marumori (Abukuma)	5.51E+2	2.10E+1		
2017-07-06	Marumori (Abukuma)	8.41E+2	1.60E+1		
2019-04-09	Marumori (Abukuma)	8.76E+2	2.90E+1		
2019-08-05	Marumori (Abukuma)	9.11E+2	4.20E+1		
2021-02-02	Marumori (Abukuma)	1.92E+2	3.40E+1		
2012-12-07	Senoue (Surikami)	5.00E+03	2.62E+02	313.3	41.9
2012-12-17	Senoue (Surikami)	4.02E+03	1.39E+02		
2013-01-09	Senoue (Surikami)	3.18E+02	1.31E+02		
2013-01-21	Senoue (Surikami)	3.00E+03	1.07E+02		
2013-02-25	Senoue (Surikami)	3.81E+03	8.30E+01		
2013-04-17	Senoue (Surikami)	3.50E+03	1.13E+02		
2013-05-20	Senoue (Surikami)	3.34E+03	8.70E+01		
2013-06-17	Senoue (Surikami)	2.54E+03	8.10E+01		
2013-07-26	Senoue (Surikami)	2.67E+02	8.40E+01		
2013-08-09	Senoue (Surikami)	4.65E+03	1.02E+02		
2013-08-23	Senoue (Surikami)	2.53E+03	7.00E+01		
2013-09-11	Senoue (Surikami)	7.85E+03	1.55E+02		
2013-09-25	Senoue (Surikami)	1.67E+03	4.30E+01		
2013-10-31	Senoue (Surikami)	1.13E+03	3.00E+01		
2013-11-19	Senoue (Surikami)	1.12E+02	4.20E+01		
2013-12-24	Senoue (Surikami)	2.98E+03	6.10E+01		
2014-01-16	Senoue (Surikami)	5.02E+03	1.93E+02		
2014-02-25	Senoue (Surikami)	1.45E+03	4.60E+01		
2014-08-04	Senoue (Surikami)	1.19E+03	3.40E+01		
2014-09-08	Senoue (Surikami)	4.09E+02	1.45E+02		
2014-10-20	Senoue (Surikami)	1.28E+02	4.00E+01		
2014-12-03	Senoue (Surikami)	1.46E+03	3.20E+01		
2015-01-13	Senoue (Surikami)	1.48E+03	3.30E+01		
2015-05-27	Senoue (Surikami)	1.17E+3	5.40E+1		
2015-07-15	Senoue (Surikami)	1.86E+3	1.43E+2		
2015-08-24	Senoue (Surikami)	3.03E+3	1.31E+2		
2015-10-08	Senoue (Surikami)	1.22E+3	2.10E+1		
2016-01-26	Senoue (Surikami)	1.91E+3	7.10E+1		
2016-02-26	Senoue (Surikami)	1.19E+3	8.00E+1		
2016-04-13	Senoue (Surikami)	9.18E+2	6.80E+1		
2017-03-02	Senoue (Surikami)	5.62E+2	3.80E+1		
2017-05-09	Senoue (Surikami)	7.81E+2	3.40E+1		
2017-07-07	Senoue (Surikami)	1.58E+3	8.10E+1		
2017-09-25	Senoue (Surikami)	1.95E+3	3.00E+1		
2017-12-08	Senoue (Surikami)	4.69E+2	1.30E+1		
2019-04-24	Senoue (Surikami)	1.71E+3	1.04E+2		
2019-08-05	Senoue (Surikami)	1.19E+3	1.08E+2		
2020-02-19	Senoue (Surikami)	4.04E+2	1.00E+1		
2020-07-10	Senoue (Surikami)	1.02E+3	2.60E+1		
2021-02-05	Senoue (Surikami)	2.65E+2	1.10E+1		
2012-12-07	Yagita (Ara)	2.76E+03	1.88E+02	184.6	52.7

Table II.1. (cont.)

Sampling date	**Site (river name)**	**Activity in suspended sediments (Bq/kg)**	**Standard deviation**	**Catchment area (km²)**	**Mean deposition in the catchment (kBq/m²)**
2012-12-17	Yagita (Ara)	3.13E+03	1.30E+02		
2013-01-09	Yagita (Ara)	1.46E+03	5.00E+01		
2013-01-21	Yagita (Ara)	1.50E+03	5.80E+01		
2013-02-25	Yagita (Ara)	1.13E+03			
2013-04-17	Yagita (Ara)	5.80E+03	1.62E+02		
2013-05-20	Yagita (Ara)	2.06E+03	3.60E+01		
2013-06-17	Yagita (Ara)	1.02E+02	2.90E+01		
2013-07-26	Yagita (Ara)	9.25E+03	2.47E+02		
2013-08-08	Yagita (Ara)	1.16E+04	2.76E+02		
2013-08-23	Yagita (Ara)	3.82E+02	1.07E+02		
2013-09-12	Yagita (Ara)	1.03E+04	2.30E+02		
2013-09-25	Yagita (Ara)	1.63E+03	4.20E+01		
2013-12-24	Yagita (Ara)	2.72E+03	9.10E+01		
2014-01-16	Yagita (Ara)	1.88E+02	4.20E+01		
2014-02-25	Yagita (Ara)	5.54E+03	1.71E+02		
2014-08-04	Yagita (Ara)	9.23E+02	3.10E+01		
2014-09-10	Yagita (Ara)	2.96E+03	7.50E+01		
2014-10-20	Yagita (Ara)	1.47E+03	3.70E+01		
2014-12-05	Yagita (Ara)	3.81E+03	1.08E+02		
2015-01-15	Yagita (Ara)	2.31E+03	6.40E+01		
2015-04-24	Yagita (Ara)	7.80E+3	2.74E+2		
2015-05-27	Yagita (Ara)	1.63E+3	8.50E+1		
2015-07-15	Yagita (Ara)	1.90E+3	1.03E+2		
2015-08-24	Yagita (Ara)	1.11E+4	2.64E+2		
2015-11-05	Yagita (Ara)	1.04E+3	2.00E+1		
2016-02-26	Yagita (Ara)	1.90E+3	6.50E+1		
2016-04-13	Yagita (Ara)	1.67E+3	5.60E+1		
2012-12-07	Kuroiwa (Abukuma)	8.16E+03	3.33E+02	2921	103.4
2012-12-17	Kuroiwa (Abukuma)	1.27E+02	4.40E+01		
2013-01-09	Kuroiwa (Abukuma)	7.62E+02	2.71E+02		
2013-01-21	Kuroiwa (Abukuma)	2.03E+04	3.58E+02		
2013-02-25	Kuroiwa (Abukuma)	1.28E+04	3.66E+02		
2013-04-17	Kuroiwa (Abukuma)	4.84E+03	1.98E+02		
2013-05-20	Kuroiwa (Abukuma)	6.62E+02	1.73E+02		
2013-06-19	Kuroiwa (Abukuma)	1.28E+03	2.70E+01		
2013-07-26	Kuroiwa (Abukuma)	5.43E+03	8.30E+01		
2013-08-10	Kuroiwa (Abukuma)	4.83E+03	1.12E+02		
2013-08-24	Kuroiwa (Abukuma)	4.27E+03	1.07E+02		
2013-09-11	Kuroiwa (Abukuma)	3.03E+02	9.30E+01		
2013-09-25	Kuroiwa (Abukuma)	1.71E+03	6.00E+01		
2013-11-19	Kuroiwa (Abukuma)	2.26E+03	6.00E+01		
2013-12-24	Kuroiwa (Abukuma)	3.06E+03	7.00E+01		
2014-01-16	Kuroiwa (Abukuma)	2.59E+03	7.20E+01		
2014-02-25	Kuroiwa (Abukuma)	1.86E+03	4.60E+01		
2014-08-04	Kuroiwa (Abukuma)	3.03E+03	8.90E+01		
2014-09-11	Kuroiwa (Abukuma)	2.90E+03	8.40E+01		
2014-10-20	Kuroiwa (Abukuma)	6.24E+02	2.00E+01		
2014-12-03	Kuroiwa (Abukuma)	2.23E+03	5.30E+01		
2015-01-13	Kuroiwa (Abukuma)	1.79E+03	5.50E+01		
2015-04-24	Kuroiwa (Abukuma)	1.96E+3	4.00E+1		
2015-05-27	Kuroiwa (Abukuma)	3.47E+3	1.47E+2		
2015-07-15	Kuroiwa (Abukuma)	4.57E+3	1.08E+2		

Table II.1. (cont.)

