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No. 2088

# Data on Freshwater Systems and Off-site Decontamination and Remediation Following the Fukushima Daiichi Nuclear Power Plant Accident and Comparison with Global Experience

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# DATA ON FRESHWATER SYSTEMS AND OFF-SITE DECONTAMINATION AND REMEDIATION FOLLOWING THE FUKUSHIMA DAIICHI NUCLEAR POWER PLANT ACCIDENT AND COMPARISON WITH GLOBAL EXPERIENCE

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# DATA ON FRESHWATER SYSTEMS AND OFF-SITE DECONTAMINATION AND REMEDIATION FOLLOWING THE FUKUSHIMA DAIICHI NUCLEAR POWER PLANT ACCIDENT AND COMPARISON WITH GLOBAL EXPERIENCE

INTERNATIONAL ATOMIC ENERGY AGENCY
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## FOREWORD

The 11 March 2011 earthquake off the Pacific coast of Tohoku and the subsequent tsunami resulted in an accident at Tokyo Electric Power Company's Fukushima Daiichi nuclear power plant. The consequence of the accident was the deposition of radioactive contamination in several areas of Japan, including Fukushima Prefecture.

In response to the Fukushima Daiichi 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. Fukushima Prefecture played a key role in planning and implementing countermeasures as well as in providing technical advice to the municipalities.

In December 2012, the IAEA and Fukushima Prefecture signed Practical Arrangements with the objective of defining the framework for cooperation between Fukushima Prefecture and the IAEA to provide broad and extensive assistance to Fukushima Prefecture relating to radiation monitoring and remediation in order to ensure ongoing protection of people and the environment from ionizing radiation resulting from the Fukushima Daiichi accident. The cooperation was designed to complement existing Japanese activities and to provide immediate assistance and support of direct benefit to residents of and visitors to Fukushima Prefecture.

This publication summarizes the studies discussed as part of the cooperation project between Fukushima Prefecture and the IAEA on decontamination and remediation in Fukushima Prefecture that ran from 2013 to 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 Fukushima Daiichi accident with data obtained in studies conducted in other parts of the world. Similarities and differences in observations following the Chernobyl and Fukushima Daiichi accidents are highlighted. This publication is intended to share this work with all IAEA Member States.

The IAEA is grateful to all project participants, to Fukushima Prefecture and to the international experts who contributed to the drafting and review of this publication. The IAEA officer responsible for this publication was J. Brown of the Division of Radiation, Transport and Waste Safety.

CONTENTS

# 1. INTRODUCTION

## 1.1. BACKROUND

As a result of the earthquake off the Tohoku Pacific coast on 11 March 2011, and the resulting tsunami, an accident occurred at the Fukushima Daiichi Nuclear Power Plant (FDNPP) 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 and radionuclide levels in foodstuffs. Levels in environmental media were also monitored to study the behaviour of radionuclides in the environment.

Requirements for the protection of people and the environment in existing exposure situations 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 past activities and events to meet the requirements established in GSR Part 3 [1] are given in IAEA Safety Standards Series No. GSG-15, Remediation Strategy and Process for Areas Affected by Past Activities or Events [2].

To support Member States in the practical management of areas affected by past activities, the IAEA has published technical reports (see Refs [3-6]) describing decontamination and remediation techniques and their effectiveness in reducing activity and radiation levels in the environment. Reference [7] provides a comprehensive description of on-site and off-site recovery efforts implemented after the Fukushima Daiichi Nuclear Power Plant accident (hereinafter referred to as ‘FDNPP accident’). Reference [8] summarizes the experience gained and the lessons learned from decommissioning and remediation projects implemented in various Member States after a nuclear accident.

In December 2012, the IAEA and the Fukushima 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 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 the IAEA has provided assistance to the Fukushima Prefecture can be summarized as follows:

- Research and studies on radiation monitoring in terrestrial and aquatic environments, including application of environmental mapping technology by using uncrewed aerial vehicles and long term monitoring of radioactive material;
- 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 FDNPP 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 Fukushima Prefecture based on international experience and best practices. International experts and IAEA staff provided technical advice based on the 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.

Some of the data summarized in this publication have been analysed within Ref. [9]. Results of radioecological studies carried out in Japan after the FDNPP 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. OBJECTIVE

The objective of this publication is to provide a compilation and analysis of the radioecological information obtained during the Fukushima Prefecture's cooperative project with the IAEA between 2013 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, particularly in freshwater systems, and the effectiveness of decontamination and remediation after the accident.

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 systems following short term deposition on catchment areas;
- Estimation of the importance of surface runoff for the movement of radiocaesium in catchment areas;
- Evaluation of the effectiveness and persistence of remediation measures in freshwater systems;
- 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 interested parties.

## 1.3. SCOPE

The topics covered in the report are:

- The behaviour of $^{137}$Cs in freshwater systems, including time-trends of radiocaesium in water and suspended and bottom sediments;
- Loss of $^{137}$Cs from catchments with surface runoff;
- Remediation activities and their effectiveness in freshwater systems 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 the above areas gained during 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 Fukushima Prefecture on environmental transfer data from Japan after the release of radionuclides to the environment from the FDNPP accident with IAEA Member States. The information compiled and summarized in this report complements 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]).

## 1.4. STRUCTURE

A brief overview of the behaviour of radiocaesium in the environment is given in Section 2. Section 3 describes the behaviour of radiocaesium in the aquatic environment in the Fukushima Prefecture and compares the results with the worldwide experience in this field. Section 4 summarizes Japanese and worldwide experience collected during decontamination work in freshwater systems. Section 5 focuses on the abundance and characteristics of CsMPs released from the FDNPP during the accident. Section 6 compares the success of decontamination work in residential areas of the Fukushima Prefecture with worldwide experience. Section 7 highlights some aspects of interaction with the public after the FDNPP accident, and Section 8 summarizes the main findings of this publication.

This publication 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 to 2021; and Appendix III presents the flux of $^{137}$Cs in rivers of the Fukushima Prefecture. Appendix IV describes a suggested matrix that can be used to define a structure for the compilation of data for the topics covered in this report.

## 2. BEHAVIOUR OF RADIOCAESIUM IN THE ENVIRONMENT

During the FDNPP accident, a wide spectrum of radionuclides was released. Most of them were short lived, so they decayed away within weeks or months. In the longer term, the most important radionuclides are $^{134}Cs$ and $^{137}Cs$ due to their longevity in the environment and contribution to exposures to the public. 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 ratio $^{134}Cs/^{137}Cs$ will drop to about 0.017 by March 2024.

The deposition of radiocaesium in the Fukushima Prefecture was heterogeneous, with the most affected areas being in the north-west of the FDNPP (Fig. 1). This is a mountainous area, it is covered mainly by forests, and where there are many freshwater water systems, 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, the routine operation of nuclear facilities and from 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, the 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 systems, 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. Caesium is taken up into fish and other biota [12], in particular in waters with low potassium concentrations, as was observed, for example, after the Chornobyl accident [10].

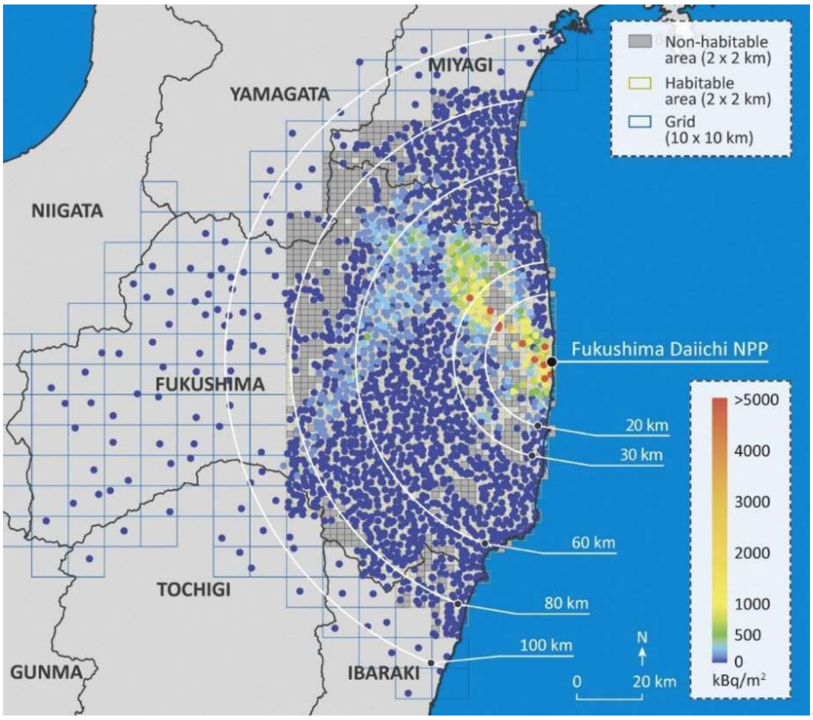


*FIG. 1. Deposition of $^{137}Cs$ in the Fukushima Prefecture as of 14 June 2011 (reproduced from Ref. [14]).*

# 3. RADIOCAESIUM IN FRESHWATER SYSTEMS

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

## 3.1. TRANSFER PROCESSES

A scheme of the transport of caesium in a freshwater system is shown in Fig. 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 runoff water is the result of a complex interaction of land use (e.g. 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 might be very low, whereas it might increase by orders of magnitude during high rainfall events. Then, rivers might overflow and areas within the catchment might become flooded and contaminated suspended matter carried with the water might 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 FDNPP accident in 2011. The monitoring programmes 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 (primarily potassium, calcium, magnesium, ammonium);
  - Concentration of suspended sediments.

Thirty monitoring stations were installed (Fig. 3) along the Abukuma River and on rivers draining coastal catchments to conduct the monitoring activities.

## 3.2. RADIOCAESIUM IN RIVER WATER

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, such as lakes and reservoirs, and in rivers with low flow rates, suspended sediments quickly deposit to the bottom sediments.

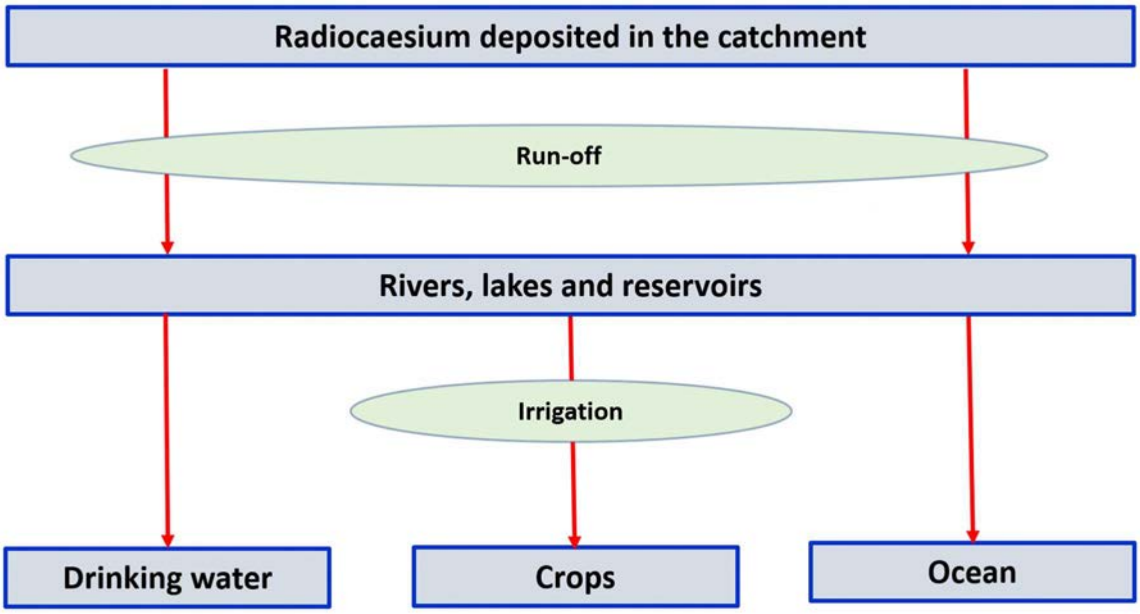


*FIG. 2. Scheme of the transport of radiocaesium from the catchment to the ocean (red arrows indicate the transport between compartments).*

