United Nations Scientific Committee on the Effects of Atomic Radiation

ATTACHMENT C-13

METHODOLOGY FOR THE ASSESSMENT OF DOSE FROM INGESTION OF RADIOACTIVE MATERIAL

UNSCEAR 2013 Report, Annex A, Levels and effects of radiation exposure due to the nuclear accident after the 2011 great east-Japan earthquake and tsunami, Appendix C (Assessment of doses to the public)

Notes

Contents

I. INTRODUCTION

1. Following an accidental release of radionuclides to the environment, the ingestion of food can be an important route by which radionuclides enter the body. This applies to releases both to atmosphere and water bodies. Following the releases from the Fukushima Daiichi nuclear power station (FDNPS) in 2011, widespread monitoring of various types of food was carried out to determine the quantities of key radionuclides contained in them. In order to limit radiation exposure of the public, restrictions on the supply of foodstuffs were introduced in Japan, with the aim of ensuring that food above defined levels of contamination was not marketed and hence consumed by the public. Where possible, the estimated doses from the ingestion of food took these restrictions into account.

2. Different approaches were used to estimate doses from the ingestion of terrestrial and marine food. For doses in the first year in Japan, the main assessment was based on the comprehensive set of measurement data obtained by the Japanese authorities and provided to the Food and Agriculture Organization of the United Nations (FAO) and the International Atomic Energy Agency (IAEA). The measured concentrations were combined with information on how much of particular food people eat to estimate radiation doses. In order to estimate doses beyond the first year, a modelling approach was used for both terrestrial and marine food. Because it was not possible to find a suitable Japanese model for the transfer of radionuclides through terrestrial food chains, a modified version of the FARMLAND model [Brown and Simmonds, 1995] was used to estimate concentrations of key radionuclides in various foods as a function of time on the basis of estimated or measured deposition densities of radionuclides on the ground (including plants). The model was adapted to Japanese agricultural practices and conditions to the extent possible. For marine food, estimated activity concentrations in seawater and sediment were used to estimate activity concentrations in various marine foods and hence doses from ingestion.

3. For intakes of terrestrial food, collective doses were also estimated by calculating a collective intake on the basis of the total production of food for human consumption in different regions of the country. In estimating collective doses, the Committee assumed that any foods with activity concentrations above the levels recommended by the Japanese authorities were not eaten.

4. Only a very limited assessment of doses in countries very close to Japan was carried out, with a simplified approach. It was assumed that there was no contribution to dose from food imported from Japan in view of the widespread controls that were introduced by both the Japanese and national authorities together with the reductions in food exports from Japan following the accident. This assumption was supported by the very low levels of radionuclides measured in food imported from Japan as reported by Member States. Account was taken of the levels in food produced only in the country of interest; these were estimated using the modified FARMLAND model, using the estimated deposition densities of radionuclides on the ground. The pattern of food consumption was assumed to be the same as that for Japan.

5. This paper summarizes the methodology used by the Committee for estimating the doses to the public from ingestion of foodstuffs.

II. DOSES ESTIMATED

6. The emphasis in the dose assessment was to estimate doses to defined groups of individuals considered representative of the different subsets of the Japanese population. The aim was to consider doses characteristic of those that have been, or will be received by typical members of the public with average habits living in different locations. The uncertainties associated with the assessment were also addressed. Estimates were also made of collective doses to the public.

7. The doses estimated were: the effective dose as defined by the International Commission on Radiological Protection (ICRP) [ICRP, 1991, Publication 60; ICRP, 2007, Publication 103] and the absorbed dose to the thyroid. In addition, absorbed doses to other organs (colon, lower large intestine, lung and red bone marrow) were estimated in some cases. In all cases, the dose estimated was the committed dose (integrated over 50 years or to age 70 as used by ICRP) from intakes by ingestion in the period of interest. Three age groups were considered (20-year-old adults, 10-year-old children and one-year-old infants) but consideration was also given to the doses to the foetus and breast-fed infant. The dose coefficients (dose per unit activity intake) for members of the public used in the assessment were those provided by ICRP [ICRP, 2012, Publication 119] and are reproduced in supplement A.

8. Doses were estimated to the three age groups for the first year following the accident. In addition, lifetime doses — up to age 80 years — were calculated taking into account ageing. Doses to those who were infants, aged one year at the time of the accident, were considered using the dose coefficients and other relevant data for one-year-old infants up to age 5 years, data for 10-year-old children were used from ages 6 to 15 years and data for adults were used from ages 16 to 80 years. Doses to those who were children, aged 10 years at the time of the accident, were considered using the data for 10-year-old children up to age 15 years and data for adults were used from ages 16 to 80 years.