Sampling date	**Site (river name)**	**Activity in suspended sediments (Bq/kg)**	**Standard deviation**	**Catchment area (km^2)**	**Mean deposition in the catchment (kBq/m^2)**
2015-08-24	Kuroiwa (Abukuma)	5.32E+2	1.60E+1		
2015-10-08	Kuroiwa (Abukuma)	8.09E+2	2.00E+1		
2016-01-20	Kuroiwa (Abukuma)	1.54E+3	4.50E+1		
2016-02-26	Kuroiwa (Abukuma)	6.27E+2	4.80E+1		
2016-04-13	Kuroiwa (Abukuma)	5.33E+2	2.30E+1		
2017-03-02	Kuroiwa (Abukuma)	8.04E+2	7.20E+1		
2017-05-09	Kuroiwa (Abukuma)	2.10E+3	8.20E+1		
2017-07-07	Kuroiwa (Abukuma)	2.70E+3	5.00E+1		
2017-09-25	Kuroiwa (Abukuma)	2.86E+3	3.70E+1		
2019-04-24	Kuroiwa (Abukuma)	1.51E+3	7.20E+1		
2020-09-04	Kuroiwa (Abukuma)	9.31E+2	2.30E+1		
2020-11-11	Kuroiwa (Abukuma)	1.10E+3	2.70E+1		
2021-02-05	Kuroiwa (Abukuma)	4.27E+2	5.50E+1		
2012-12-18	Tomita (Ouse)	2.10E+04	4.76E+02	72.6	98.5
2013-01-10	Tomita (Ouse)	1.68E+04	3.83E+02		
2013-01-22	Tomita (Ouse)	4.78E+02	7.22E+02		
2013-02-26	Tomita (Ouse)	5.17E+04	5.05E+02		
2013-04-17	Tomita (Ouse)	1.04E+04	2.34E+02		
2013-05-20	Tomita (Ouse)	4.54E+03	9.80E+01		
2013-06-17	Tomita (Ouse)	1.41E+04	6.97E+02		
2013-07-25	Tomita (Ouse)	1.38E+04	9.00E+01		
2013-08-08	Tomita (Ouse)	4.82E+03	1.54E+02		
2013-08-22	Tomita (Ouse)	7.51E+03	2.05E+02		
2013-09-12	Tomita (Ouse)	7.75E+03	1.48E+02		
2013-09-26	Tomita (Ouse)	4.60E+01	8.90E+01		
2013-10-30	Tomita (Ouse)	8.42E+03	2.00E+02		
2013-11-20	Tomita (Ouse)	1.53E+04	5.42E+02		
2013-12-24	Tomita (Ouse)	1.70E+04	3.45E+02		
2014-01-16	Tomita (Ouse)	1.55E+04	5.01E+02		
2014-02-25	Tomita (Ouse)	1.63E+02	7.90E+01		
2014-08-06	Tomita (Ouse)	3.89E+03	9.70E+01		
2014-09-09	Tomita (Ouse)	6.22E+03	1.23E+02		
2014-10-22	Tomita (Ouse)	4.00E+03	8.30E+01		
2014-12-05	Tomita (Ouse)	9.15E+03	2.23E+02		
2015-01-14	Tomita (Ouse)	3.30E+03	1.10E+02		
2015-05-01	Tomita (Ouse)	7.85E+3	1.41E+2		
2015-05-28	Tomita (Ouse)	3.70E+3	8.30E+1		
2015-07-23	Tomita (Ouse)	5.77E+3	1.24E+2		
2015-08-27	Tomita (Ouse)	5.90E+3	1.30E+2		
2015-10-06	Tomita (Ouse)	2.85E+3	6.00E+1		
2015-12-04	Tomita (Ouse)	1.58E+3	6.00E+1		
2016-01-28	Tomita (Ouse)	1.89E+3	4.40E+1		
2016-02-16	Tomita (Ouse)	4.78E+3	1.10E+2		
2016-04-13	Tomita (Ouse)	3.79E+3	1.42E+2		
2016-06-10	Tomita (Ouse)	5.40E+3	2.68E+2		
2016-08-05	Tomita (Ouse)	5.91E+3	1.03E+2		
2016-09-29	Tomita (Ouse)	3.38E+3	1.10E+2		
2016-12-20	Tomita (Ouse)	4.81E+3	2.80E+2		
2017-02-27	Tomita (Ouse)	1.22E+3	4.20E+1		
2017-05-09	Tomita (Ouse)	3.08E+3	1.12E+2		
2017-07-10	Tomita (Ouse)	4.60E+3	1.10E+2		
2017-09-06	Tomita (Ouse)	2.67E+3	1.18E+2		

Table II.1. (cont.)

Sampling date	Site (river name)	Activity in suspended sediments (Bq/kg)	Standard deviation	Catchment area (km²)	Mean deposition in the catchment (kBq/m²)
2017-12-12	Tomita (Ouse)	9.77E+2	2.50E+1		
2018-05-31	Tomita (Ouse)	1.43E+3	2.30E+1		
2018-07-04	Tomita (Ouse)	2.49E+3	3.30E+1		
2019-04-25	Tomita (Ouse)	4.03E+3	1.29E+2		
2019-07-05	Tomita (Ouse)	3.07E+3	1.22E+2		
2019-11-15	Tomita (Ouse)	1.36E+3	2.70E+1		
2020-02-26	Tomita (Ouse)	1.26E+4	2.56E+2		
2020-05-12	Tomita (Ouse)	5.71E+2	1.40E+1		
2020-07-06	Tomita (Ouse)	2.39E+3	5.30E+1		
2020-11-11	Tomita (Ouse)	1.84E+3	3.40E+1		
2021-02-01	Tomita (Ouse)	1.80E+3	1.03E+2		
2012-12-06	Ota (Ota)	5.13E+04	1.32E+03	49.9	1768
2012-12-18	Ota (Ota)	7.50E+03			
2013-01-10	Ota (Ota)	3.88E+04	1.09E+03		
2013-01-22	Ota (Ota)	6.70E+04	2.84E+03		
2013-02-26	Ota (Ota)	7.50E+03			
2013-04-18	Ota (Ota)	3.76E+04	1.93E+03		
2013-05-21	Ota (Ota)	1.53E+04	2.89E+02		
2013-06-18	Ota (Ota)	2.83E+04	7.50E+01		
2013-07-25	Ota (Ota)	5.34E+04	6.99E+02		
2013-08-08	Ota (Ota)	5.29E+04	6.30E+02		
2013-08-22	Ota (Ota)	9.06E+04	2.09E+02		
2013-09-11	Ota (Ota)	1.03E+04	2.30E+02		
2013-09-26	Ota (Ota)	4.91E+04	1.51E+03		
2013-10-30	Ota (Ota)	3.58E+03	3.45E+02		
2013-11-20	Ota (Ota)	3.76E+04	8.50E+02		
2013-12-23	Ota (Ota)	2.96E+04	7.24E+02		
2014-01-17	Ota (Ota)	5.48E+04	4.83E+02		
2014-02-26	Ota (Ota)	2.51E+04	1.77E+02		
2014-08-06	Ota (Ota)	4.02E+04	1.29E+03		
2014-09-09	Ota (Ota)	3.64E+04	7.88E+02		
2014-10-21	Ota (Ota)	3.91E+04	1.04E+03		
2014-12-04	Ota (Ota)	2.84E+04	2.82E+02		
2015-01-14	Ota (Ota)	3.75E+04	1.10E+03		
2015-04-30	Ota (Ota)	2.17E+4	3.27E+2		
2015-06-17	Ota (Ota)	2.89E+4	4.90E+2		
2015-07-27	Ota (Ota)	2.77E+4	3.79E+2		
2015-09-02	Ota (Ota)	3.15E+4	3.69E+2		
2016-02-22	Ota (Ota)	1.15E+4	3.11E+2		
2016-04-08	Ota (Ota)	1.54E+4	2.16E+2		
2016-06-10	Ota (Ota)	2.33E+4	1.20E+3		
2016-10-27	Ota (Ota)	1.82E+4	1.63E+2		
2016-12-20	Ota (Ota)	7.86E+3	3.33E+2		
2017-03-02	Ota (Ota)	7.29E+3	4.31E+2		
2017-05-09	Ota (Ota)	7.81E+3	3.06E+2		
2017-07-10	Ota (Ota)	9.70E+3	1.77E+2		
2017-09-06	Ota (Ota)	1.03E+4	1.34E+2		
2017-12-11	Ota (Ota)	7.66E+3	7.30E+1		
2018-05-31	Ota (Ota)	1.29E+4	4.49E+2		
2018-07-02	Ota (Ota)	1.17E+4	1.63E+2		
2018-10-12	Ota (Ota)	1.48E+4	1.70E+1		
2018-12-04	Ota (Ota)	1.74E+4	5.56E+2		

Table II.1. (cont.)