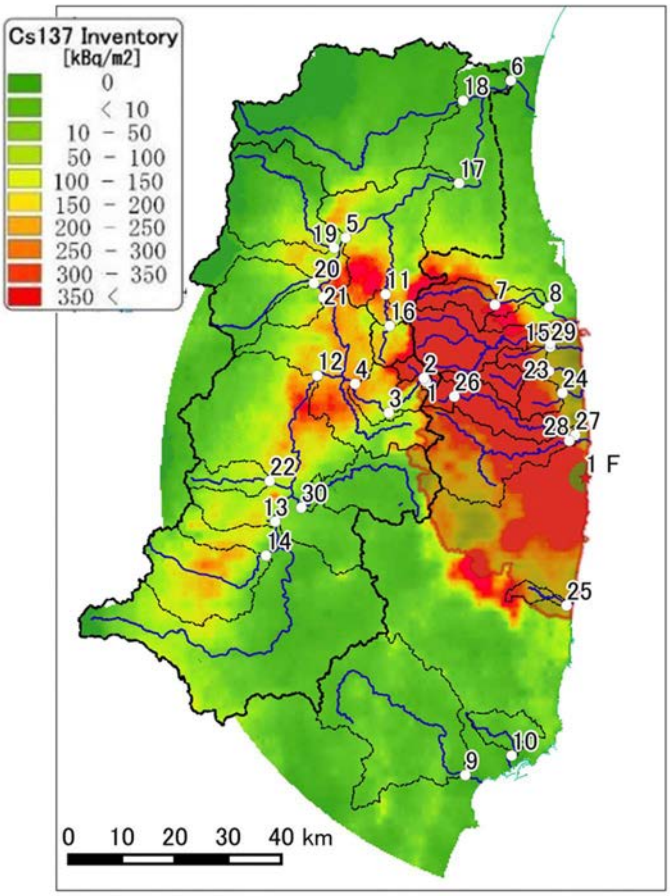


*FIG. 3. Map of $^{137}$Cs-deposition calculated for 2 July 2011. Red shaded areas indicate the original evacuation zone. The numbers in the map correspond to the sites listed in Table 12. (Reproduced from Ref. [15] with permission).*

### 3.2.1. Particulate and dissolved radiocaesium

Figure 4 shows the absolute and normalized $^{137}Cs$ activity concentration in suspended sediments, and Fig. 5 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 one to two orders of magnitude; 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. There is less variation in the normalized concentration of suspended sediments. The underlying data for Fig. 4 for the activity concentration of $^{137}Cs$ in suspended sediments from 2011 to 2021 [16] are summarized in Appendix II.

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 (WHO) [18] recommended quality criterion for $^{137}Cs$ in drinking water of 10 Bq/L; this level is marked in Fig. 5 (top). The underlying data for Fig. 4 for the activity concentration of dissolved $^{137}Cs$ in river water from 2017 to 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] such as 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 2012–2021 are summarized in Table 1. The concentrations of particulate $^{137}Cs$ decline slightly slower, and the variation of half-lives is lower 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 in 2011–2021 is presented in Fig. 6. 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 years for the Ukedo River and 2.2 years for the Ota River. The values are in the same range as given in Table 1.

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

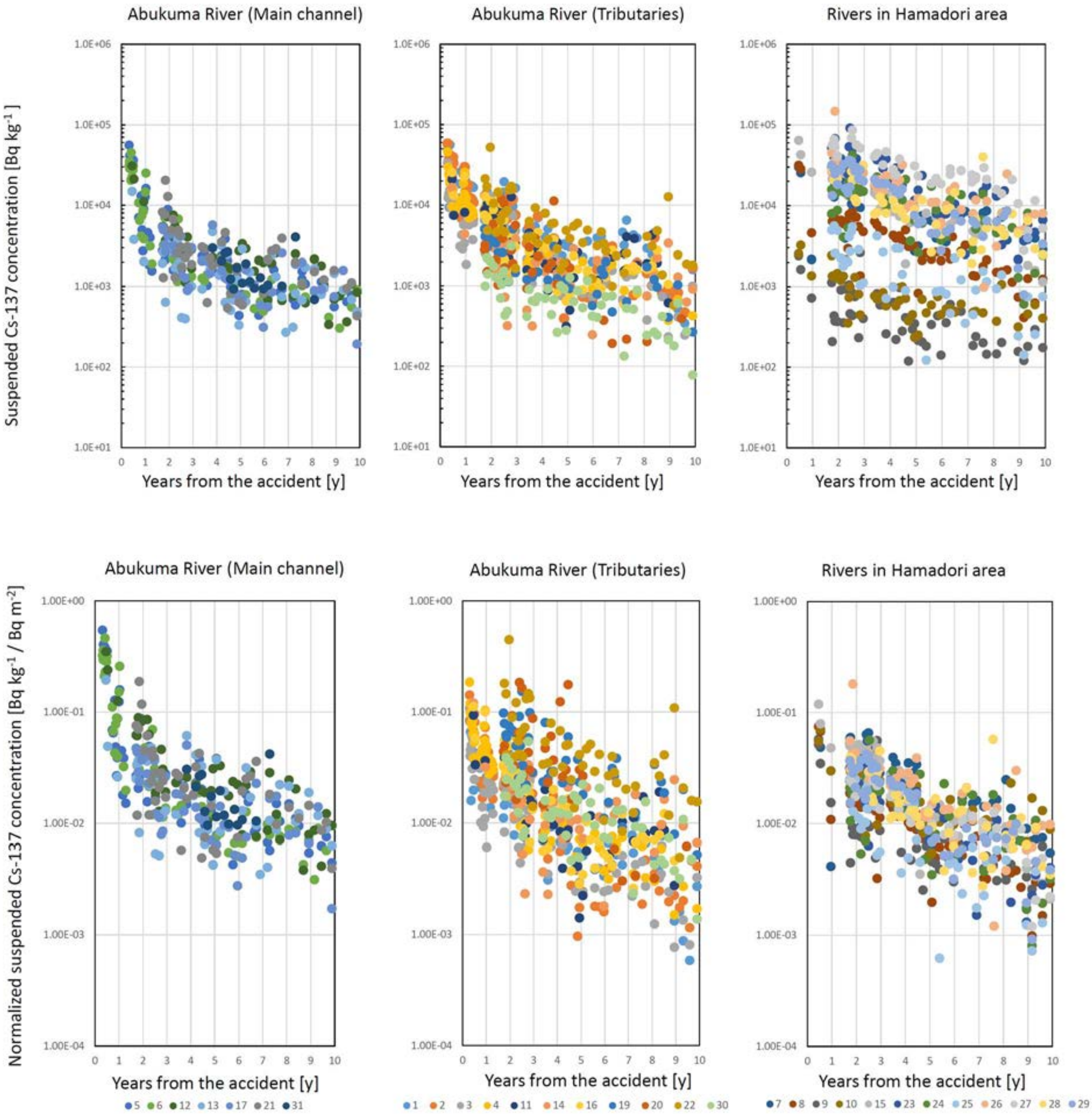


*FIG. 4. Absolute (top) and normalized (bottom) activity concentration of $^{137}Cs$ in suspended sediments in water of rivers of the Fukushima Prefecture from 2011 to 2021 (reproduced from Ref. [16] with permission).*

*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.*

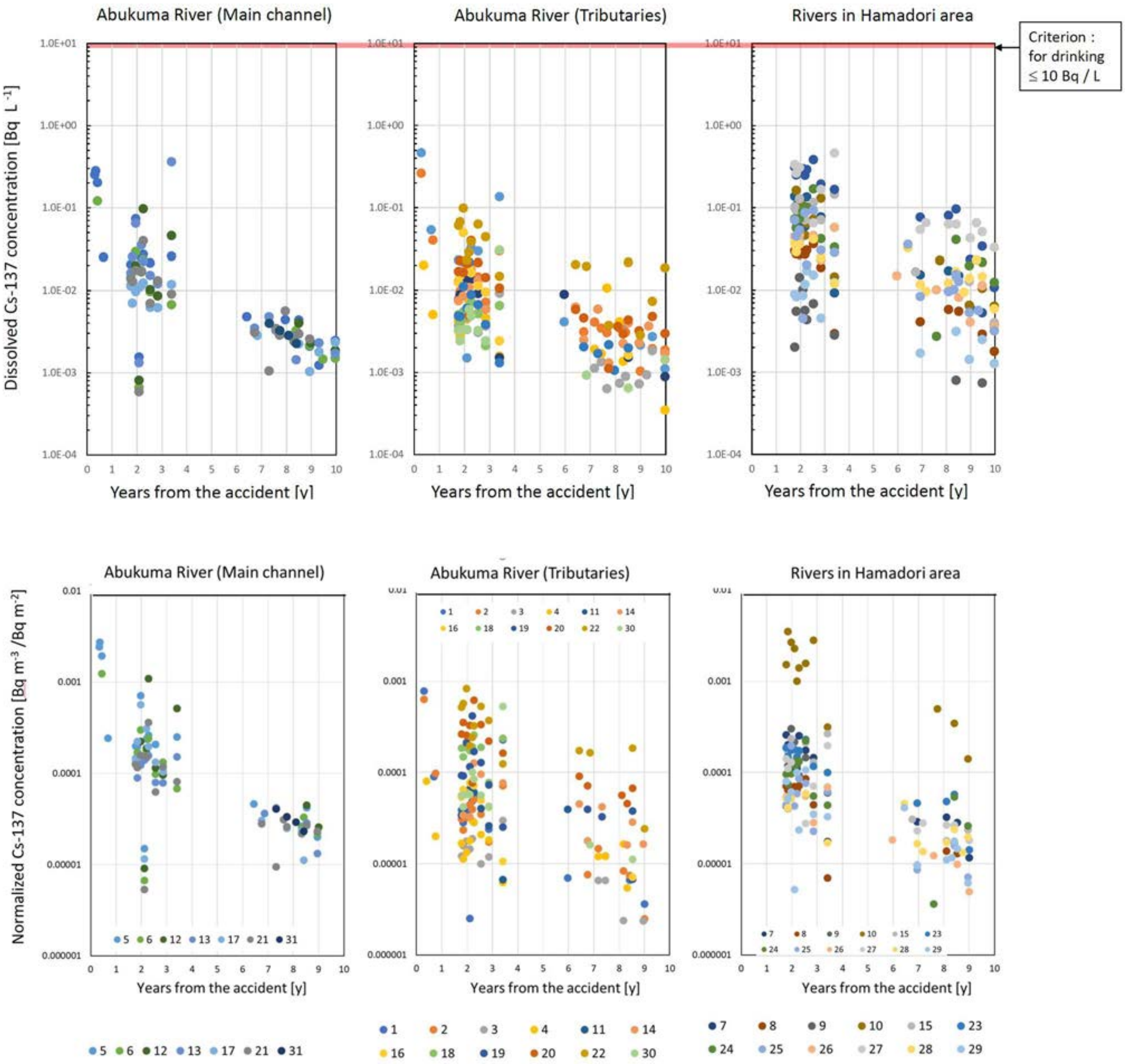


*FIG. 5. Absolute (top) and normalized (bottom) activity concentration of dissolved $^{137}Cs$ in water of rivers of the Fukushima Prefecture from 2011 to 2021 (reproduced from Ref. [17] with permission). The red line in the upper figure marks the WHO guidance level of 10 Bq/L for $^{137}Cs$ in drinking water [18].*