III. ASSESSMENT OF DOSES FROM INGESTION ON THE BASIS OF MEASUREMENT DATA

A. Evaluation of data

9. A combined FAO/IAEA/MAFF database of measured activity concentrations in foods in Japan was used in this assessment to estimate radiation doses in the first year following the releases from the FDNPS. The data were obtained from the relevant Japanese authorities through the FAO/WHO International Food Safety Authorities Network (INFOSAN) and considerable effort was required by the staff of FAO/IAEA to manually check these data, to ensure that the nomenclature (food and location names) was clear and consistent and that the data were appropriate for further use. These data were also further developed by the Japanese Ministry of Agriculture, Forestry and Fisheries (MAFF) and the two sets of data were combined to form an overall database for use in this assessment. Detailed cross-checks were carried out to ensure that the combined database was correct and consistent. Further details on the database are given in attachment C-8.

10. The database contains data for a wide variety of foods but in order to assess doses, these were grouped for use with the available data on food consumption. The following broad

categories of food were considered (full details of the categories used in the database, the data on food consumption and the FARMLAND model are given in supplement B):

- *Vegetables.* Leafy vegetables, root vegetables, and other vegetables;
- *Fruits.* Fresh and processed fruits, and juices;
- *Fish and shellfish.* Marine and migratory fish (such as salmon and freshwater fish), and crustaceans and molluscs;
- *Meats.* Beef/cattle, pork (excluding wild boar), poultry, and other meat;
- *Eggs.*
- *Milk and dairy products.* Milk, and dairy (including cheese);
- *Cereals.* Rice and rice products, wheat and wheat products, and other cereals;
- *Other food.* Soya and soya products, mushrooms, and algae.

11. The locations provided in the database are defined by name and can cover broad areas. However, this was not a problem in the assessment of doses to representative individuals because people do not generally obtain all of their food from their immediate locality. Rather, they consume food produced throughout the country and imported from outside Japan. For this assessment, the approach was to estimate average doses from ingestion to be added to the average individual doses from the other exposure pathways (external irradiation plus inhalation). In addition, an estimate was made of the possible distribution in doses from ingestion resulting from the variability in activity concentrations in food and the extent to which people eat locally produced food.

B. Assessment of doses to representative individuals from ingestion of radionuclides

12. The aim was to estimate doses to representative individuals with typical habits living in specific locations. It would be very cautious and unrealistic to assume that the average person obtained all of their food from the location where they lived. However, the measurements of activity concentration that are given in the database and used in this assessment were for food as marketed and so should, to some extent, be representative of the food consumed. However, for the first few months following the accident, insufficient data were available to permit the Committee to estimate doses from ingestion at a local level (settlement or town). It was therefore necessary to estimate the doses from ingestion for wider areas. Three sets of doses were estimated: for Fukushima Prefecture; for the neighbouring prefectures (Chiba, Gunma, Ibaraki, Miyagi and Tochigi) treated together; and for the rest of Japan.

13. A significant amount of food is imported into Japan. The dose assessment was based on the average proportion of each type of food that is imported into Japan on a yearly basis [MAFF, 2012]. This proportion was assumed to be independent of location and time (see supplement B). The importance of this assumption was investigated through an assessment of the doses that would have been received if it had been assumed that 100% of all food had been produced in Japan.

14. Approximately 126,000 records of activity concentrations of radionuclides in food are included in the database for the period from March 2011 to March 2012. About 5,000 samples were collected in the first three months, predominantly from Fukushima Prefecture and the neighbouring prefectures; there was a rapid increase in the number of samples collected after

three months including a higher proportion from more distant prefectures, as discussed in attachment C-8. Results for a large number of different types of food are included in the database, but there are far more data for some foods than for others. For example over 84,000 measurements of beef were made (about 67% of the total), which was significantly greater than for any other food type. Nevertheless, the Committee concluded that sufficient data were available for the dose assessment.