Sampling date	Site (river name)	Activity in suspended sediments (Bq/kg)	Standard deviation	Catchment area (km²)	Mean deposition in the catchment (kBq/m²)
2019-04-18	Ota (Ota)	1.34E+4	1.30E+3		
2019-07-03	Ota (Ota)	3.20E+3	7.90E+1		
2020-02-17	Ota (Ota)	2.14E+3	2.90E+1		
2020-05-14	Ota (Ota)	3.73E+3	5.00E+1		
2020-07-09	Ota (Ota)	5.70E+3	2.59E+2		
2020-10-14	Ota (Ota)	4.63E+3	1.38E+2		
2021-02-04	Ota (Ota)	6.57E+3	1.84E+2		
2012-12-06	Odaka (Odaka)	1.56E+04	7.50E+02	50.3	724.2
2012-12-18	Odaka (Odaka)	7.85E+03	3.20E+02		
2013-01-10	Odaka (Odaka)	1.35E+04	3.62E+02		
2013-01-22	Odaka (Odaka)	1.38E+04	2.73E+02		
2013-02-26	Odaka (Odaka)	8.62E+03	2.70E+02		
2013-04-18	Odaka (Odaka)	1.49E+04	4.30E+02		
2013-05-21	Odaka (Odaka)	4.01E+03	5.80E+01		
2013-06-18	Odaka (Odaka)	1.43E+04	4.87E+02		
2013-07-25	Odaka (Odaka)	1.19E+04	8.60E+01		
2013-08-08	Odaka (Odaka)	1.94E+04	3.92E+02		
2013-08-22	Odaka (Odaka)	1.30E+04	3.81E+02		
2013-09-11	Odaka (Odaka)	1.36E+04	3.15E+02		
2013-09-26	Odaka (Odaka)	4.04E+04	6.83E+02		
2013-10-30	Odaka (Odaka)	1.73E+04	2.20E+02		
2013-11-20	Odaka (Odaka)	2.36E+04	4.25E+02		
2013-12-23	Odaka (Odaka)	1.63E+04	5.10E+02		
2014-01-17	Odaka (Odaka)	1.45E+04	3.93E+02		
2014-02-26	Odaka (Odaka)	1.48E+04	5.07E+02		
2014-08-06	Odaka (Odaka)	1.73E+04	3.60E+02		
2014-09-09	Odaka (Odaka)	2.23E+04	7.40E+02		
2014-10-21	Odaka (Odaka)	1.64E+04	3.72E+02		
2014-12-04	Odaka (Odaka)	1.28E+04	1.92E+02		
2015-01-14	Odaka (Odaka)	9.96E+03	2.91E+02		
2015-04-30	Odaka (Odaka)	1.64E+4	1.59E+2		
2015-07-27	Odaka (Odaka)	1.27E+4	2.09E+2		
2015-09-01	Odaka (Odaka)	1.16E+4	2.19E+2		
2015-10-23	Odaka (Odaka)	2.08E+4	1.58E+2		
2015-12-21	Odaka (Odaka)	3.59E+3	1.36E+2		
2016-02-22	Odaka (Odaka)	6.46E+3	9.90E+1		
2016-04-08	Odaka (Odaka)	2.61E+3	1.46E+2		
2016-06-10	Odaka (Odaka)	6.00E+3	4.40E+2		
2016-10-27	Odaka (Odaka)	1.71E+4	1.73E+2		
2016-12-20	Odaka (Odaka)	8.69E+3	3.59E+2		
2017-03-02	Odaka (Odaka)	3.65E+3	2.25E+2		
2017-05-09	Odaka (Odaka)	4.09E+3	1.65E+2		
2017-07-10	Odaka (Odaka)	1.17E+4	2.29E+2		
2017-09-06	Odaka (Odaka)	1.45E+4	1.18E+2		
2017-12-11	Odaka (Odaka)	1.35E+4	4.50E+1		
2018-05-17	Odaka (Odaka)	2.82E+3	4.90E+1		
2018-07-02	Odaka (Odaka)	5.07E+3	1.13E+2		
2018-10-12	Odaka (Odaka)	1.36E+4	1.91E+2		
2018-12-04	Odaka (Odaka)	5.62E+3	6.79E+2		
2019-04-23	Odaka (Odaka)	4.54E+3	5.75E+2		
2019-07-03	Odaka (Odaka)	4.94E+3	5.55E+2		
2019-12-04	Odaka (Odaka)	5.26E+3	4.30E+1		

Table II.1. (cont.)

Sampling date	Site (river name)	Activity in suspended sediments (Bq/kg)	Standard deviation	Catchment area (km²)	Mean deposition in the catchment (kBq/m²)
2020-03-05	Odaka (Odaka)	1.28E+3	1.40E+1		
2020-05-14	Odaka (Odaka)	5.99E+2	9.00E+0		
2020-07-09	Odaka (Odaka)	7.96E+3	7.40E+1		
2020-10-14	Odaka (Odaka)	1.45E+3	2.10E+1		
2021-02-04	Odaka (Odaka)	2.41E+3	4.10E+1		
2012-12-08	Asamai (Asami)	4.90E+03	1.93E+02	25.8	193.8
2012-12-17	Asamai (Asami)	1.07E+02			
2013-01-09	Asamai (Asami)	5.55E+03	1.64E+02		
2013-01-21	Asamai (Asami)	2.53E+03	1.52E+02		
2013-02-25	Asamai (Asami)	4.88E+03	6.50E+01		
2013-04-17	Asamai (Asami)	2.21E+03	6.70E+01		
2013-05-20	Asamai (Asami)	1.76E+03	6.90E+01		
2013-06-17	Asamai (Asami)	2.04E+02	6.70E+01		
2013-07-25	Asamai (Asami)	4.27E+03	7.70E+01		
2013-08-08	Asamai (Asami)	4.08E+03	1.05E+02		
2013-08-22	Asamai (Asami)	2.66E+03	3.00E+01		
2013-09-11	Asamai (Asami)	4.74E+03	1.23E+02		
2013-09-25	Asamai (Asami)	5.40E+03	2.10E+02		
2013-12-23	Asamai (Asami)	2.80E+03	6.30E+01		
2014-01-15	Asamai (Asami)	1.03E+03	7.00E+00		
2014-02-24	Asamai (Asami)	1.09E+03	3.40E+01		
2014-09-08	Asamai (Asami)	4.16E+03	1.19E+02		
2014-12-03	Asamai (Asami)	2.63E+03	4.80E+01		
2015-01-13	Asamai (Asami)	7.09E+02	4.60E+01		
2015-04-30	Asamai (Asami)	9.69E+2	3.00E+1		
2015-06-03	Asamai (Asami)	2.94E+3	1.35E+2		
2015-08-03	Asamai (Asami)	2.92E+3	1.13E+2		
2015-09-01	Asamai (Asami)	1.40E+3	6.60E+1		
2015-10-13	Asamai (Asami)	8.86E+2	2.30E+1		
2016-08-02	Asamai (Asami)	1.21E+2	6.00E+0		
2016-12-20	Asamai (Asami)	8.54E+2	3.80E+1		
2017-02-27	Asamai (Asami)	8.74E+2	5.70E+1		
2017-05-11	Asamai (Asami)	7.96E+2	3.40E+1		
2017-07-10	Asamai (Asami)	4.61E+2	1.90E+1		
2017-09-20	Asamai (Asami)	2.23E+3	6.40E+1		
2017-12-11	Asamai (Asami)	1.21E+3	1.90E+1		
2018-05-28	Asamai (Asami)	4.44E+2	1.10E+1		
2018-07-02	Asamai (Asami)	8.95E+2	1.60E+1		
2018-10-12	Asamai (Asami)	1.53E+3	3.00E+1		
2018-12-04	Asamai (Asami)	1.14E+3	8.60E+1		
2019-04-23	Asamai (Asami)	9.27E+2	5.70E+1		
2019-07-03	Asamai (Asami)	1.35E+4	7.45E+2		
2020-02-18	Asamai (Asami)	2.42E+2	1.80E+1		
2020-05-13	Asamai (Asami)	1.42E+2	4.00E+0		
2020-07-09	Asamai (Asami)	7.36E+2	2.30E+1		
2020-10-15	Asamai (Asami)	2.54E+2	9.00E+0		
2021-02-04	Asamai (Asami)	7.47E+2	8.10E+1		
2012-12-05	Tsushima (Ukedo)	4.48E+04	1.03E+03	25.4	951.5
2012-12-18	Tsushima (Ukedo)	2.48E+04	3.33E+02		
2013-01-11	Tsushima (Ukedo)	3.43E+04	8.87E+02		
2013-01-23	Tsushima (Ukedo)	1.45E+04	8.24E+02		
2013-02-27	Tsushima (Ukedo)	3.51E+04	8.64E+02		

Table II.1. (cont.)