*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.*

TABLE 1. 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) |

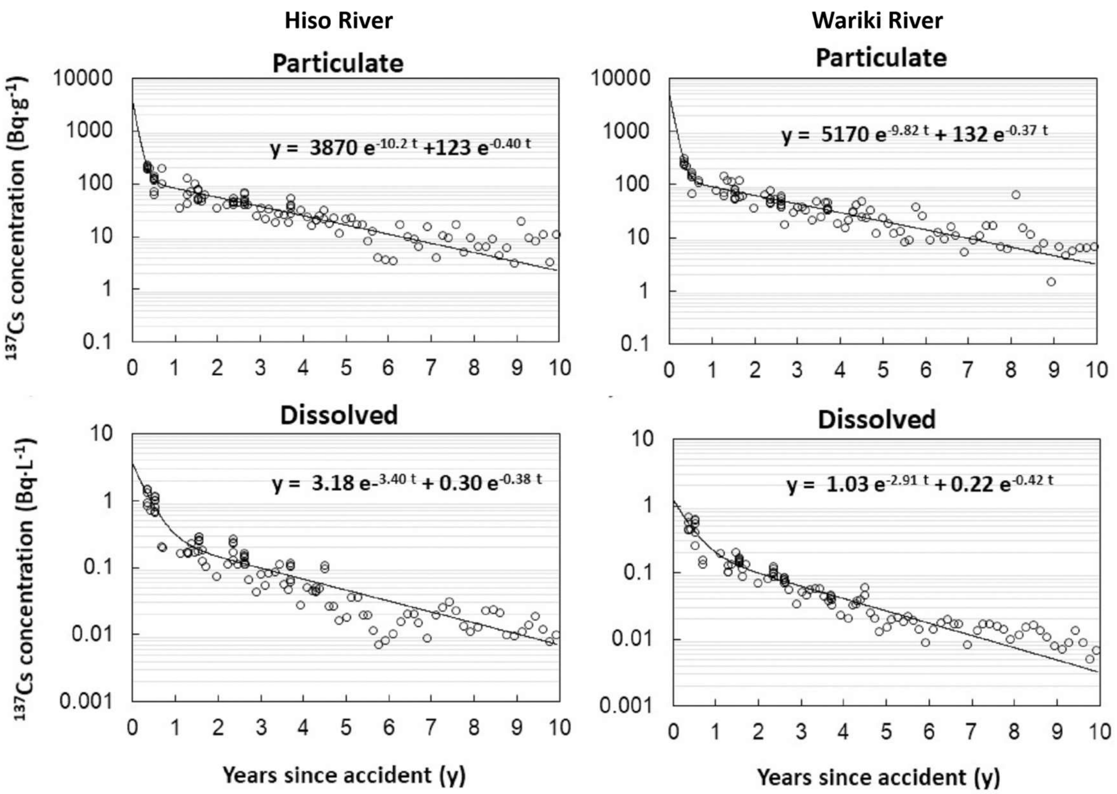


*FIG. 6. Activity concentration of particulate and dissolved $^{137}$Cs from 2011 to 2021 in the Hiso and the Wariki River. Image credit: Fukushima Prefecture (reproduced from Ref. [20] with permission). (Please note: Some circles are on top of each other due to datapoints (open circles) being on top of one another and subsequently look like filled circles.).*

The values in Table 1 for the effective half-lives for $^{137}$Cs in river water are somewhat shorter; however, the observation period in Table 1 is from 2012 to 2021 [15–17, 21], whereas the observation period is 2015–2018 in Ref. [19]. Therefore, it is important not to overemphasize the differences.

### 3.2.2. Leaching of Cs-137 from litter and concentrations of dissolved Cs-137 in runoff 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]. The authors 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 (ratio of dissolved $^{137}$Cs in river water and the average $^{137}$Cs-deposition in the catchment area [m²/L]) in 66 rivers of East Japan were determined. It was found that the normalized concentrations of dissolved $^{137}$Cs decreased with increasing coverage of forest in the catchment areas, whereas they 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)[2] [22]. The topographical wetness index is high for flat areas, because runoff is low, and the periods of wetted surfaces are longer than on slopes. Forested areas are mainly on slopes and therefore have a lower topographical wetness index; 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 was studied by Sakakibara et al [23], the key findings are:

- The amount of $^{137}$Cs leached from litter increased with increasing contact area and the contact time between the litter and rainwater.
- The concentration of dissolved $^{137}$Cs in runoff water increased with increasing amount of rainfall, which also increased the contact area and the contact time between the 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 runoff 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 Figs 4, 5 and 6 show, the by far dominating fraction of $^{137}$Cs in river water is bound to suspended sediments.

### 3.2.3. Dynamic of Cs-137 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 runoff water was approximated by exponential functions with one or two components. The periods of the first 200 days after the FDNPP accident 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 2).

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

TABLE 2. 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 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 runoff water was bound to suspended sediments. The concentration of this fraction varied widely with reported $T_{eff}$ values ranging from 1.6–22 years.

In general, the decline of $^{137}$Cs in runoff 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.

## 3.3. RADIOCAESIUM OF CAESIUM-137 IN SUSPENDED SEDIMENTS

There are a number of environmental processes that influence the relationship between radiocaesium in river water and suspended sediments; these are discussed in this Section.

### 3.3.1. 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 in water and in suspended sediments; and (iii) the $^{137}Cs$ and total organic carbon 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[3] 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 $^{137}Cs$, total organic carbon and the $\delta^{13}C$-signature[4] 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 Fig. 7. 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;
- The $\delta^{13}C$-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.

### 3.3.2. Origin of suspended sediments in rivers during high water periods

The $\delta^{13}C$-signatures, the total organic carbon concentration in water and the $^{137}Cs$ activity concentration in suspended sediments were used to determine the source of carbon in a sample. The $\delta^{13}C$-signatures in different media and forest soil samples indicate the origin of the increased amounts of suspended matter in river water. Table 3 summarizes the $\delta^{13}C$-signatures, the $^{137}Cs$ concentrations and the total organic carbon concentrations in various samples in the study site. The $\delta^{13}C$-signatures for material from the river vary from -25.4 to -26.4 ‰, whereas the $\delta^{13}C$-signatures in forest soil and litter varies from -26.4 to -30.0 ‰. This means, there is a clear difference of the $\delta^{13}C$-signatures among river sediments, riverbank soil, forest soil and forest litter.

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

[4] $^{13}C$ is a natural stable carbon isotope; about 1.1% of the global carbon is $^{13}C$. The $\delta^{13}C$ signature quantifies the deviation of the ratio of $^{13}C/^{12}C$ from Vienna PeeDee Belemnite (VPDB) standard [28] in an environmental sample in permille. The $\delta^{13}C$ signature is calculated from the concentrations of $^{13}C$ and $^{12}C$ in the samples and in the VPDB standard according to the following equation:

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

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.

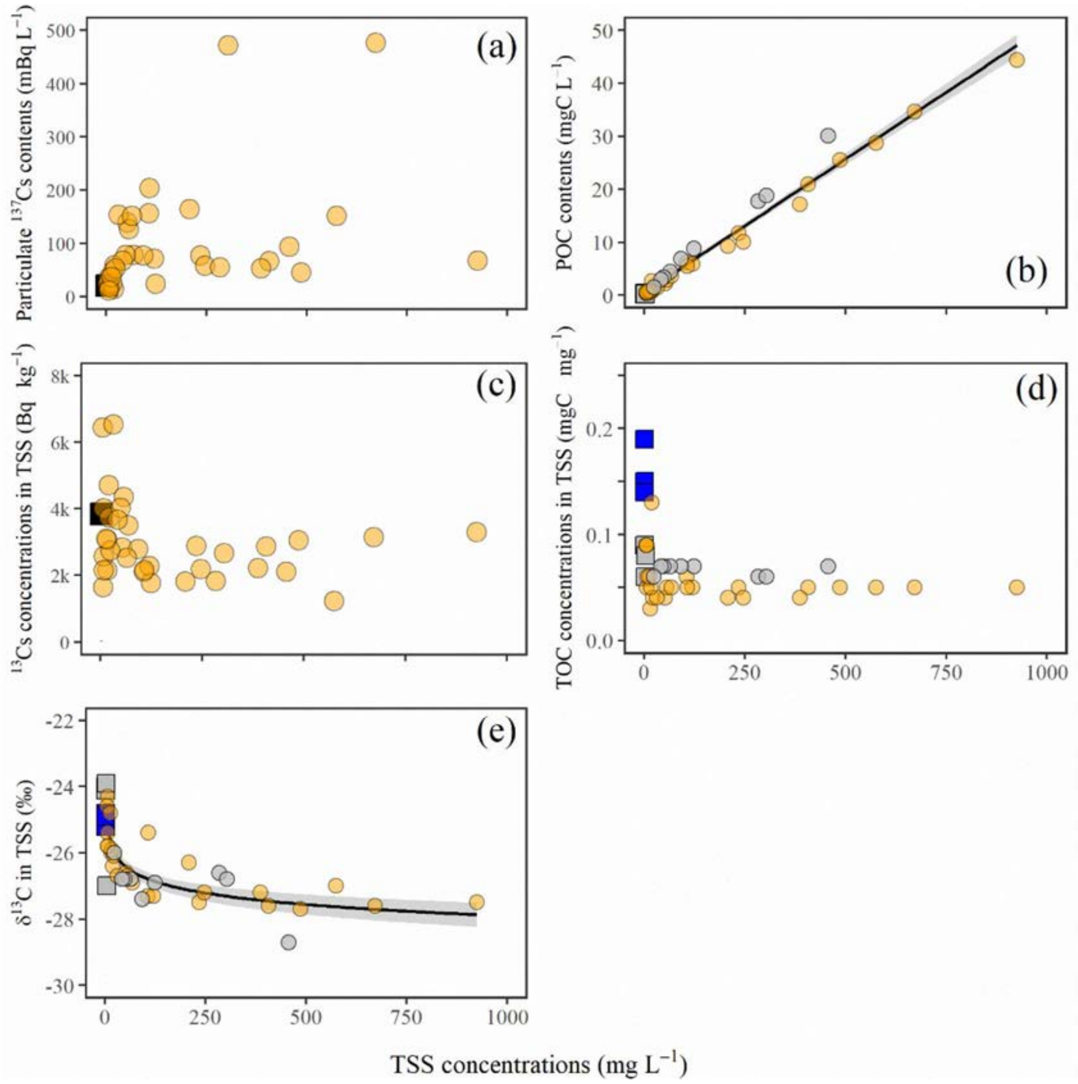


*FIG. 7. Dependence of particulate $^{137}Cs$, particulate organic matter (POC), total organic carbon (TOC) and $\delta^{13}C$ on the concentration of total suspended sediment (TSS) in water. The average value and standard deviation under the base-TSS-load conditions (black squares) and all the data measured under high-TSS load conditions (orange circles) are shown. For particulate organic matter, total organic carbon, and $\delta^{13}C$, 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-TSS-load conditions 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) $\delta^{13}C$ values in TSS. The shaded areas represent the 95% confidence intervals. (Reproduced from Ref. [27] with permission).*

TABLE 3. $\delta^{13}$C-SIGNATURES, $^{137}$CS ACTIVITY CONCENTRATION AND TOTAL ORGANIC CARBON FOR RIVER AND FOREST SAMPLES [27]

| **Material** | **$\delta^{13}$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 |

The decline of the $\delta^{13}C$ signature with increasing concentrations of suspended sediments 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 suspended sediments increases with increasing concentrations of suspended sediments in river water. A simulation of the different contributors to suspended sediments confirms this hypothesis:

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

### 3.3.3. Normalized Cs-137 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.

The time dependence of the activity concentrations was approximated by exponential functions with two components. The results are shown in Fig. 8. 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: $C_1'(t) = a_1 \cdot e^{-\lambda_1 \cdot t}$ (1);
— For the period April 2012 to August 2015: $C_2'(t) = a_2 \cdot e^{-\lambda_2 \cdot t}$ (2),

where $a_1$ and $a_2$ are fitting parameters for period 1 and 2, respectively, and $\lambda_1$ and $\lambda_2$ 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 4 ($T_{eff,n}$ corresponds to $\lambda_n$ in Eqs (1) and (2) according to: $T_{eff,n} = \ln2/\lambda_n$). 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 and it is equivalent to half-lives of 1.4 to 2.7 years.

Table 4 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.