15. *Limits of detection.* A number of the measurements were reported as less than the limit of detection (in most cases, the specific limits of detection were not provided). When this was the case, the approach was to assume that the activity concentration of each of three major radionuclides (^{131}I, ^{134}Cs and ^{137}Cs; see paragraph 21) was 10 Bq/kg (except for the situations given below). In some cases, this assumption was likely to overestimate actual concentrations because some analytical techniques were available for which the limit of detection was considerably lower than 10 Bq/kg. However, owing to the needed throughput of a large number of samples in a short time frame, less sensitive techniques were also used and, in some cases, the limits of detection were reported to be up to 50 Bq/kg. Hence overall, the assumption of 10 Bq/kg was thought to be reasonable.

16. There were two situations where the assumption of a minimum value of activity concentration of 10 Bq/kg was not adopted:

(a) For ^{131}I, all samples collected after 15 July 2011 were reported to be below the limit of detection. In view of the short half-life of iodine (8 days), the activity concentration four months after the accident was assumed to be zero;

(b) Rice in Japan is not harvested until September each year, so the activity concentrations of radionuclides in rice were also assumed to be zero before this month in 2011.

17. Where insufficient measurement data were available (particularly during the first six months after the accident in the prefectures other than Fukushima Prefecture), an activity concentration of each radionuclide (^{131}I, ^{134}Cs and ^{137}Cs) in food of 10 Bq/kg was assumed, except as indicated in the previous paragraph.

18. *Variation with time.* The activity concentrations of radionuclides in food after an accident vary significantly with time and depend on the season of the year when the release occurs and farming practices. For this reason, the doses received during different periods of time were estimated from the measured activity concentrations. For the first four months after the release (15 March to 14 July 2011), the doses received during each month were estimated from the activity concentrations of ^{131}I, ^{134}Cs and ^{137}Cs measured during the particular month. From 4 to 6 months after the release (15 July to 15 September 2011), again the doses received during each month were estimated but only for ^{134}Cs and ^{137}Cs. For the period from 15 September 2011 to 15 March 2012, the doses were estimated for each period of three months because there was comparatively little change in the activity concentrations during this time. These were summed to obtain the doses from ingestion in the first year. Beyond one year after the accident, the dose assessment was based on modelling and not directly on the measurement data.

19. *Delays between production and consumption.* Generally, food is not eaten immediately after it is produced owing to the time taken to process and distribute it. Food may also be stored in the home prior to consumption. For a crop such as rice which is harvested at one time of year and then eaten over the next year or more, the time lag between production and consumption may be particularly long. Long time-lags may also occur with preserved food (frozen or canned). However, some food, such as fresh vegetables, is usually eaten within a day

or two of harvest. The radioactive decay between production and consumption is negligible for ^{134}Cs and ^{137}Cs but could be significant for ^{131}I. The use of the measured activity concentrations carries the implicit assumption that the levels in food stayed the same until consumption. This may have led to some overestimation of the doses from ^{131}I but would have had a negligible effect for ^{134}Cs and ^{137}Cs.

20. *Losses due to food processing and preparation.* Commercial processing of food prior to sale and preparation in the home prior to consumption may lead to a reduction in the activity concentrations of radionuclides in food; more rarely, it may lead to an increase in the activity concentrations. Information on the losses of radionuclides in processing and preparation is collated in [IAEA, 2010]. The FAO/IAEA/MAFF database includes the results of measurements of the activity concentrations of radionuclides in some processed foods and in many instances in foods that have been prepared to some extent (e.g. outer leaves removed from leafy vegetables). For the dose assessment, any additional losses due to processing and preparation were not taken into account.

21. *Radionuclides.* The FAO/IAEA/MAFF database contains the results of measurements of the activity concentrations of ^{131}I, ^{134}Cs and ^{137}Cs only. Other radionuclides were released from the FDNPS, but experience from other studies [Kamada et al., 2012; WHO, 2012] has shown that the majority of the dose from ingestion following a nuclear accident is from ^{131}I, ^{134}Cs and ^{137}Cs.

IV. DOSES FROM THE INGESTION OF TERRESTRIAL FOODS

22. For the assessment of doses beyond the first year from ingestion in Japan, data on the activity concentrations of radionuclides in terrestrial food were obtained through the use of models. Models were also used for the assessment of doses in the nearby countries. In general, the same dosimetric and other data were used to assess doses from ingestion regardless of whether the activity concentrations in food were obtained from measurements or from modelling. However, in the case where the activity concentrations were obtained using models, the activity concentrations were those for food grown at particular locations. Because most people obtain their food from supermarkets supplied through national distribution networks, the activity concentrations were averaged over each prefecture and it was assumed that only 25% of the food consumed came from the local prefecture with the remaining 75% coming from the rest of Japan. A sensitivity analysis was carried out to estimate the doses from ingestion from eating greater amounts of locally produced food, particularly for individuals living in the most contaminated areas.