Sampling date	Site (river name)	Activity in suspended sediments (Bq/kg)	Standard deviation	Catchment area (km²)	Mean deposition in the catchment (kBq/m²)
2013-09-13	Tsushima (Ukedo)	3.51E+03	1.11E+03		
2013-09-27	Tsushima (Ukedo)	2.01E+04	6.82E+02		
2013-10-29	Tsushima (Ukedo)	2.16E+04	4.33E+02		
2013-11-21	Tsushima (Ukedo)	2.48E+04	5.78E+02		
2014-01-15	Tsushima (Ukedo)	2.27E+04	5.79E+02		
2014-02-26	Tsushima (Ukedo)	2.53E+04	5.44E+02		
2014-08-09	Tsushima (Ukedo)	1.77E+04	3.52E+02		
2014-09-10	Tsushima (Ukedo)	1.60E+04	4.31E+02		
2014-10-22	Tsushima (Ukedo)	2.06E+03	3.29E+02		
2014-12-05	Tsushima (Ukedo)	1.49E+03	2.09E+02		
2015-01-15	Tsushima (Ukedo)	2.31E+04	5.18E+02		
2015-04-22	Tsushima (Ukedo)	2.31E+4	3.69E+2		
2015-05-29	Tsushima (Ukedo)	1.86E+4	3.33E+2		
2015-07-21	Tsushima (Ukedo)	2.05E+4	1.96E+2		
2015-09-03	Tsushima (Ukedo)	3.15E+4	2.46E+2		
2015-10-22	Tsushima (Ukedo)	9.09E+3	6.50E+1		
2015-12-24	Tsushima (Ukedo)	1.03E+4	1.20E+2		
2016-01-21	Tsushima (Ukedo)	9.91E+3	1.82E+2		
2016-02-23	Tsushima (Ukedo)	9.24E+3	1.50E+2		
2016-04-15	Tsushima (Ukedo)	1.21E+4	5.76E+2		
2016-09-27	Tsushima (Ukedo)	1.08E+4	1.39E+2		
2016-12-21	Tsushima (Ukedo)	1.09E+4	4.22E+2		
2017-03-01	Tsushima (Ukedo)	5.69E+3	2.31E+2		
2017-04-19	Tsushima (Ukedo)	9.94E+3	3.41E+2		
2017-07-10	Tsushima (Ukedo)	1.51E+4	2.25E+2		
2017-09-05	Tsushima (Ukedo)	1.70E+4	2.57E+2		
2017-12-12	Tsushima (Ukedo)	8.76E+3	8.70E+1		
2018-05-30	Tsushima (Ukedo)	7.88E+3	1.31E+2		
2018-07-03	Tsushima (Ukedo)	1.16E+4	1.50E+2		
2018-12-03	Tsushima (Ukedo)	1.12E+4	9.09E+2		
2019-04-24	Tsushima (Ukedo)	3.09E+3	8.90E+1		
2019-07-05	Tsushima (Ukedo)	7.91E+3	6.10E+1		
2020-02-26	Tsushima (Ukedo)	4.72E+3	1.11E+2		
2020-05-15	Tsushima (Ukedo)	5.00E+3	5.60E+1		
2020-07-06	Tsushima (Ukedo)	7.03E+3	1.64E+2		
2020-10-21	Tsushima (Ukedo)	7.75E+3	7.10E+1		
2021-02-01	Tsushima (Ukedo)	7.95E+3	5.00E+2		
2012-12-17	Ukedo (Ukedo)	5.55E+04	1.04E+03	152.6	2566
2013-01-09	Ukedo (Ukedo)	6.55E+04	8.02E+02		
2013-01-21	Ukedo (Ukedo)	5.32E+04	8.80E+02		
2013-02-25	Ukedo (Ukedo)	4.06E+04	3.54E+02		
2013-09-11	Ukedo (Ukedo)	6.78E+04	1.38E+03		
2013-09-25	Ukedo (Ukedo)	8.48E+04	1.83E+03		
2013-11-19	Ukedo (Ukedo)	5.60E+04	5.58E+02		
2014-01-15	Ukedo (Ukedo)	5.11E+04	7.09E+02		
2014-02-27	Ukedo (Ukedo)	3.13E+04	6.44E+02		
2014-08-08	Ukedo (Ukedo)	4.05E+04	5.13E+02		
2014-09-10	Ukedo (Ukedo)	4.40E+04	1.21E+03		
2014-12-05	Ukedo (Ukedo)	3.14E+04	3.43E+02		
2015-01-13	Ukedo (Ukedo)	4.60E+04	1.40E+03		
2015-04-30	Ukedo (Ukedo)	2.78E+4	1.62E+2		
2015-06-03	Ukedo (Ukedo)	2.36E+4	2.92E+2		

Table II.1. (cont.)

Sampling date	Site (river name)	Activity in suspended sediments (Bq/kg)	Standard deviation	Catchment area (km^2)	Mean deposition in the catchment (kBq/m^2)
2015-08-03	Ukedo (Ukedo)	3.73E+4	2.01E+2		
2016-02-22	Ukedo (Ukedo)	3.07E+4	2.85E+2		
2016-04-08	Ukedo (Ukedo)	2.29E+4	5.21E+2		
2016-10-27	Ukedo (Ukedo)	1.84E+4	2.03E+2		
2016-12-20	Ukedo (Ukedo)	2.14E+4	3.36E+2		
2017-03-01	Ukedo (Ukedo)	1.84E+4	2.78E+2		
2017-07-10	Ukedo (Ukedo)	2.82E+4	2.34E+2		
2017-07-10	Ukedo (Ukedo)	2.41E+4	2.99E+2		
2017-12-11	Ukedo (Ukedo)	2.68E+4	1.45E+2		
2017-12-11	Ukedo (Ukedo)	2.70E+4	1.26E+2		
2018-05-01	Ukedo (Ukedo)	2.38E+4	1.58E+2		
2018-05-01	Ukedo (Ukedo)	1.93E+4	8.30E+1		
2018-07-02	Ukedo (Ukedo)	2.25E+4	1.48E+2		
2018-07-02	Ukedo (Ukedo)	2.13E+4	1.31E+2		
2018-10-26	Ukedo (Ukedo)	2.91E+4	1.60E+2		
2018-12-04	Ukedo (Ukedo)	2.10E+4	1.50E+2		
2019-04-23	Ukedo (Ukedo)	1.55E+4	3.51E+2		
2019-07-03	Ukedo (Ukedo)	1.38E+4	6.32E+2		
2019-11-18	Ukedo (Ukedo)	2.06E+4	1.01E+2		
2020-02-18	Ukedo (Ukedo)	1.04E+4	8.30E+1		
2020-05-13	Ukedo (Ukedo)	2.77E+3	2.90E+1		
2020-07-09	Ukedo (Ukedo)	4.78E+3	3.07E+2		
2020-10-15	Ukedo (Ukedo)	1.13E+4	1.44E+2		
2021-02-04	Ukedo (Ukedo)	5.15E+3	1.12E+2		
2012-12-17	Takase (Takase)	2.75E+04	3.63E+02	263.7	726.0
2013-01-09	Takase (Takase)	2.03E+04	4.57E+02		
2013-01-21	Takase (Takase)	2.57E+04	3.63E+02		
2013-02-25	Takase (Takase)	2.13E+04	3.58E+02		
2013-09-11	Takase (Takase)	2.62E+04	9.11E+02		
2013-09-25	Takase (Takase)	2.05E+04	7.10E+02		
2013-10-29	Takase (Takase)	1.20E+04	2.95E+02		
2013-11-19	Takase (Takase)	1.09E+04	2.09E+02		
2014-01-15	Takase (Takase)	2.05E+04	2.00E+02		
2014-02-27	Takase (Takase)	3.13E+04	7.81E+02		
2014-08-08	Takase (Takase)	7.75E+03	1.62E+02		
2014-09-10	Takase (Takase)	8.10E+03	1.94E+02		
2014-10-22	Takase (Takase)	1.26E+04	2.57E+02		
2014-12-05	Takase (Takase)	1.07E+04	2.49E+02		
2015-01-13	Takase (Takase)	7.91E+03	1.04E+02		
2015-04-30	Takase (Takase)	1.14E+4	1.60E+2		
2015-06-03	Takase (Takase)	9.03E+3	2.71E+2		
2015-08-03	Takase (Takase)	9.07E+3	1.34E+2		
2015-09-02	Takase (Takase)	8.01E+3	1.12E+2		
2015-10-15	Takase (Takase)	6.73E+3	6.80E+1		
2016-02-22	Takase (Takase)	8.72E+3	1.36E+2		
2016-04-08	Takase (Takase)	6.42E+3	3.07E+2		
2016-06-10	Takase (Takase)	1.16E+4	1.62E+2		
2016-10-27	Takase (Takase)	2.63E+3	2.50E+1		
2016-12-20	Takase (Takase)	5.70E+3	1.73E+2		
2017-03-01	Takase (Takase)	4.34E+3	1.87E+2		
2017-05-15	Takase (Takase)	8.69E+3	3.10E+2		
2017-07-10	Takase (Takase)	9.12E+3	2.22E+2		