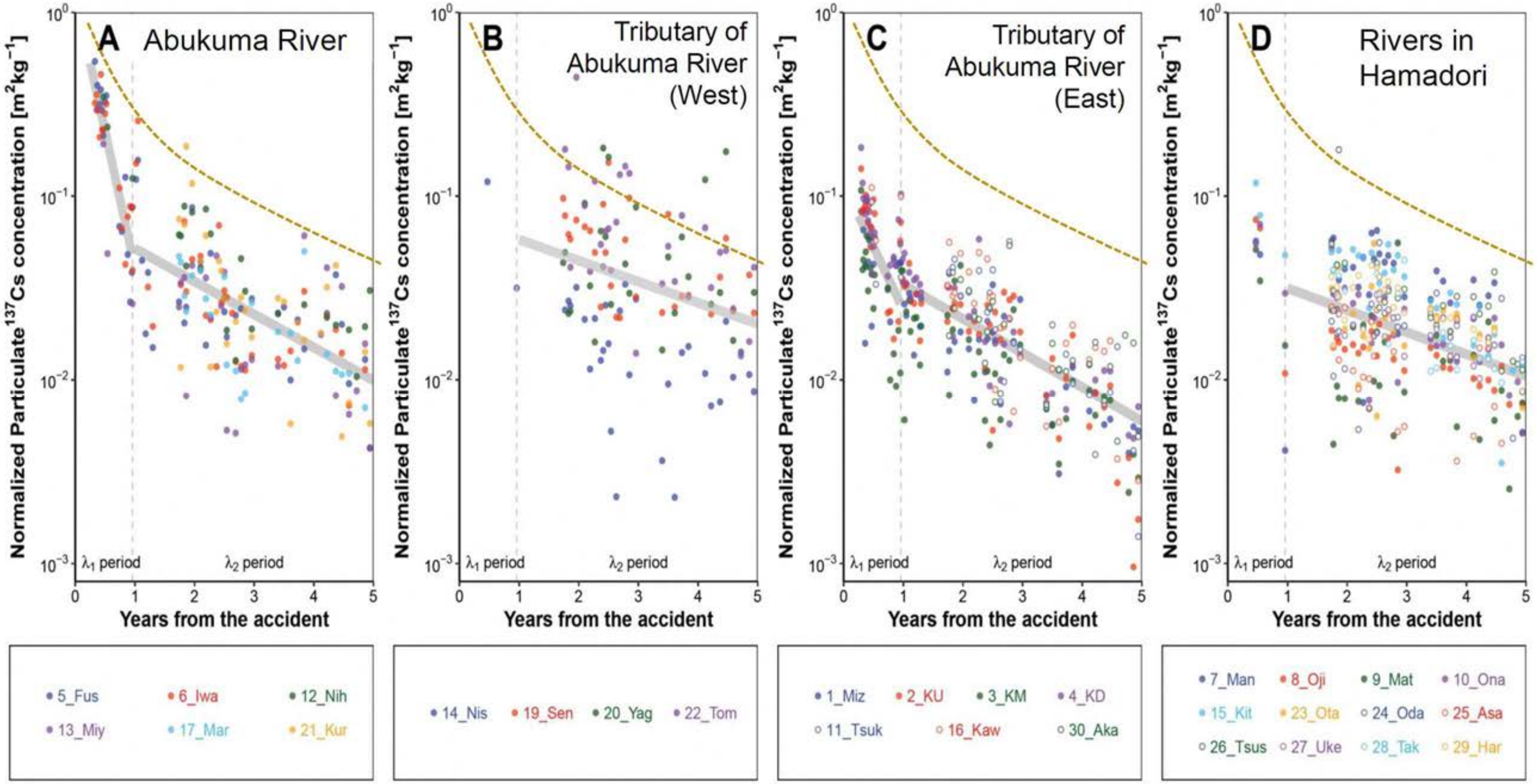


*FIG. 8. Time dependence of particulate $^{137}Cs$ in river water normalized to the deposition density in the related catchments for rivers of: (A) Abukuma mainstream; (B) Abukuma tributaries (West); (C) Abukuma tributaries (East); and (D) coastal catchments (Hamadori district). In plot C, sites 1_Miz and 2_KU were excluded from the analysis due to ongoing decontamination activities (reproduced from Ref. [15] with permission). The underlying data on the $^{137}Cs$ activity concentrations in suspended sediments for Fig. 8 are summarized in Appendix II.*

TABLE 4. 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 (REPRODUCED FROM REF. [15] WITH PERMISSION); THE MEASUREMENTS FOR SITES 7–30 STARTED IN APRIL 2012

| 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 |

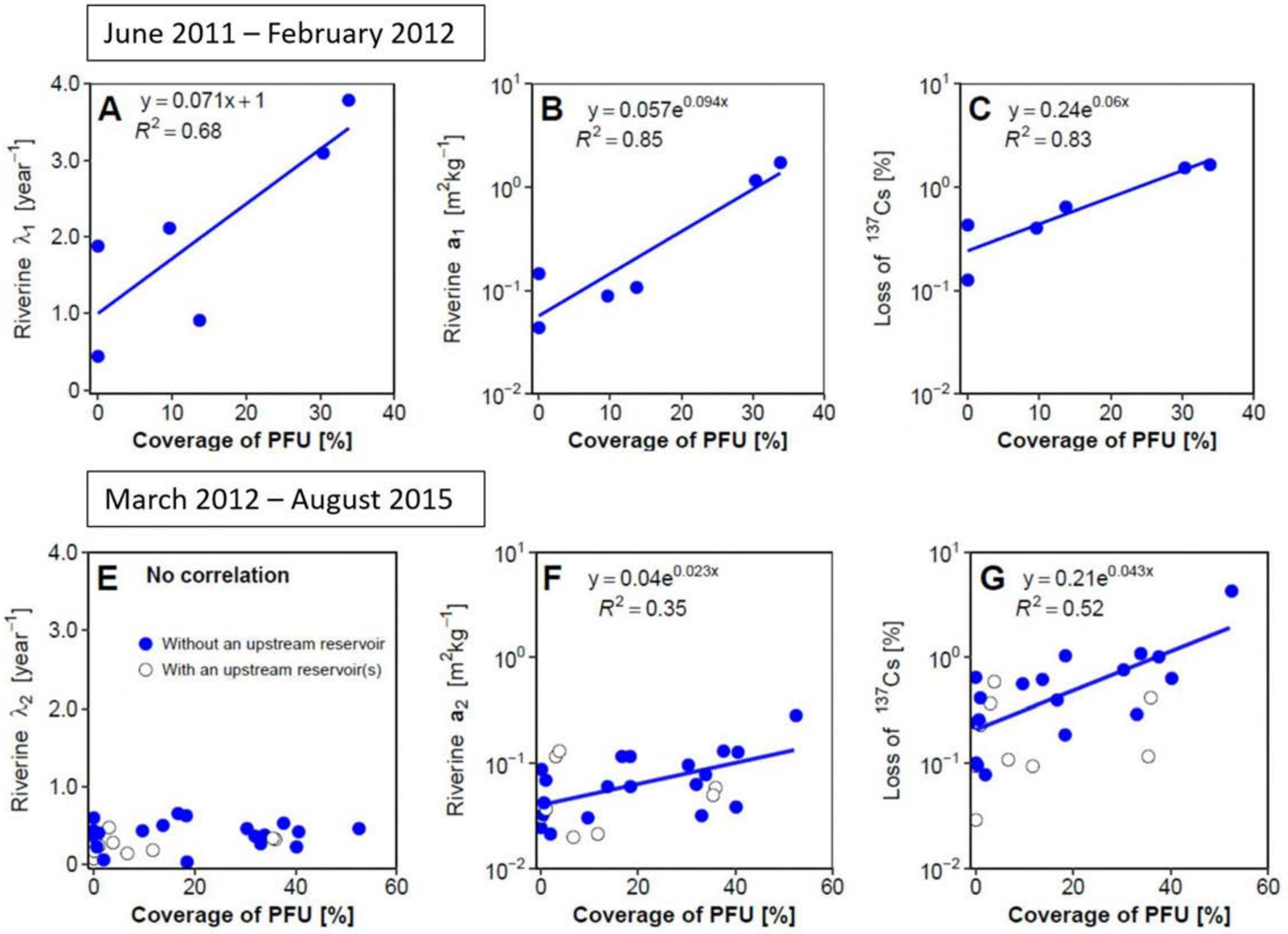


*FIG. 9. Relationship between the coverage of the catchment with paddies, farmland and urban (PFU) areas and the scaling factor a, the decline rate λ of the normalized $^{137}$Cs-activity concentration in suspended sediments, and the total loss of $^{137}$Cs from the catchment with surface runoff. (Reproduced from Ref. [15] with permission).*

### 3.3.4. Land-use and Cs-137-loss with surface runoff

Additionally, in the Upper Kuchibuto catchment, the relationship of the land use and the loss of $^{137}Cs$ with surface runoff was studied [15]. The land use was classified into forest areas – which are thought to have low runoff — and areas with paddies, farmland and urban (PFU) use with a higher runoff. Results are shown in Fig. 9. Since immediately after the FDNPP accident the loss of $^{137}Cs$ activity with surface runoff is more pronounced, the periods June 2011 to February 2012 and March 2012 onwards are considered separately.

The relationships of the coverage of the catchment with PFU with the following parameters have been plotted in Fig. 9 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 (Eqs (1) and (2)) increase with increasing PFU coverage;
- The scaling factors a (Eqs (1) and (2)) increase with increasing PFU coverage;
- The total loss of $^{137}Cs$ from the catchment increases with increasing PFU coverage.

The data clearly indicate that surface runoff 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 (Fig. 10) for the Iwanuma catchment [15]. It needs to be noted that the first 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 5). 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 $^{137}Cs$ activity concentrations in soils and sediments.

### 3.3.5. Flux of Cs-137 with suspended sediments

For the monitoring stations in Table 5, 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 runoff 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 such as flowrate and turbidity;
- Precipitation;
- Topographical data including elevation and land use data.

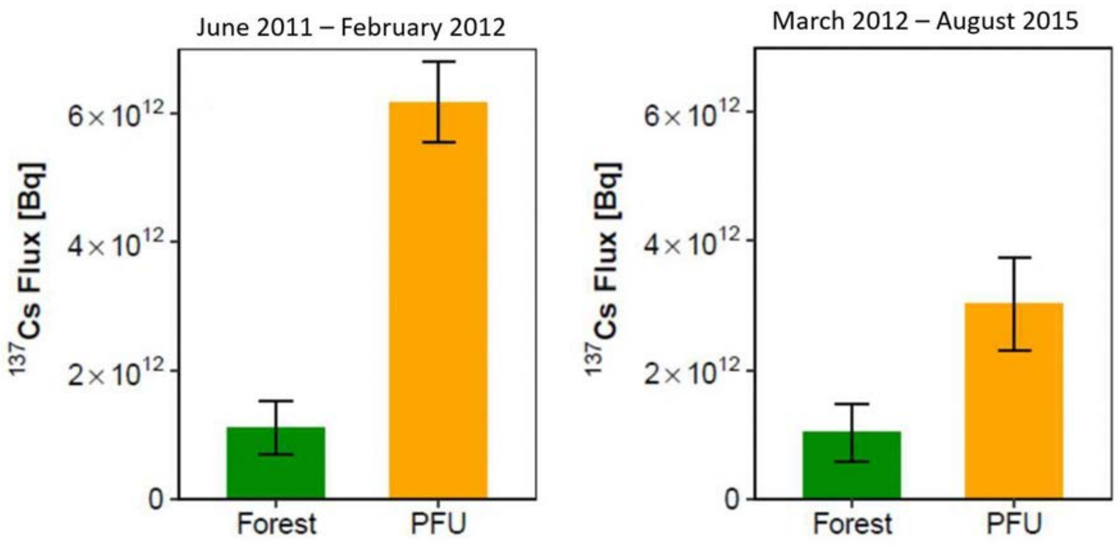


*FIG. 10. Flux of particulate $^{137}$Cs from forests and PFU from observed in the catchment Iwanuma (Forest: 62%, PFU 30%). (Reproduced from Ref. [15] with permission).*

TABLE 5. CHARACTERISTICS OF THE CATCHMENTS INCLUDED IN THE STUDY ON THE LOSS OF $^{137}$CS (REPRODUCED FROM REF. [15] WITH PERMISSION)

| Site name | Catchment area (km²) | Average deposition (kBq/m²) | 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.

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 5. The underlying data for Table 5 are summarized in Appendix III.

In general, the losses of $^{137}Cs$ activity from the catchments due to runoff and river transport are low. In the first year, the loss varies 0.13–1.7%, and 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 runoff. More than 95% of the $^{137}Cs$ is lost in particulate form.

## 3.4. 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[5] 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 Fig. 11, 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 and 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.

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

In this section, a comparison of the dynamics of radiocaesium in rivers is made between observations in the Prefecture after the FDNPP accident and international experience.

### 3.5.1. Effective half-lives of Cs-137 in river water

Following the accident in the Chornobyl Nuclear Power Plant in 1986, freshwater systems 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, the size of the water body, precipitation, rainfall intensity, slope and land use.

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[5] The TODAM model (time-dependent, one-dimensional degradation and migration) is presented in Ref. [29]. This model has been applied in many countries to simulate the transport of radionuclides in freshwater systems, for example, in the framework of remediation projects in Hanford (Washington, USA), Chornobyl (Ukraine) and Mayak (Russian Federation).

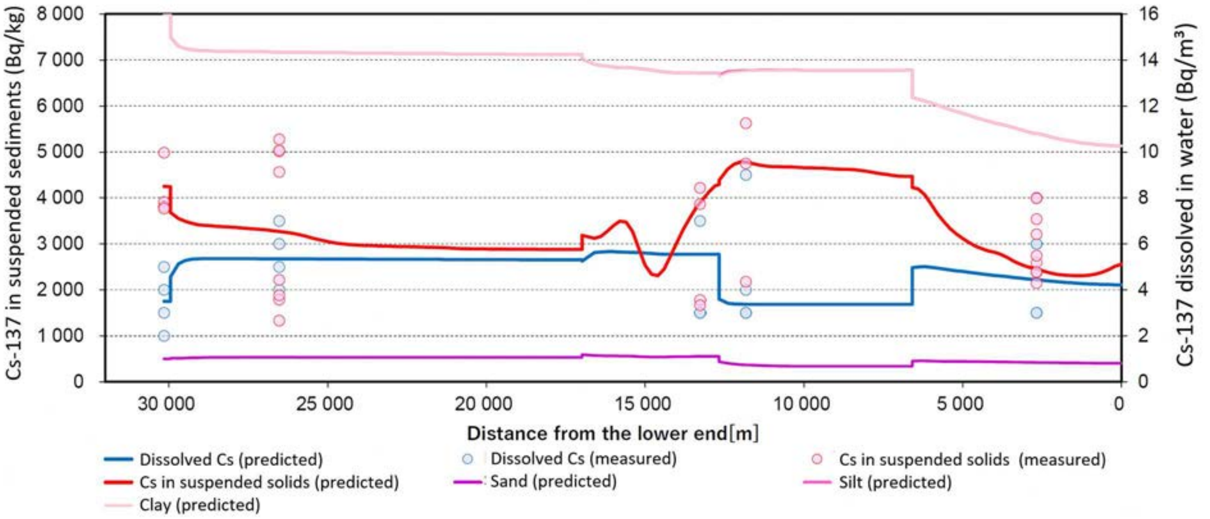


*FIG. 11. Comparison of measured concentrations for particulate and dissolved $^{137}$Cs in the Hirose River with simulations using the TODAM model.*

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:

$$C_w(t) = C_0 \cdot \sum_1^n a_n \cdot e^{-\lambda_n \cdot t} \quad (3)$$

$$C'_w(t) = \frac{C_0}{D_0} \cdot \sum_1^n a_n \cdot e^{-\lambda_n \cdot t} \quad (4)$$

where:

$C_w(t)$ is the time-dependent activity concentration in sediments (Bq/kg) or water (Bq/L);
$C'_w(t)$ is the time-dependent normalized activity concentration in sediments/water ($m^2$/kg or $m^2$/L);
$C_0$ is the initial concentration in sediments (Bq/kg) or water (Bq/L);
$D_0$ is the initial average deposition in the catchment (Bq/$m^2$);
$A_n$ is the weighting factor for the exponential function n;
$\lambda_n$ 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 (3) and (4), which reflect global experience, as well as those determined in studies conducted in the Fukushima Prefecture after 2011, are compiled in Table 12 (see Appendix I, with all underlying references). However, not all parameters included in Eqs (3) and (4) 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 three 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 12 (Appendix I), the following trends can be extracted:

(a) General aspects.

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

(ii) Most data are for suspended sediments. However, the effective half-lives observed for particulate and dissolved $^{137}Cs$ are in the same range.

(iii) 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.

(b) Initial decline.

(i) Initially, concentrations in water decrease rapidly, but 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 the 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 a half-life of 1.6 y was observed.

(ii) The results achieved in the Fukushima Prefecture agree well with the global experience.

(c) Decline within an observation period of 5–15 years.

(i) 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. Forty-two values were in the range of 1.1–4.6 years.

(ii) The results from the Prefecture agree very well with the effective half-lives observed in Ukraine, Russia, and Finland.

(d) Long term decline.

(i) If the observation period is long enough, in some cases a third phase can be identified. However, quantifying a third decline component involves 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.

(ii) 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.

### 3.5.2. Loss of Cs-137 from catchments

As was the case for the releases during the accident in the 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 runoff processes as function of time. In agreement with the studies carried out in the Fukushima Prefecture, the runoff depends on specific circumstances such as the characteristics of the catchment, the radionuclide and the quantity considered (i.e. runoff of dissolved or particle-bound radionuclides, total runoff). The transfer function consists of two components:

$$f(t) = f_1 \cdot \lambda_1 \cdot \exp\left[-(\lambda_1 + \lambda_r) \cdot t\right] + f_2 \cdot \lambda_2 \cdot \exp\left[-(\lambda_2 + \lambda_r) \cdot t\right] \quad (5)$$

$$f_1 + f_2 = 1 \quad (6)$$

where:

$f_l$ is the fraction of activity that is available for short term (rapid) runoff;
$f_2$ is the fraction of activity deposited which is subject to long term runoff;
$\lambda_1$, $\lambda_2$, $\lambda_r$ are the loss rates for the short term and the long term components of runoff and the physical decay respectively ($a^{-1}$).

The parameters $f_l$ and $f_2$ and the loss rates $\lambda_l$ and $\lambda_2$ have been determined from wash-off experiments and observations in the field.

Regarding total $^{137}Cs$-runoff, the parameter $f_l$ 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, a value for $f_l$ of the order of one percent is given as a typical estimate for radiocaesium.

The loss rate for short term wash-off $\lambda_l$ 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 runoff is much lower. The ranges for $\lambda_2$ for runoff 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 runoff is very low by nature. Regarding the total loss due to runoff, the $\lambda_2$ values for $^{137}Cs$ cover a wide range from 0.00004–0.01 $a^{-1}$. For catchment areas, $\lambda_2$ values of less than 1% are given as a typical estimate for radiocaesium [31]. The upper limit of $\lambda_2$ of 0.01 $a^{-1}$ is lower than the activity loss due to physical decay rate $\lambda_r$ of 0.023 $a^{-1}$, namely, 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.

# 4. EXPERIENCE GAINED DURING DECONTAMINATION OF FRESHWATER SYSTEMS

Since the early 1950s, experience has been gained worldwide in the management of contaminated rivers. This Section describes the experience in the Fukushima Prefecture of the impact of decontamination of river catchments, riverbeds and riverbanks. A brief summary of world-wide experiences is given.

## 4.1. EFFECT OF DECONTAMINATION ACTIVITIES ON RIVERS AND CATCHMENTS IN FUKUSHIMA PREFECTURE

In the upper part of the Kuchibuto River, from March 2013 to December 2015, a decontamination project, as part of the environmental remediation process was implemented on an area of 1600 ha. The area comprises forestland (730 ha) and agricultural land (610 ha), with 71 ha covered by roads and the rest used for residential purposes. The decontamination work mainly comprised 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 main mechanism for radiocaesium to be transferred from the catchment area to rivers is via runoff water containing sediments to which Cs is attached (see Section 3.1). The loss of suspended sediments from the catchment before, during and after the decontamination work is shown in Fig. 12. The 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 [32].

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 Fig. 13. The monthly losses from runoff were highest immediately after 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 in September 2016 that caused widespread flooding due to heavy rains. This is reflected in an increase in monthly $^{137}$Cs losses at the times of the thyphoons. After decontamination was completed, $^{137}$Cs losses decreased.

During the decontamination work, the total loss of $^{137}$Cs from the catchment due to surface runoff is of the order of 0.03% per month and does not contribute significantly to the decrease of the total $^{137}$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 was considerable whereas other parts it was not affected by erosion at all. The same is true for the landscape that receives the activity lost from the upstream catchment, where the total inventory of the receiving landscape element might not change significantly, but locally, the activity concentration might be modified considerably.

## 4.2. DECONTAMINATION OF RIVERBEDS AND RIVERBANKS IN RESIDENTIAL AND PUBLIC AREAS IN FUKUSHIMA PREFECTURE

Immediately after the FDNPP 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.

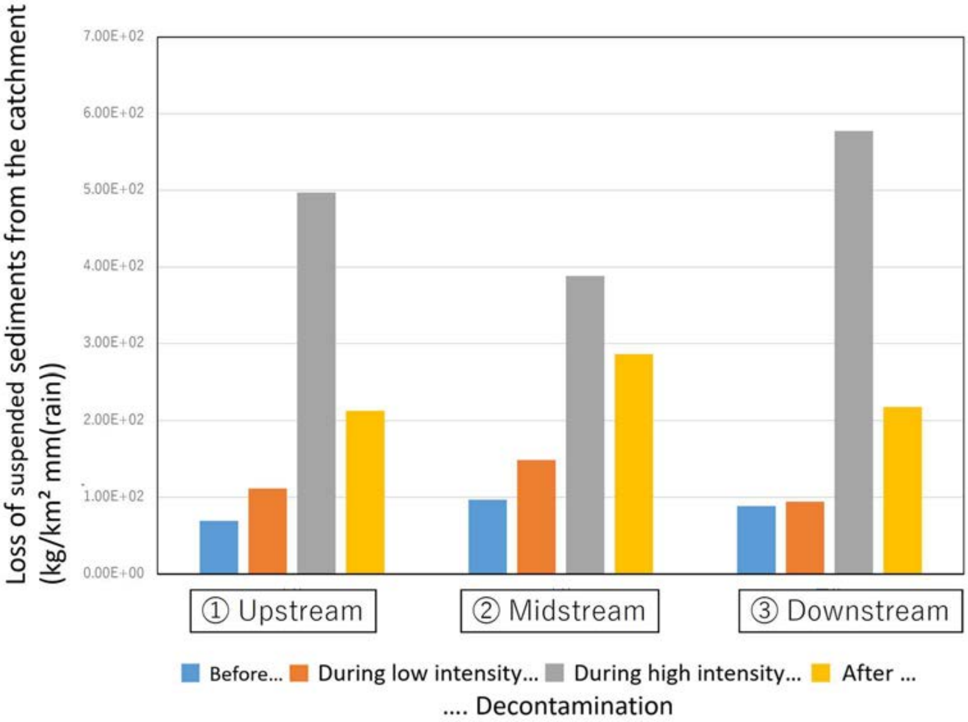


*FIG. 12. Loss of suspended sediments from the Upper Kuchibuto catchment per mm of rainfall before, during and after the decontamination work. (Reproduced from Ref. [32]).*

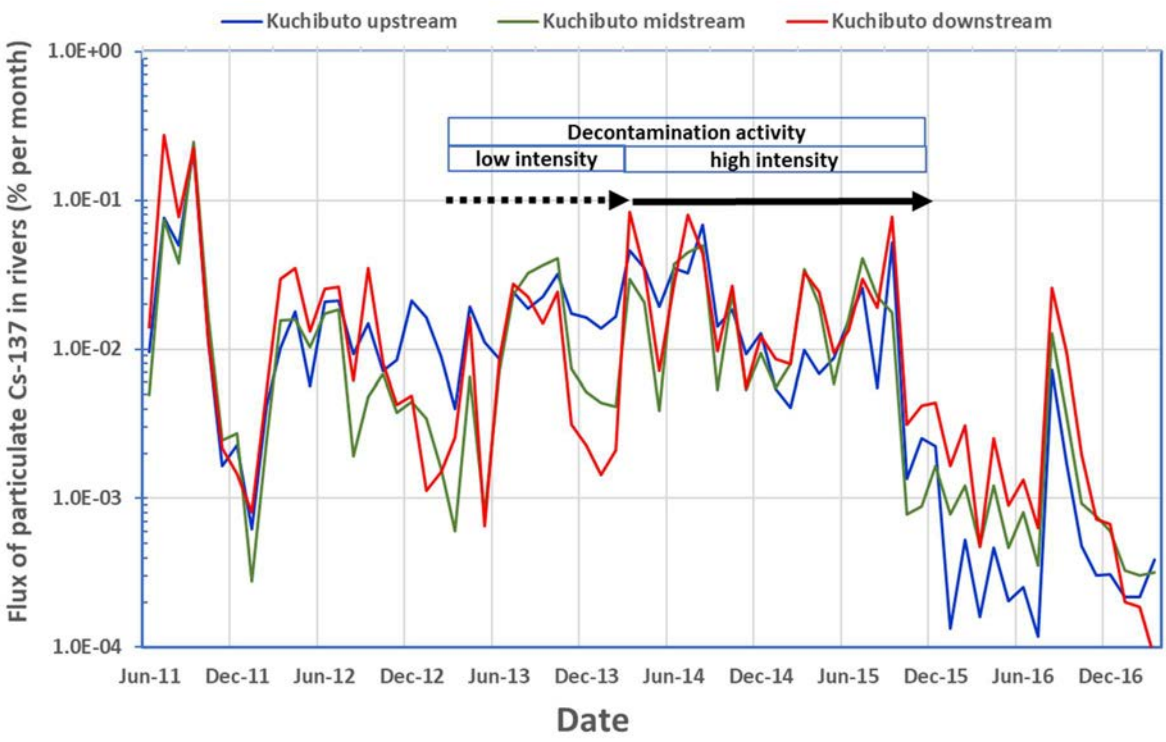


*FIG. 13. Monthly loss of $^{137}Cs$ with suspended solids from the Kuchibuto catchment upstream, midstream and downstream. Decontamination work was carried out from April 2014 to March 2015, the decontamination intensity was highest from April 2014 to March 2015. (Courtesy of the Fukushima Prefecture).*

For demonstrating the feasibility and to explore the effectiveness of decontamination measures in reducing of gamma dose rates in air, two sites of the Fukushima Prefecture were studied:

- 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 were undertaken. Additionally, vegetation and soil were removed from the river dikes, as shown in fig. 2 of Ref. [33]. The decontamination activities were carried out from August to November 2014. Gamma dose rates in air were reduced by about a factor of 2 [33].
- Niida River Park: An area close to the river which is used for leisure purposes. Model predictions were carried out to estimate the possible reduction of gamma dose rates. The calculations suggested that dose rates in the park and near the river could be reduuced by about 35%, including the reduction from radioactive decay.
  Similar model simulations were also carried out for the Nature Park at the Mizunashi River in Minami-Soma city,used for leisure.