Table II.1. (cont.)

Sampling date	**Site (river name)**	**Activity in suspended sediments (Bq/kg)**	**Standard deviation**	**Catchment area (km^2)**	**Mean deposition in the catchment (kBq/m^2)**
2017-09-05	Takase (Takase)	1.44E+4	2.33E+2		
2017-12-11	Takase (Takase)	2.54E+3	2.50E+1		
2018-05-28	Takase (Takase)	3.55E+3	5.50E+1		
2018-07-02	Takase (Takase)	6.55E+3	2.23E+2		
2018-09-20	Takase (Takase)	2.77E+3	2.30E+1		
2018-10-12	Takase (Takase)	3.96E+4	1.36E+2		
2018-12-04	Takase (Takase)	5.19E+3	4.98E+2		
2019-04-23	Takase (Takase)	5.41E+3	7.61E+2		
2019-07-03	Takase (Takase)	4.92E+3	1.19E+2		
2020-07-09	Takase (Takase)	6.41E+3	1.18E+2		
2020-10-15	Takase (Takase)	2.87E+3	3.20E+1		
2021-02-04	Takase (Takase)	2.44E+3	6.30E+1		
2012-12-06	Haramachi (Niida)	3.13E+04	1.10E+03	200.3	963.7
2012-12-18	Haramachi (Niida)	1.32E+04	1.31E+03		
2013-01-10	Haramachi (Niida)	2.75E+04	5.15E+02		
2013-01-22	Haramachi (Niida)	2.43E+04	5.06E+02		
2013-02-26	Haramachi (Niida)	1.81E+04	5.83E+02		
2013-04-18	Haramachi (Niida)	2.74E+04	3.60E+02		
2013-05-21	Haramachi (Niida)	3.18E+04	7.79E+02		
2013-06-18	Haramachi (Niida)	1.61E+04	2.08E+02		
2013-07-25	Haramachi (Niida)	2.92E+04	2.67E+02		
2013-08-08	Haramachi (Niida)	3.61E+04	7.71E+02		
2013-08-22	Haramachi (Niida)	1.68E+04	1.05E+02		
2013-09-11	Haramachi (Niida)	3.51E+04	4.78E+02		
2013-09-26	Haramachi (Niida)	3.12E+04	1.10E+03		
2013-10-30	Haramachi (Niida)	2.66E+04	3.25E+02		
2013-11-20	Haramachi (Niida)	2.93E+04	4.59E+02		
2013-12-23	Haramachi (Niida)	2.13E+03	5.19E+02		
2014-01-17	Haramachi (Niida)	2.72E+04	6.05E+02		
2014-02-26	Haramachi (Niida)	2.00E+04	3.86E+02		
2014-08-05	Haramachi (Niida)	2.08E+03	3.58E+02		
2014-09-09	Haramachi (Niida)	1.87E+04	4.03E+02		
2014-10-21	Haramachi (Niida)	1.84E+04	3.19E+02		
2014-12-04	Haramachi (Niida)	1.86E+04	2.79E+02		
2015-01-14	Haramachi (Niida)	1.84E+04	4.91E+02		
2015-04-17	Haramachi (Niida)	1.62E+4	1.72E+2		
2015-06-17	Haramachi (Niida)	1.45E+4	2.59E+2		
2015-07-27	Haramachi (Niida)	1.37E+4	1.94E+2		
2015-09-02	Haramachi (Niida)	1.58E+4	1.68E+2		
2016-02-22	Haramachi (Niida)	7.46E+3	1.19E+2		
2016-05-09	Haramachi (Niida)	5.87E+3	9.00E+1		
2016-06-21	Haramachi (Niida)	6.29E+3	3.49E+2		
2016-10-27	Haramachi (Niida)	4.45E+3	4.40E+1		
2016-12-20	Haramachi (Niida)	4.46E+3	7.70E+1		
2017-03-02	Haramachi (Niida)	2.73E+3	1.43E+2		
2017-05-09	Haramachi (Niida)	4.67E+3	1.17E+2		
2017-07-07	Haramachi (Niida)	5.06E+3	7.70E+1		
2017-09-06	Haramachi (Niida)	7.77E+3	4.90E+1		
2017-12-04	Haramachi (Niida)	6.33E+3	3.30E+1		
2018-05-31	Haramachi (Niida)	6.36E+3	6.60E+1		
2018-07-02	Haramachi (Niida)	5.82E+3	4.20E+1		
2018-10-11	Haramachi (Niida)	4.11E+3	3.00E+1		

Table II.1. (cont.)

Sampling date	Site (river name)	Activity in suspended sediments (Bq/kg)	Standard deviation	Catchment area (km²)	Mean deposition in the catchment (kBq/m²)
2018-12-04	Haramachi (Niida)	6.37E+3	5.59E+2		
2019-04-25	Haramachi (Niida)	6.23E+3	1.48E+2		
2019-08-05	Haramachi (Niida)	7.32E+3	1.21E+2		
2020-03-06	Haramachi (Niida)	1.67E+3	1.10E+1		
2020-05-14	Haramachi (Niida)	7.84E+2	1.00E+1		
2021-02-02	Haramachi (Niida)	3.29E+3	4.00E+1		
2012-12-18	Akanuma (Otakine)	9.88E+02	3.80E+01	242.6	52.6
2013-01-10	Akanuma (Otakine)	2.19E+03	4.00E+01		
2013-01-22	Akanuma (Otakine)	1.39E+03	4.20E+01		
2013-02-26	Akanuma (Otakine)	1.99E+03	7.40E+01		
2013-04-17	Akanuma (Otakine)	1.74E+02	7.90E+01		
2013-05-20	Akanuma (Otakine)	1.26E+03	1.90E+01		
2013-06-17	Akanuma (Otakine)	1.21E+03	2.20E+01		
2013-07-25	Akanuma (Otakine)	1.66E+03	4.60E+01		
2013-08-08	Akanuma (Otakine)	1.04E+03	3.70E+01		
2013-08-22	Akanuma (Otakine)	1.40E+03	4.90E+01		
2013-09-12	Akanuma (Otakine)	1.52E+03	5.90E+01		
2013-09-26	Akanuma (Otakine)	4.28E+02	1.30E+01		
2013-10-30	Akanuma (Otakine)	4.77E+02	1.70E+01		
2013-11-20	Akanuma (Otakine)	1.14E+03	4.10E+01		
2013-12-24	Akanuma (Otakine)	3.06E+03	4.90E+01		
2014-01-16	Akanuma (Otakine)	1.59E+03			
2014-02-25	Akanuma (Otakine)	3.98E+02			
2014-08-06	Akanuma (Otakine)	4.13E+02	1.70E+01		
2014-09-08	Akanuma (Otakine)	8.96E+02	3.10E+01		
2014-10-20	Akanuma (Otakine)	6.48E+02	1.70E+01		
2014-12-03	Akanuma (Otakine)	6.31E+02	8.00E+00		
2015-01-14	Akanuma (Otakine)	7.23E+02	2.80E+01		
2015-05-01	Akanuma (Otakine)	6.93E+2	4.00E+1		
2015-05-28	Akanuma (Otakine)	9.09E+2	5.40E+1		
2015-07-23	Akanuma (Otakine)	4.36E+2	2.40E+1		
2015-08-27	Akanuma (Otakine)	6.71E+2	5.10E+1		
2015-10-06	Akanuma (Otakine)	2.62E+2	1.10E+1		
2015-12-04	Akanuma (Otakine)	9.94E+2	4.00E+1		
2016-01-28	Akanuma (Otakine)	9.02E+2	4.10E+1		
2016-02-22	Akanuma (Otakine)	2.78E+2	4.70E+1		
2016-04-13	Akanuma (Otakine)	1.25E+3	1.00E+2		
2016-06-10	Akanuma (Otakine)	6.34E+2	5.30E+1		
2016-08-02	Akanuma (Otakine)	8.60E+2	3.10E+1		
2016-09-29	Akanuma (Otakine)	5.32E+2	1.00E+1		
2016-12-20	Akanuma (Otakine)	1.16E+3	5.10E+1		
2017-03-01	Akanuma (Otakine)	4.19E+2	6.80E+1		
2017-05-09	Akanuma (Otakine)	4.04E+2	2.70E+1		
2017-07-10	Akanuma (Otakine)	5.76E+2	5.00E+1		
2017-09-06	Akanuma (Otakine)	7.27E+2	1.60E+1		
2017-12-12	Akanuma (Otakine)	7.41E+2	4.30E+1		
2018-05-31	Akanuma (Otakine)	1.33E+2	9.00E+0		
2018-07-04	Akanuma (Otakine)	5.23E+2	3.60E+1		
2018-10-17	Akanuma (Otakine)	5.08E+2	2.70E+1		
2018-12-03	Akanuma (Otakine)	8.74E+2	1.03E+2		
2019-04-25	Akanuma (Otakine)	2.40E+2	2.00E+1		
2019-08-06	Akanuma (Otakine)	2.64E+2	2.10E+1		