#### 4.2.1. 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 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 air shown in Fig. 14 from February 2015 to September 2015 appears to indicate the impact of a typhoon. Sediments and vegetation in the river were removed and new material (mainly coarse material and stones) was deposited. 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 in air were 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 6. At all three sites, the gamma dose rates in air 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.

### 4.3. INTERNATIONAL EXPERIENCE ON APPROACHES FOR THE REMEDIATION OF FRESHWATER SYSTEMS

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. From the mid-1940s, freshwater environments were also contaminated due to releases from the Hanford site (USA) including discharges from process facilities and poorly stored liquid wastes [36]. The Chernobyl accident in 1986 [37] caused a deposition of radionuclides on the floodplain of the Prypiat River (Ukraine), which resulted in the long term input of radionuclides to the Pripyat River.

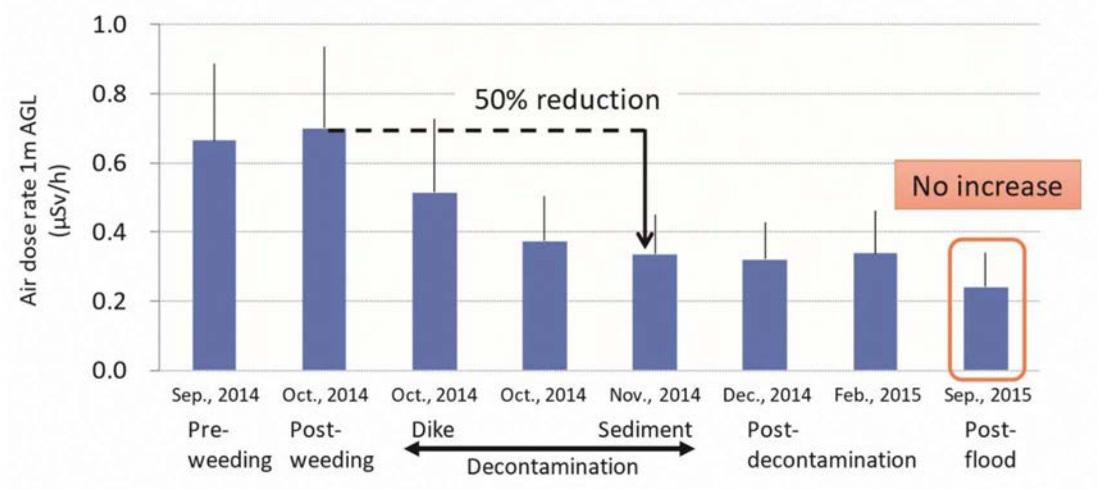


*FIG. 14: Time-dependent γ–dose-rate (1m above ground level (AGL)) at a demonstration site at the Kami-Oguni River for a decontaminated area (removal of weed, riverbed sediments, soil, and of vegetation from the dykes), a flood occurred in August 2015 (reproduced from Ref. [32]).*

TABLE 6. COMPARISON OF AVERAGE GAMMA- DOSE RATES BEFORE AND AFTER TYPHOON NO. 19 (REPRODUCED FROM REF. [32])

| Study sites | Quantity | γ-dose rate at 1 m above ground level (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) |

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.

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 which lead to varying concentrations of radionuclides in dissolved and suspended form. Radionuclides in dissolved and suspended 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 of which are:

(a) Administrative measures:
   (i) Restrictions on the use of drinking water for humans and livestock and for irrigation;
   (ii) Restrictions on access to contaminated riverbanks and surface waters;
   (iii) Restrictions on fishing and freshwater fish consumptions.

(b) Technical measures:
   (i) Treatment of contaminated surface waters at water treatment works;

(ii) Modifying the water flow by the construction of dikes;
(iii) Implementing sedimentation traps to force sedimentation of suspended sediments;
(iv) Measures to reduce the radionuclide uptake by fish from water;
(v) Removal of dissolved radionuclides by means of agents that adsorb radionuclides.

### 4.3.1. 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 straightforward to implement provided that sufficient water and fish can be made available from other sources. This may be easy to ensure for localized contaminations and for small water bodies, but it is likely to be more challenging for large scale contamination that affects 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.

### 4.3.2. Technical measures

In the early phase after the Chernobyl accident, charcoal and zeolite were used in some water treatment works. 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 to reduce activity levels in water and sediments in freshwater bodies need to be carefully planned, taking into consideration the specific local hydrological conditions.

For reducing the transport of suspended 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 the deep reservoirs in the Fukushima Prefecture along the rivers Ota (Yokokawa Dam), Mizunashi, (Takanokura Dam), Ukedo (Ogaki Dam) and Kuma (Sakashita Dam) effectively act as sediment traps [41, 42]. This is because the low flowrate in dams favours the sedimentation of particulates. As a result, this phenomenon effectively causes the 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 and therefore this measure was not considered to be 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 to be feasible [43].

Depending on the local conditions, hydrological measures might help prevent the dispersion of radionuclides from contaminated land into surface 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 runoff of radionuclides from the contaminated floodplain to the Prypiat River [41]. This measure was technically feasible, as the area around the Chornobyl NPP is flat. Implementing such hydrological measures in mountainous terrains as found in the Fukushima Prefecture, if technically feasible, may be much more complicated and costly.

In 18 Swedish lakes, the application of lime following the Chernobyl accident had no influence on the $^{137}Cs$ levels in freshwater fish [44]. In another 13 Swedish lakes, the influence of potassium on caesium uptake into fish was tested by applying potash. However, the results were not conclusive, as the water turnover of the lakes was too high to maintain sufficiently high levels of potassium concentrations in the lake water.

The application of potassium chloride to Lake Svyatoe (Belarus) after the Chernobyl accident was more successful. This lake has low natural potassium concentrations and a lower water turnover, leading to a longer residence time of the water in the lake. After potassium application of 0.05 kg/m$^2$ to the lake surface in 1998, the $^{137}Cs$ activity concentrations in large perch were reduced by approximately a factor of 3 [45]. Model calculations indicated that the reduced $^{137}Cs$ levels in large perch would be sustainable for about 15 years after the potassium application. However, the application of potassium led to increased radiocaesium activity concentrations in water due to competition with potassium in sediments. This rise in activity concentrations could have implications for the use of the water for drinking or irrigation.

Following the Chernobyl accident, numerous countermeasures were tested and implemented to minimize the runoff of 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 such as rivers. Engineering measures were costly and often difficult to implement and the overall impact on public doses was low [37]. In terms of reducing exposures to the public, restrictions on drinking water abstraction and fishing were most effective.

# 5. MICROPARTICLES CONTAINING RADIOCAESIUM

## 5.1. DESCRIPTION OF MICROPARTICLES CONTAINING RADIOCAESIUM

In several investigations carried out in the Fukushima Prefecture, a kind of glassy particles containing radiocaesium was found by autoradiography methods in various materials such as air filters, house dust, soils, plant leaves near the FDNPP accident site, agriculture materials, feathers of birds and river water (for examples see Refs [46–49]). The particles are usually called 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 particle have been identified, Type A and Type B particles [48, 50]:

— Type A particles are almost spherical and their diameter is typically less than 5 µm. Type A particles originate from silicate glass. The activity is several Bq of $^{137}Cs$ per particle. The $^{134}Cs$:$^{137}Cs$ ratio is above 1, which reflects the fuel burnup 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 CsMPs 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 low solubility and high persistence. Investigations in soil samples collected between 2011 and 2017 in the vicinity of FDNPS [52] indicate that 2–80% of the radiocaesium in soil might be associated with such particles.

## 5.2. MICROPARTICLES CONTAINING RADIOCAESIUM FOUND IN SUSPENDED SEDIMENTS OF THE HAMADORI RIVER

During investigations by the 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 Fig. 15). The enhanced $^{137}Cs$ activity in the sample of suspended sediments was associated with the presence of CsMPs.

Characteristics of CsMPs found in the Kuchibuto River during campaigns carried out from 2011 to 2016 (see Table 7) 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.

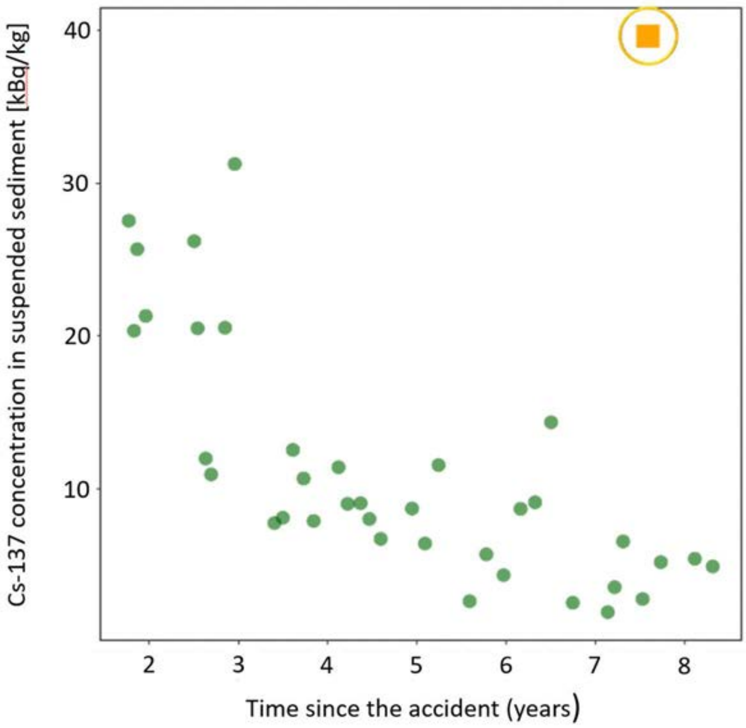


*FIG. 15. Time-dependent $^{137}Cs$ activity concentration in suspended sediments at a monitoring station of the Hamadori River, one sample has an exceptionally high $^{137}Cs$ concentration (courtesy of the Fukushima Prefecture).*

TABLE 7. CONCENTRATIONS OF $^{137}CS$ IN MICROPARTICLES COLLECTED IN THE KUCHIBUTO RIVER; THE NUMBER OF MICROPARTICLES CONTAINING RADIOCAESIUM AND $K_D$ VALUES WITH OR WITHOUT MICROPARTICLES IN THE SOLID PHASE (REPRODUCED FROM REF. [53] WITH PERMISSION)

| 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].

## 5.3. 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 Chernobyl, 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 reactor after the Chernobyl accident, they were called 'hot particles'. These particles from are classified into condensation particles and fuel particles.

### 5.3.1. Condensation particles

Condensation particles were generated at high temperatures during the breakdown of fuel elements and typically have a size of the order of 1 µm. Volatile fission products (e.g. isotopes of I, Cs) 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 such as $^{106}Ru$ and $^{140}Ba$ (half-lives 374 d and 12.8 d, respectively) 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].

### 5.3.2. 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 (e.g. $^{131}I$, $^{134}Cs$, $^{137}Cs$, $^{106}Ru$) were depleted. The size of fuel particles ranged from a fraction of a micrometre to hundreds of micrometres; their activity was typically 100–1000 Bq/particle.

### 5.3.3. 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 percentage of non-exchangeable $^{137}Cs$ in the fallout near Chornobyl was 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 accident had higher distribution coefficients ($K_d$) than, for example, radiocaesium originating from atmospheric nuclear weapons tests. Consequently, migration in soil was slower, and the bioavailable 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.