Table II.1. (cont.)

Sampling date	Site (river name)	Activity in suspended sediments (Bq/kg)	Standard deviation	Catchment area (km²)	Mean deposition in the catchment (kBq/m²)
2019-11-15	Akanuma (Otakine)	4.15E+2	1.70E+1		
2020-02-26	Akanuma (Otakine)	2.12E+2	8.00E+0		
2020-05-12	Akanuma (Otakine)	1.79E+2	4.00E+0		
2020-07-06	Akanuma (Otakine)	6.07E+2	3.30E+1		
2020-11-11	Akanuma (Otakine)	2.69E+2	1.50E+1		
2021-02-01	Akanuma (Otakine)	7.70E+1	1.40E+1		

APPENDIX III. FLUX OF CAESIUM-137 IN RIVERS OF THE FUKUSHIMA PREFECTURE

Table III.1: Monthly flux of particulate ^{137}Cs (Bq) in rivers of the Fukushima Prefecture [15]. For the months/sites with green or brown values, data on water level and/or turbidity data were not available. For these cases, the flux of particulate ^{137}Cs was determined as described in Ref. [15]. The data are the basis for the preparation of Figure 12.

Sampling month	**Monthly flux of particulate Cs-137 in rivers (Bq)**					
	Mizusakai	**Kuchibuto (up)**	**Kuchibuto (mid)**	**Kuchibuto (down)**	**Fushiguro**	**Iwanuma**
06/2011	1.31E+08	9.69E+08	1.11E+09	5.10E+09	1.29E+12	1.05E+12
07/2011	1.56E+09	7.75E+09	1.66E+10	1.00E+11	2.09E+12	1.95E+12
08/2011	1.55E+09	5.07E+09	8.45E+09	2.81E+10	3.69E+11	4.25E+11
09/2011	2.88E+09	2.26E+10	5.53E+10	8.17E+10	1.36E+12	3.41E+12
10/2011	2.49E+08	1.13E+09	3.65E+09	4.10E+09	9.72E+10	1.81E+11
11/2011	8.58E+07	1.69E+08	5.52E+08	7.88E+08	5.71E+10	9.49E+10
12/2011	9.49E+07	2.32E+08	6.14E+08	5.34E+08	5.43E+10	4.00E+10
01/2012	4.74E+07	6.34E+07	6.25E+07	2.94E+08	7.46E+10	5.95E+10
02/2012	1.10E+08	4.27E+08	5.52E+08	1.93E+09	1.27E+11	5.75E+10
03/2012	3.60E+08	1.03E+09	3.47E+09	1.07E+10	5.04E+11	2.21E+11
04/2012	3.96E+08	1.83E+09	3.53E+09	1.27E+10	2.12E+11	6.45E+10
05/2012	3.42E+08	5.82E+08	2.30E+09	4.77E+09	8.83E+11	7.28E+11
06/2012	3.19E+08	2.11E+09	3.89E+09	9.19E+09	1.90E+11	2.11E+11
07/2012	3.39E+08	2.14E+09	4.10E+09	9.47E+09	1.60E+11	1.84E+11
08/2012	1.42E+07	9.42E+08	4.34E+08	2.24E+09	2.93E+10	6.38E+10
09/2012	1.52E+08	1.52E+09	1.08E+09	1.27E+10	5.40E+10	6.09E+10
10/2012	5.38E+07	7.26E+08	1.53E+09	2.94E+09	1.03E+11	8.86E+10
11/2012	1.22E+07	8.57E+08	8.43E+08	1.56E+09	2.88E+10	7.54E+10
12/2012	4.63E+07	2.16E+09	1.00E+09	1.78E+09	2.81E+10	6.05E+10
01/2013	3.26E+06	1.66E+09	7.72E+08	4.13E+08	7.50E+10	6.74E+10
02/2013	1.78E+07	9.09E+08	3.55E+08	5.51E+08	1.59E+11	5.49E+10
03/2013	3.08E+08	4.06E+08	1.35E+08	9.43E+08	1.04E+11	4.64E+10
04/2013	4.06E+08	1.97E+09	1.46E+09	5.92E+09	1.40E+11	5.54E+10
05/2013	2.02E+07	1.14E+09	1.76E+08	2.39E+08	2.26E+10	3.29E+10
06/2013	1.50E+08	8.74E+08	1.59E+09	3.13E+09	3.86E+10	3.87E+10
07/2013	1.09E+09	2.47E+09	5.20E+09	9.99E+09	3.24E+11	5.72E+11
08/2013	1.51E+08	1.90E+09	7.23E+09	8.15E+09	2.64E+11	4.99E+11
09/2013	9.85E+07	2.29E+09	8.17E+09	5.40E+09	4.08E+11	3.15E+11
10/2013	5.03E+08	3.27E+09	9.07E+09	8.77E+09	2.12E+11	2.67E+11
11/2013	9.08E+07	1.76E+09	1.65E+09	1.14E+09	3.92E+10	2.04E+10
12/2013	3.92E+07	1.66E+09	1.16E+09	8.26E+08	5.06E+10	2.38E+10
01/2014	1.69E+07	1.40E+09	9.84E+08	5.22E+08	3.28E+10	1.47E+10
02/2014	2.41E+07	1.70E+09	9.24E+08	7.70E+08	4.62E+10	1.76E+10
03/2014	1.56E+09	4.68E+09	6.58E+09	3.02E+10	1.80E+11	6.06E+10
04/2014	9.03E+08	3.59E+09	4.61E+09	1.21E+10	9.44E+10	9.68E+10
05/2014	1.32E+08	1.96E+09	8.66E+08	2.60E+09	3.75E+10	2.50E+10
06/2014	3.75E+09	3.59E+09	8.29E+09	9.99E+09	9.72E+10	1.40E+11
07/2014	2.36E+09	3.32E+09	9.98E+09	2.90E+10	2.27E+11	2.24E+11
08/2014	1.02E+09	6.99E+09	1.12E+10	1.60E+10	1.17E+11	5.02E+10
09/2014	1.06E+08	1.44E+09	1.20E+09	3.53E+09	1.85E+10	3.28E+10
10/2014	9.96E+07	1.87E+09	5.37E+09	9.65E+09	1.96E+11	2.13E+11
11/2014	3.48E+07	9.48E+08	1.19E+09	2.02E+09	3.30E+10	4.69E+10
12/2014	4.52E+07	1.30E+09	2.11E+09	4.42E+09	3.27E+10	5.21E+10
01/2015	1.59E+07	5.51E+08	1.24E+09	3.14E+09	4.73E+10	3.51E+10
02/2015	1.65E+07	4.15E+08	1.79E+09	2.89E+09	4.95E+10	2.94E+10
03/2015	5.97E+07	1.01E+09	7.74E+09	1.19E+10	1.55E+11	1.03E+11
04/2015	3.51E+07	6.97E+08	4.47E+09	8.88E+09	1.25E+11	7.68E+10
05/2015	1.29E+07	8.92E+08	1.31E+09	3.40E+09	2.82E+10	4.06E+10
06/2015	2.12E+07	1.60E+09	3.58E+09	4.87E+09	6.49E+10	3.45E+10
07/2015	2.76E+07	2.64E+09	9.09E+09	1.08E+10	1.95E+11	1.03E+11
08/2015	1.62E+07	5.60E+08	5.05E+09	6.92E+09	3.33E+10	4.42E+10
Total 06/11- 08/15	**2.19E+10**	**1.14E+11**	**2.34E+11**	**5.10E+11**	**1.13E+13**	**1.24E+13**

Table III.1. (cont.)