### 5.3.4. Fukushima microparticles containing radiocaesium and Chornobyl hot particles

Following both accidents, in the FDNPP and Chornobyl, particles with enhanced levels of radionuclides were found. However, the particles are quite different and the differences can be outlined as follows:

- Fukushima type A particles have a similar size spectrum as condensation particles that were found, for example, after weapons' fallout. However, type B particles are smaller than Chornobyl hot particles;
- Chornobyl hot particles are mainly fuel fragments, whereas CsMPs are of glassy nature generated during any liquifying and evaporation process of reactor materials [48];
- The total activity of the CsMPs is in general lower than that of Chornobyl hot particles;
- The hot particles released from the Chornobyl reactor contain a wider spectrum of radionuclides, whereas the CsMPs from the FDNPS accident contain mainly $^{137}Cs$;
- Due to their larger diameter, Chornobyl 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 the dose conversion coefficient for the 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 might cause a lower gut absorption and lower values for the dose per unit intake [Sv/Bq]. Further studies are needed to confirm this hypothesis.

# 6. DECONTAMINATION WORK IN TERRESTRIAL AREAS

This Section summarizes the experience in the Fukushima Prefecture of the impact of decontamination of terrestrial land and compares this with the experience after the Chernobyl accident.

## 6.1. 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 two categories:

- The Special Decontamination Area (SDA) consisting of the former 'Warning Zone' within a 20 km radius of the FDNPP, and the former 'Planned Evacuation Zone', which was situated beyond the 20 km radius from the NPP and where the annual dose from the accident for individuals could exceed 20 mSv in the first year after the FDNPP accident [14].
- The Intensive Contamination Survey Area (ISCA) which includes those municipalities where the radiation dose in the first year after the accident was estimated to be between 1 and 20 mSv for individuals in some parts of the municipality. Areas with an air dose rate of 0.23 μSv/h and above were assigned to the ICSA. This value was used as criterion for the designation of the intensive contamination survey area, but it was not a decontamination target.

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

During the decontamination, approximately 14 million $m^3$ [58] of soil and waste was generated and 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 soil and waste coming from the 'difficult-to-return zones'.

The effectiveness of the decontamination work is compiled in Ref. [59]. The results are summarized in Table 8 for agricultural land, forest, roads and residential areas [59–61]. The data are based on demonstration tests carried out by the Japanese Atomic Energy Agency [59]. The effectiveness is quantified as a reduction factor, which is determined as the ratio of the gamma dose rates at 1 m height above the ground before and after the decontamination work. The reduction factors are given as a function of the air gamma dose rate before decontamination. Interestingly, the effectiveness was higher in areas with higher air dose rates, as shown in Table 8.

The effectiveness of decontamination work under field conditions is shown in Fig. 16 for the SDA [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 in the decontamination tests where a dose rate of about 1 μSv/h was measured prior to decontamination, as shown in Table 8.

TABLE 8. REDUCTION OF GAMMA DOSE RATE IN AIR AS A PERCENTAGE RESULTING FROM DECONTAMINATION WORK IN THE INTENSIVE CONTAMINATION SURVEY AREA [59–61]

| Decontamination measure | Reduction factor of gamma dose rate | | | |
|---|---|---|---|---|
| | 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 |

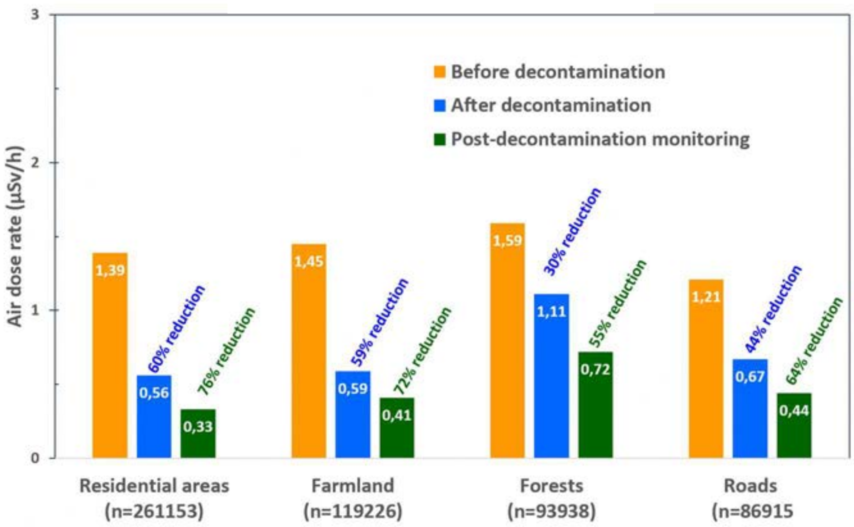


*FIG. 16. Effectiveness of decontamination work for different land uses in the special decontamination area (SDA). N = number of air dose rate measurements. (Reproduced from data in Ref. [57] with permission.)*

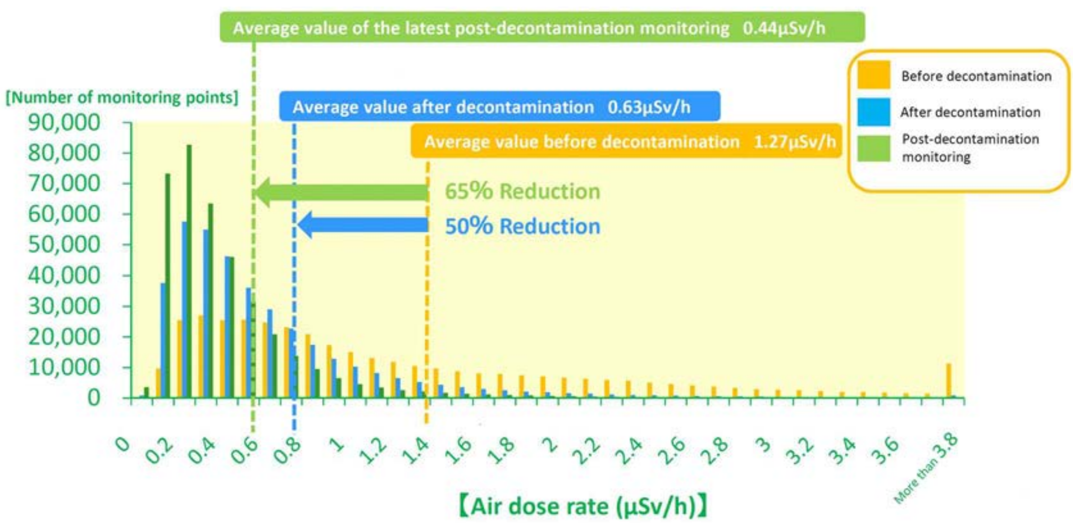


*FIG. 17. Distribution of gamma dose rates in the special decontamination area before and after decontamination work. (Reproduced from Ref. [62] with permission.)*

The distribution of the air gamma dose rates before and after the decontamination work for the special decontamination area is shown in Fig. 17 [62]. The measurements were performed before, immediately after and a few months after completion of the decontamination activities. The average value of the air 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 8 and Fig. 16. The ongoing decline of the air gamma dose rate after the completion of the decontamination work confirms the persistence of the measures; the results indicate that recontamination is, if there is any, a phenomenon of minor importance.

## 6.2. 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 such as 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; 63]. 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 9 summarizes the achievable decontamination factors for contaminated surfaces for a variety of measures [37] tested in an area affected by fallout from the Chernobyl accident. 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 needs to 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 (reduction in gamma dose rate in air) observed during demonstration tests in Japan (Table 8) under more realistic conditions are smaller. However, they are consistent with the lower values of the ranges presented in Table 9 where similar techniques were also applied during the decontamination work in areas affected by fallout from the Chernobyl accident.

The reduction of the annual effective dose from external exposure due to large scale decontamination campaigns was studied in the Bryansk oblast (Russian Federation) in 1989 [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 to pasture and crops, as this process represents a potential long term source for internal exposure of people. 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 also needs to 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 9. ACHIEVABLE DECONTAMINATION FACTORS (DIMENSIONLESS) FOR VARIOUS URBAN SURFACES [37]

| Surface | Decontamination technique | Dose rate reduction factor[a] |
|---|---|---|
| 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 |

[a] Reduction of the gamma dose rate in air 1m above the treated surface after decontamination compared to before decontamination.

TABLE 10: COMPARISON OF REDUCTION FACTORS FOR RADIOCAESIUM TRANSFER TO AGRICULTURAL PRODUCTS DERIVED AFTER THE CHERNOBYL [37] AND FUKUSHIMA DAIICHI ACCIDENTS [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.

Table 10 compares the effectiveness of a spectrum of countermeasures for reducing the uptake of radiocaesium from soil[6] applied after the accidents at Chornobyl and the FDNNPP [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 uptake by roots. Both soil removal, depending on the depth removed, and deep ploughing can have a severe impact for the soil quality, and deep ploughing cannot be applied at all sites. The other countermeasures are part of normal agricultural practice. The reduction factors in the uptake of radiocaesium into crops 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.

[6] Decontamination is quantified in terms of reduction of the uptake of $^{137}Cs$ from soil.

# 7. INTERACTION WITH THE PUBLIC

## 7.1. ACTIVITIES IMPLEMENTED AFTER THE FUKUSHIMA DAIICHI NUCLEAR POWER PLANT ACCIDENT

The release of human 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 such as:

- The Commutan Fukushima (Fukushima Prefectural Centre for Environmental Creation) was established in 2016. Since then, this Centre has been also one of the important information channels for the public.
- Local newspapers, radio stations and TV programmes.
- Organiation of explanatory and consultation meetings for the people living in affected areas.
- Providing basic and comprehensive information that helps people understand 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 to discuss 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[7].

Over time, the focus of the information campaign shifted from the simple transmission of results from measurements and 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

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

the possible implications for daily life. In principle, there is a rational understanding of the 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 to support the communication between 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.

## 7.2. 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 to the public on the environmental contamination, 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 in 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, decontamination of the affected area and 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 International Chernobyl Research and Information Network (ICRIN) programme [66]. This programme was launched in 2009 by four International Organisations (UNDP, UNICEF, IAEA, WHO)[8] in rural areas affected by the Chornobyl fallout in Belarus, Russia and Ukraine. The aim of the programme was to provide scientifically 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-accident situations was discussed in detail. The essential points of the discussion are summarized in Table 11.

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 might be difficult for the people to clearly differentiate between reliable and non-reliable information sources, which undermines the confidence in the official information channels. Therefore, according to the experience made after the Chernobyl accident and the Goiânia accident, the development, and maintenance of trust is the most important factor for the successful dialogue and fruitful discussions with the local and national population.

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

TABLE 11. ASPECTS ON COMMUNICATION WITH THE PUBLIC IDENTIFIED AS ESSENTIAL DURING MANAGEMENT OF POST-ACCIDENT SITUATIONS OUTSIDE JAPAN (REPRODUCED FROM REFS [65, 66])

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

# 8. SUMMARY

This publication summarizes the results of the cooperation of the Fukushima Prefecture and the IAEA in the field of decontamination and remediation of areas affected by the deposition of radionuclides during the accident in the Fukushima Daiichi Nuclear Power Plant. The main findings of the discussions and findings of the work carried out from 2018 to 2022 are:

- Comprehensive monitoring and research programmes were initiated in 2011 to study 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 might 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 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 involves observation times of at least 15 years. Such long observation periods cannot yet be available for Fukushima Prefecture.
  - In the 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 runoff 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 runoff. In a study carried out during ongoing decontamination work, a total loss of $^{137}Cs$ due to surface runoff 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 at the FDNPP and at the Chornobyl reactor, particles with enhanced levels of radionuclides were detected. The Chornobyl 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, 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 collected after the Chernobyl accident.

- For reducing $^{137}Cs$ levels in 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.

A suggested structure for a data matrix that can be used to compile the data and results for the processes and topics covered in this report in a consistent way is given in Appendix IV.

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

Table 12 gives a compilation of data that describes the dynamics of $^{137}Cs$ in rivers. The 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.

TABLE 12. COMPILATION OF DATA THAT DESCRIBES THE DYNAMICS OF $^{137}CS$ IN RIVERS COMMUNICATION WITH THE PUBLIC IDENTIFIED AS ESSENTIAL DURING MANAGEMENT

| 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 (Chornobyl) | 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 12. (cont.)

| River or site name | Observation period | Medium | Effective half-lives (Weighting factors, if available) $T_{eff,1}$ (short term) | $T_{eff,2}$ (intermediate) | $T_{eff,3}$ (long term) | Reference number |
|---|---|---|---|---|---|---|
| ***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 12. (cont.)

| River or site name | Observation period | Medium | Effective half-lives (Weighting factors, if available) $T_{eff,1}$ (short term) | $T_{eff,2}$ (intermediate) | $T_{eff,3}$ (long term) | Reference |
|---|---|---|---|---|---|---|
| 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 two 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 therefore need to 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 13 gives the underlying data for Figs 4 and 5 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 in 2011–2021 (reproduced from Refs [15] and [78] with permission).