Sampling month	**Monthly flux of particulate Cs-137 in rivers (Bq)**										
	Mano	**Ojimadazeki**	**Matsubara**	**Onahama**	**Tsukidate**	**Nihomatsu**	**Nishikawa**	**Kitamachi**	**Kawamata**	**Senoue**	**Yagita**
10/2012	2.74E+08	6.14E+08	5.42E+08	4.82E+07	1.82E+08	4.46E+09	8.77E+08	2.84E+09	1.20E+08	7.36E+08	4.77E+08
11/2012	8.57E+08	1.15E+09	3.60E+08	3.93E+07	1.34E+09	4.31E+09	7.12E+08	3.08E+09	3.85E+08	1.13E+09	4.02E+08
12/2012	7.14E+08	1.25E+09	1.80E+08	4.05E+07	3.39E+08	1.51E+10	4.56E+08	2.88E+09	8.13E+08	3.46E+09	3.53E+08
01/2013	3.54E+08	1.21E+09	1.25E+08	1.75E+07	1.46E+08	7.90E+09	2.11E+08	7.25E+07	2.45E+08	4.16E+08	7.76E+07
02/2013	5.13E+08	1.04E+09	2.14E+08	1.27E+07	5.50E+08	2.61E+09	5.76E+08	2.57E+08	8.49E+08	7.20E+08	1.55E+08
03/2013	1.14E+09	1.09E+09	4.77E+08	1.33E+07	7.32E+06	1.94E+09	9.55E+07	3.98E+08	7.67E+07	2.62E+09	1.35E+09
04/2013	2.58E+09	1.02E+09	1.63E+09	1.17E+09	2.18E+09	8.49E+10	3.11E+09	1.04E+10	7.79E+08	1.82E+09	6.35E+09
05/2013	5.69E+08	1.09E+09	3.55E+08	2.29E+07	1.44E+08	4.88E+09	4.79E+08	1.15E+09	2.49E+08	1.32E+09	4.40E+08
06/2013	6.72E+08	1.07E+09	8.92E+08	2.59E+07	3.95E+08	3.15E+10	8.91E+08	2.39E+09	5.98E+08	5.77E+08	9.78E+08
07/2013	1.14E+09	2.00E+08	1.95E+09	5.69E+07	3.20E+09	7.10E+10	1.02E+10	3.98E+08	8.25E+09	8.93E+09	9.73E+09
08/2013	9.49E+08	7.26E+08	4.53E+08	5.05E+07	2.42E+09	2.27E+10	1.54E+10	3.73E+09	2.09E+09	2.91E+09	3.31E+09
09/2013	9.46E+08	4.85E+09	2.17E+09	4.79E+08	5.44E+09	3.09E+10	6.14E+09	2.48E+09	1.97E+09	5.42E+09	3.03E+09
10/2013	8.94E+08	3.63E+09	9.83E+08	2.85E+09	1.83E+09	8.45E+09	2.19E+10	5.57E+09	2.03E+09	3.96E+09	3.49E+09
11/2013	3.43E+08	3.09E+08	5.92E+07	1.24E+07	6.47E+08	1.56E+09	2.85E+08	5.45E+08	2.32E+08	1.43E+09	2.28E+08
12/2013	2.47E+08	2.58E+08	4.51E+08	1.10E+07	5.48E+08	3.21E+09	2.32E+08	5.34E+08	3.31E+08	3.29E+09	3.01E+08
01/2014	1.48E+08	9.66E+07	5.25E+08	5.10E+06	4.24E+08	2.65E+08	7.21E+07	4.66E+08	7.80E+07	2.78E+09	1.31E+08
02/2014	3.35E+08	5.24E+08	4.38E+08	1.25E+08	8.12E+08	1.33E+09	1.52E+08	3.56E+09	1.31E+08	1.12E+09	2.28E+08
03/2014	1.27E+09	3.16E+09	3.75E+08	8.27E+07	2.26E+09	2.02E+10	4.44E+09	1.66E+09	5.48E+08	2.77E+09	8.91E+08
04/2014	1.20E+09	2.42E+09	1.65E+09	7.60E+08	1.12E+09	1.19E+10	1.66E+09	4.86E+09	8.05E+08	2.01E+09	1.51E+09
05/2014	2.21E+09	8.46E+08	2.09E+08	1.33E+08	8.57E+09	4.08E+09	2.61E+08	4.21E+09	5.16E+07	9.35E+08	5.48E+08
06/2014	3.63E+09	5.36E+09	6.13E+08	1.13E+09	8.21E+09	1.95E+10	4.21E+09	3.82E+09	4.51E+08	3.01E+09	5.10E+09
07/2014	7.43E+09	4.41E+09	6.43E+08	6.76E+08	6.29E+09	5.37E+10	7.48E+09	7.72E+09	9.59E+08	6.51E+09	9.39E+09
08/2014	1.03E+09	1.49E+09	5.96E+08	1.93E+08	2.05E+10	2.74E+10	4.35E+09	5.38E+09	6.00E+08	1.93E+09	6.25E+09
09/2014	3.28E+08	2.78E+08	4.90E+08	7.01E+07	5.79E+08	1.29E+10	6.53E+08	6.56E+08	1.17E+08	8.53E+08	5.12E+09
10/2014	1.30E+09	3.19E+09	8.86E+08	2.05E+09	2.46E+09	6.94E+10	4.44E+09	3.85E+09	4.61E+08	1.50E+09	1.28E+10
11/2014	1.44E+08	1.41E+08	8.28E+08	6.11E+07	1.13E+09	4.16E+09	1.32E+09	1.37E+08	1.59E+08	7.90E+08	1.69E+09
12/2014	3.14E+08	9.90E+07	4.34E+08	5.61E+07	1.00E+09	2.78E+10	1.97E+09	1.27E+08	1.54E+08	1.26E+09	9.08E+08
01/2015	4.31E+08	4.26E+07	5.87E+08	9.07E+07	4.93E+08	1.09E+10	1.37E+09	6.28E+07	1.16E+08	1.05E+09	1.70E+09
02/2015	6.33E+08	1.01E+08	5.89E+08	9.75E+07	5.63E+07	4.76E+09	1.19E+09	4.16E+07	8.55E+07	9.11E+08	2.50E+09
03/2015	1.16E+09	2.69E+09	2.49E+08	5.10E+08	3.92E+08	1.17E+10	4.75E+09	4.43E+08	3.06E+08	2.72E+09	2.68E+09
04/2015	1.09E+09	9.07E+08	1.35E+08	1.23E+08	2.19E+08	9.60E+09	3.11E+09	2.72E+08	2.19E+08	2.78E+09	2.99E+09
05/2015	4.22E+08	6.78E+08	1.64E+08	8.73E+07	2.50E+07	1.29E+09	7.64E+08	1.31E+08	7.60E+07	1.32E+09	4.58E+09
06/2015	2.98E+08	5.87E+08	2.20E+08	7.34E+07	2.99E+07	3.25E+09	1.33E+09	4.31E+08	6.52E+07	1.16E+09	2.37E+09
07/2015	2.75E+08	8.82E+08	3.75E+08	1.68E+08	7.47E+07	1.54E+10	4.74E+09	6.98E+08	9.95E+07	1.83E+09	4.48E+09
08/2015	7.30E+07	1.11E+09	8.16E+08	1.63E+08	1.05E+08	4.37E+09	3.73E+09	2.05E+08	1.02E+08	1.81E+09	4.83E+09
Total 10/12-08/15	**3.59E+10**	**4.85E+10**	**2.17E+10**	**1.15E+10**	**7.42E+10**	**6.09E+11**	**1.14E+11**	**7.54E+10**	**2.46E+10**	**7.78E+10**	**1.01E+11**

Table III.1 (cont.)