TABLE 13. ACIVITY CONCENTRATIONS OF $^{137}$CS IN SUSPENDED SEDIMENTS IN RIVERS IN FUKUSHIMA PREFECTURE

| Sampling date | Site (river name) | Activity in suspended sediments (Bq/kg) | Standard deviation | Catchment area (km²) | Mean deposition in the catchment (kBq/m²) |
|---|---|---|---|---|---|
| 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 | | |

TABLE 13. (cont.)

| Sampling date | Site (river name) | Activity in suspended sediments (Bq/kg) | Standard deviation | Catchment area (km²) | Mean deposition in the catchment (kBq/m²) |
|---|---|---|---|---|---|
| 2014-01-17 | 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 | | |
| 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 | | |

TABLE 13. (cont.)

| Sampling date | Site (river name) | Activity in suspended sediments (Bq/kg) | Standard deviation | Catchment area (km²) | Mean deposition in the catchment (kBq/m²) |
|---|---|---|---|---|---|
| 2012-03-09 | Kuchibuto-upper (Kuchibuto) | 1.44E+04 | 4.21E+02 | | |
| 2012-03-20 | Kuchibuto-upper (Kuchibuto) | 1.32E+04 | 1.90E+02 | | |
| 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 | | |

TABLE 13. (cont.)

| Sampling date | Site (river name) | Activity in suspended sediments (Bq/kg) | Standard deviation | Catchment area (km²) | Mean deposition in the catchment (kBq/m²) |
|---|---|---|---|---|---|
| 2020-02-26 | Kuchibuto-upper (Kuchibuto) | 9.13E+2 | 2.50E+1 | | |
| 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 13. (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 | | |
| 2012-04-17 | Kuchibuto-down (Kuchibuto) | 9.54E+03 | 2.72E+02 | | |

TABLE 13. (cont.)

| Sampling date | Site (river name) | Activity in suspended sediments (Bq/kg) | Standard deviation | Catchment area (km²) | Mean deposition in the catchment (kBq/m²) |
|---|---|---|---|---|---|
| 2012-04-26 | 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 | | |
| 2011-07-25 | Fushiguro (Abukuma) | 4.10E+04 | 9.71E+02 | | |
| 2011-08-09 | Fushiguro (Abukuma) | 3.23E+03 | 4.27E+02 | | |

TABLE 13. (cont.)

| Sampling date | Site (river name) | Activity in suspended sediments (Bq/kg) | Standard deviation | Catchment area (km²) | Mean deposition in the catchment (kBq/m²) |
|---|---|---|---|---|---|
| 2011-08-16 | 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 | | |
| 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 | | |

TABLE 13. (cont.)

| Sampling date | Site (river name) | Activity in suspended sediments (Bq/kg) | Standard deviation | Catchment area (km²) | Mean deposition in the catchment (kBq/m²) |
|---|---|---|---|---|---|
| 2018-12-05 | 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 | | |
| 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 | | |

TABLE 13. (cont.)

| Sampling date | Site (river name) | Activity in suspended sediments (Bq/kg) | Standard deviation | Catchment area (km²) | Mean deposition in the catchment (kBq/m²) |
|---|---|---|---|---|---|
| 2015-01-13 | 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 | | |
| 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 | | |

TABLE 13. (cont.)

| Sampling date | Site (river name) | Activity in suspended sediments (Bq/kg) | Standard deviation | Catchment area (km²) | Mean deposition in the catchment (kBq/m²) |
|---|---|---|---|---|---|
| 2015-08-25 | 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 | | |
| 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 | | |

TABLE 13. (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 | 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 | | |
| 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 | | |

TABLE 13. (cont.)

| Sampling date | Site (river name) | Activity in suspended sediments (Bq/kg) | Standard deviation | Catchment area (km²) | Mean deposition in the catchment (kBq/m²) |
|---|---|---|---|---|---|
| 2016-09-30 | 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 | | |
| 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 | | |

TABLE 13. (cont.)

| Sampling date | Site (river name) | Activity in suspended sediments (Bq/kg) | Standard deviation | Catchment area (km²) | Mean deposition in the catchment (kBq/m²) |
|---|---|---|---|---|---|
| 2017-09-20 | 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 | | |
| 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 | | |

TABLE 13. (cont.)

| Sampling date | Site (river name) | Activity in suspended sediments (Bq/kg) | Standard deviation | Catchment area (km²) | Mean deposition in the catchment (kBq/m²) |
|---|---|---|---|---|---|
| 2018-12-05 | 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 | | |
| 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 | | |

TABLE 13. (cont.)

| Sampling date | Site (river name) | Activity in suspended sediments (Bq/kg) | Standard deviation | Catchment area (km²) | Mean deposition in the catchment (kBq/m²) |
|---|---|---|---|---|---|
| 2012-12-18 | 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 |
| 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 | | |

TABLE 13. (cont.)

| Sampling date | Site (river name) | Activity in suspended sediments (Bq/kg) | Standard deviation | Catchment area (km²) | Mean deposition in the catchment (kBq/m²) |
|---|---|---|---|---|---|
| 2013-10-29 | 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 | | |
| 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 | | |

TABLE 13. (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 | 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 | | |
| 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 | | |

TABLE 13. (cont.)

| Sampling date | Site (river name) | Activity in suspended sediments (Bq/kg) | Standard deviation | Catchment area (km²) | Mean deposition in the catchment (kBq/m²) |
|---|---|---|---|---|---|
| 2016-04-19 | 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 | | |
| 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 | | |

TABLE 13. (cont.)

| Sampling date | Site (river name) | Activity in suspended sediments (Bq/kg) | Standard deviation | Catchment area (km²) | Mean deposition in the catchment (kBq/m²) |
|---|---|---|---|---|---|
| 2013-01-21 | 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 |
| 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 | | |

TABLE 13. (cont.)

| Sampling date | Site (river name) | Activity in suspended sediments (Bq/kg) | Standard deviation | Catchment area (km²) | Mean deposition in the catchment (kBq/m²) |
|---|---|---|---|---|---|
| 2014-08-04 | 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 | | |
| 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 | | |

TABLE 13. (cont.)

| Sampling date | Site (river name) | Activity in suspended sediments (Bq/kg) | Standard deviation | Catchment area (km²) | Mean deposition in the catchment (kBq/m²) |
|---|---|---|---|---|---|
| 2013-02-26 | 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 | | |
| 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 | | |

TABLE 13. (cont.)

| Sampling date | Site (river name) | Activity in suspended sediments (Bq/kg) | Standard deviation | Catchment area (km²) | Mean deposition in the catchment (kBq/m²) |
|---|---|---|---|---|---|
| 2013-05-21 | 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 | | |
| 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 | | |

TABLE 13. (cont.)

| Sampling date | Site (river name) | Activity in suspended sediments (Bq/kg) | Standard deviation | Catchment area (km²) | Mean deposition in the catchment (kBq/m²) |
|---|---|---|---|---|---|
| 2013-09-11 | 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 | | |
| 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 | | |

TABLE 13. (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 | 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 | | |
| 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 | | |

TABLE 13. (cont.)

| Sampling date | Site (river name) | Activity in suspended sediments (Bq/kg) | Standard deviation | Catchment area (km²) | Mean deposition in the catchment (kBq/m²) |
|---|---|---|---|---|---|
| 2016-09-27 | 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 | | |
| 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 | | |

TABLE 13. (cont.)

| Sampling date | Site (river name) | Activity in suspended sediments (Bq/kg) | Standard deviation | Catchment area (km²) | Mean deposition in the catchment (kBq/m²) |
|---|---|---|---|---|---|
| 2020-07-09 | 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 | | |
| 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 | | |

TABLE 13. (cont.)

| Sampling date | Site (river name) | Activity in suspended sediments (Bq/kg) | Standard deviation | Catchment area (km²) | Mean deposition in the catchment (kBq/m²) |
|---|---|---|---|---|---|
| 2013-08-22 | 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 | | |
| 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 | | | |

TABLE 13. (cont.)

| Sampling date | Site (river name) | Activity in suspended sediments (Bq/kg) | Standard deviation | Catchment area (km²) | Mean deposition in the catchment (kBq/m²) |
|---|---|---|---|---|---|
| 2014-08-06 | 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 | | |
| 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 14 shows the monthly flux of particulate $^{137}$Cs (Bq) in rivers of the Fukushima Prefecture [15]. For the months and/or 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 Fig. 13.

TABLE 14. MONTHLY FLUX OF PARTICULATE $^{137}$CS (BQ) IN RIVERS OF THE FUKUSHIMA PREFECTURE

| **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 |

TABLE 14. (cont.)

| Sampling month | Monthly flux of particulate Cs-137 in rivers (Bq) | | | | | |
|---|---|---|---|---|---|---|
| | Mizusakai | Kuchibuto (up) | Kuchibuto (mid) | Kuchibuto (down) | Fushiguro | Iwanuma |
| 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 06/2011–08/2015** | **2.19E+10** | **1.14E+11** | **2.34E+11** | **5.10E+11** | **1.13E+13** | **1.24E+13** |

TABLE 14. (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 10/2012–08/2015** | **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 14 (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 10/2012–08/2015** | **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** |

# APPENDIX IV. SUGGESTED STRUCTURE FOR A COMPILATION OF RESULTS IN A MATRIX FORMAT

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 that could be used 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 from other accidental releases of radionuclides to the environment.

The structure of the matrix used is shown in Table 15. 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 specific datapoints in a table. Many data sets consist of many individual data points collected at different places over many years which need 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 items are included; more 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 and 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 of rivers;
- Decontamination of residential areas.

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 or quantity.
- Sampling location.
- Observation period.
- Unit of the parameter or 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 characterize the process considered.

TABLE 15. SUGGESTED MATRIX THAT CAN BE USED AS A STRUCTURE FOR COMPREHENSIVE AND CONCISE COMPILATION OF DATA FOR THE TOPICS COVERED IN TH|IS REPORT

| | 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/m³ | Time series for monitoring points in a river | Flow rate<br>Turbidity<br>Concentration of suspended sediments |
| | | Measured levels of particulate Cs-137 | | | | Bq/kg | | |
| | | Simulated levels of dissolved Cs-137 | | | | Bq/m³ | | |
| | | Simulated levels of particulate Cs-137 | | | | Bq/kg | | |
| 2 | **Time dependence of Cs-137 in dam lake or water reservoir** | Measured levels of dissolved Cs-137 | | | | Bq/m³ | Time series for monitoring points in dam lake or water reservoir | |
| | | Measured levels of particulate Cs-137 | | | | Bq/kg | | |
| | | Simulated levels of dissolved Cs-137 | | | | Bq/m³ | | |
| | | 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/m³ | Time series for monitoring points in a river, dam lake or water reservoir | |
| | | Simulated levels of particulate Cs-137 | | | | Bq/kg | | |
| 4 | **Loss of Cs-137 from catchment areas** | Loss of Cs-137 from catchments and/or catchment areas | | | | Bq/ m² a,<br>(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<br>Number of half-life components identified | | Time after the accident, media considered, environmental conditions |
| 6 | **Micro-particles in the environment** | Cs-MPs found | | | | Particles per unit area | Number of particles found | Particle type |
| | | Composition | | | | Main elements in the particles (mg/kg) | | |
| | | Activity | | | | Bq per particles<br>Bq/kg | | |
| 7 | **Decontamination of rivers** | Decontamination measure (e.g. removal of shore sediments, removal of bottom sediments, removal of weed) | | | | As applicable:<br>Activity (Bq/kg) in before and after decontamination<br>Activity (Bq/m²) before and after decontamination<br>Dose rate before and after decontamination (μSv/h) | | Rainfall after decontamination,<br>high rainfall events after precipitation,<br>slope of the terrain,<br>intensity of decontamination, area decontaminated, amount of material (e.g. soil, sediments, litter) removed, decontamination measures applied |
| 8 | **Decontamination of residential areas** | Decontamination measure (e.g. removal of soil) | | | | | | |

The exact format of the results would depend on the nature of the topic. The results of studies may be reported as, for example, single values, time series of values or functions describing the dependency of the results on one or more variables, etc. Maps could be used to show spatial distributions of parameters, such as activity levels in environmental media.

Data available from other countries could be reported in the same structure as this could facilitate comparison with the studies carried out in the Fukushima Prefecture.

The matrix is not to be considered as a ‘big table’ to include data in a 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. However, the matrix provides a general structure for the reporting of data on the work done in the Fukushima Prefecture and could also be used for the reporting of data elsewhere.

The data presented in this report could provide a starting point for integration of future data into a data structure, such as that presented in Table 15.

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