Sampling month	**Monthly flux of particulate Cs-137 in rivers (Bq)**											
	Senoue	**Yagita**	**Kuroiwa**	**Tomita**	**Ota**	**Odaka**	**Asami**	**Tsushima**	**Ukedo**	**Takase**	**Haramachi**	**Akanuma**
10/2012	7.36E+08	4.77E+08	3.91E+10	6.70E+09	1.82E+08	8.09E+07	1.68E+06	1.26E+08	2.49E+09	4.84E+07	1.09E+09	2.80E+08
11/2012	1.13E+09	4.02E+08	2.89E+10	6.10E+09	4.88E+08	1.36E+08	6.20E+06	2.71E+08	4.47E+09	3.80E+08	1.74E+09	2.60E+08
12/2012	3.46E+09	3.53E+08	2.25E+10	2.11E+09	3.77E+08	7.92E+07	1.72E+07	2.41E+08	4.88E+09	4.58E+08	1.33E+09	1.67E+08
01/2013	4.16E+08	7.76E+07	2.81E+10	1.57E+09	3.78E+08	4.59E+07	8.02E+06	3.86E+08	3.33E+09	1.60E+08	7.39E+08	1.25E+08
02/2013	7.20E+08	1.55E+08	4.43E+10	1.19E+10	2.52E+08	3.66E+07	6.23E+06	1.62E+08	2.39E+09	7.57E+07	7.77E+08	1.02E+08
03/2013	2.62E+09	1.35E+09	1.99E+10	1.69E+09	2.94E+08	4.52E+07	1.46E+06	2.23E+08	6.44E+09	2.41E+08	1.24E+09	1.14E+08
04/2013	1.82E+09	6.35E+09	9.07E+10	3.08E+09	4.03E+08	2.01E+08	5.37E+07	6.71E+08	1.61E+10	7.06E+09	8.99E+09	4.46E+08
05/2013	1.32E+09	4.40E+08	1.48E+10	2.65E+09	1.92E+08	5.76E+06	3.87E+06	1.58E+08	2.55E+09	4.59E+08	7.42E+08	1.50E+08
06/2013	5.77E+08	9.78E+08	2.35E+10	6.43E+09	3.74E+08	1.97E+08	6.20E+06	1.58E+08	2.02E+09	2.04E+09	1.86E+09	1.30E+08
07/2013	8.93E+09	9.73E+09	7.43E+11	8.79E+10	3.79E+08	1.80E+08	1.11E+07	2.55E+08	1.12E+10	6.53E+09	1.14E+10	1.10E+09
08/2013	2.91E+09	3.31E+09	4.74E+11	4.90E+09	6.99E+08	6.97E+07	7.88E+06	7.02E+08	3.63E+10	2.35E+09	9.86E+09	3.00E+08
09/2013	5.42E+09	3.03E+09	1.65E+11	1.62E+10	4.73E+08	1.52E+09	4.03E+07	1.52E+09	2.00E+11	1.61E+10	5.73E+10	6.21E+08
10/2013	3.96E+09	3.49E+09	1.53E+11	7.08E+10	6.52E+08	3.01E+09	1.01E+08	2.10E+09	3.98E+10	2.81E+11	8.51E+10	2.46E+08
11/2013	1.43E+09	2.28E+08	5.23E+09	1.73E+09	9.55E+07	1.53E+08	2.33E+07	2.51E+08	4.32E+09	2.21E+09	4.74E+09	2.01E+07
12/2013	3.29E+09	3.01E+08	1.61E+10	2.35E+09	3.57E+07	1.02E+08	2.94E+07	4.52E+08	5.13E+09	3.65E+08	2.23E+09	2.14E+08
01/2014	2.78E+09	1.31E+08	3.40E+09	8.97E+08	2.77E+07	1.44E+08	7.66E+06	3.17E+08	1.78E+09	6.04E+07	1.51E+09	9.78E+07
02/2014	1.12E+09	2.28E+08	9.67E+09	1.40E+09	2.89E+07	3.42E+08	3.44E+07	3.38E+08	4.24E+09	2.58E+08	3.29E+09	2.95E+07
03/2014	2.77E+09	8.91E+08	6.39E+10	9.60E+09	2.64E+08	3.41E+08	9.22E+07	1.34E+09	4.98E+10	4.83E+10	4.31E+10	4.25E+08
04/2014	2.01E+09	1.51E+09	5.77E+10	3.20E+09	1.76E+09	6.43E+08	2.63E+08	1.16E+09	6.18E+10	1.09E+11	3.14E+10	5.72E+08
05/2014	9.35E+08	5.48E+08	1.26E+10	5.37E+09	2.23E+08	3.25E+08	1.70E+08	5.23E+08	5.14E+09	4.06E+08	1.06E+10	4.43E+08
06/2014	3.01E+09	5.10E+09	9.41E+10	1.09E+10	9.20E+08	1.84E+09	3.57E+08	4.49E+09	8.99E+10	8.00E+10	6.49E+10	3.49E+08
07/2014	6.51E+09	9.39E+09	3.01E+11	1.67E+10	6.84E+08	1.52E+09	2.40E+08	2.15E+08	8.22E+10	3.61E+10	3.90E+10	7.77E+08
08/2014	1.93E+09	6.25E+09	1.32E+11	2.33E+09	1.89E+09	2.57E+09	5.32E+08	1.46E+09	4.05E+10	1.76E+10	5.01E+10	7.56E+08
09/2014	8.53E+08	5.12E+09	3.10E+10	6.55E+08	1.51E+09	8.71E+08	2.50E+08	5.29E+08	3.01E+10	5.92E+09	5.74E+09	4.05E+08
10/2014	1.50E+09	1.28E+10	2.39E+11	1.06E+10	7.99E+09	6.32E+09	1.09E+09	3.78E+09	6.85E+10	7.64E+10	2.99E+10	1.29E+09
11/2014	7.90E+08	1.69E+09	1.31E+10	7.43E+08	7.09E+08	6.50E+08	9.58E+07	3.88E+08	1.16E+10	3.07E+09	2.26E+09	2.29E+08
12/2014	1.26E+09	9.08E+08	8.87E+09	6.37E+08	6.36E+08	2.99E+08	1.21E+08	4.31E+08	1.38E+10	2.08E+09	1.60E+09	2.81E+08
01/2015	1.05E+09	1.70E+09	4.50E+09	4.13E+08	4.78E+08	3.36E+08	6.38E+07	1.10E+08	7.44E+09	9.94E+08	1.17E+09	2.38E+08
02/2015	9.11E+08	2.50E+09	4.62E+09	3.12E+08	3.17E+08	4.57E+08	6.26E+07	9.99E+07	7.79E+09	1.20E+09	1.36E+09	2.19E+08
03/2015	2.72E+09	2.68E+09	5.44E+10	5.14E+09	6.12E+08	3.47E+09	1.67E+08	8.92E+08	2.59E+10	2.07E+10	1.31E+10	1.05E+09
04/2015	2.78E+09	2.99E+09	4.07E+10	3.79E+09	5.41E+08	6.90E+08	3.98E+07	5.28E+08	1.26E+10	9.75E+09	5.17E+09	8.30E+08
05/2015	1.32E+09	4.58E+09	1.68E+10	8.86E+08	4.78E+08	4.12E+08	4.18E+08	1.30E+08	5.71E+09	2.99E+09	6.98E+08	5.33E+08
06/2015	1.16E+09	2.37E+09	3.33E+10	2.23E+09	2.92E+08	5.55E+08	6.60E+07	6.45E+07	1.10E+10	2.11E+09	1.30E+09	3.23E+08
07/2015	1.83E+09	4.48E+09	6.12E+10	3.21E+09	8.07E+08	6.88E+08	3.07E+08	2.35E+08	1.90E+10	6.45E+10	3.11E+09	1.32E+09
08/2015	1.81E+09	4.83E+09	6.69E+09	2.71E+09	4.27E+08	5.80E+08	1.35E+08	1.68E+08	9.08E+09	3.13E+09	6.28E+09	3.94E+08
Total 10/12-08/15	**7.78E+10**	**1.01E+11**	**3.06E+12**	**3.08E+11**	**2.59E+10**	**2.89E+10**	**4.83E+09**	**2.49E+10**	**8.99E+11**	**8.03E+11**	**5.05E+11**	**1.48E+10**

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