23. Doses were estimated for Japan and, to a limited extent, for nearby countries. The atmospheric dispersion model used did not provide sufficient information for the estimation of doses to members of the public elsewhere in the world. The radionuclides considered reflected the source term data provided, with priority given to assessing doses from ^{131}I, ^{134}Cs and ^{137}Cs.

A. Individual doses

24. The doses to representative individuals from each ingested radionuclide and foodstuff, D_{ing} (Sv), was estimated using the following equation:

$$D_{ing} = DC_{ing} \times AI \times Food_{TF} \times \text{Deposition density} \tag{1}$$

where DC_{ing} is the dose coefficient for ingestion for the radionuclide (Sv/Bq) taken from [ICRP, 2012, Publication 119] and given in supplement A; AI is the average annual intake of the foodstuff (kg) (see table 1); $Food_{TF}$ is the transfer factor for the foodstuff ((Bq a)/kg per (Bq/m^2)) (see supplement D); Deposition density is given in Bq/m^2.

25. A breakdown of dose by radionuclide and type of food, and also the total dose from ingestion, were calculated.

B. Collective doses

26. Collective doses from the ingestion of terrestrial food were estimated by calculating a collective intake on the basis of the total production of food for human consumption in different regions of the country [MHLW, 2010]. The Committee assumed that any food above the restriction levels recommended by the Japanese authorities was not eaten. Nevertheless, a calculation was also carried out without this assumption to determine the implications. The dose coefficients for adults were used in the assessment of collective dose. The collective dose from each ingested radionuclide and foodstuff, $CDose_{ing}$ (man Sv) from a year's production, is given by:

$$CDose_{ing} = DC_{ing} \times AFP \times Food_{TF} \times \text{Deposition density} \qquad (2)$$

where AFP is the annual food production in kg (see supplement B), and the other symbols are as in equation (1).

27. A breakdown of collective dose by radionuclide and type of food, and also the total collective dose from ingestion, was calculated.

C. Intake rates

28. Annual intakes of food in Japan were based on the data provided by MHLW using the results of the National Health and Nutrition Survey undertaken in 2009 [MHLW, 2010]. Average daily intakes for adults were provided for all of the categories of food considered. More limited data were provided for the other age groups; for example, information only on the total intake of meat was provided, without any breakdown for each type of meat. Where this was the case, the total was split between the different food subgroups by assuming the same intake ratios as for adults. The resulting intake data are given in table 1 for the categories of food (see supplement B). The intakes in table 1 make up around 75% of the adult diet as recorded by the survey. Of the food categories not included in the assessment, beverages were the largest contributor, making up 16% of the total adult intake. The intakes in table 1 were also used for the estimates of doses from ingestion in the nearby countries.

Table 1. Data on food intake by age group used in the dose assessment

These age ranges are from the reports of the surveys provided by the Government of Japan and were adopted by the Committee without amendment for age

Food category	*Sub-classifications (see attachment C-8 and supplement B)*	*Per capita food intake by age group (g/d)*		
		Adults (≥20 years)	*Children (7–14 years)*	*Infants (1–6 years)*
Leafy vegetables	27, 30, 34, 37	71.3	60.4	35.7
Root vegetables	13–16, 26	75.1	77.7	52.7
Other vegetables	25, 28, 29, 31–33, 35, 38	193.0	161.8	96.7
Soya and soya products	18–22	57.5	38.1	25.9
Rice and rice products	1, 2	342.2	312.1	190.1
Wheat and wheat products	3, 4, 6–9	96.4	88.8	65.1
Other cereals	10–12	8.3	7.6	4.8
Fresh and processed fruits	39, 40, 42, 43	86.0	81.9	76.8
Juices	36, 45	22.4	20.0	16.3
Marine and migratory fish	48–52, 60	37.1	25.3	14.9
Crustaceans and molluscs	53–59	42.8	29.2	17.2
Eggs	70	34.3	33.6	23.8
Beef/cattle	61	13.6	17.6	9.5
Pork (excluding wild boar)	62, 63	43.1	55.9	30.1
Poultry	65, 66	21.4	27.7	15.0
Other meat	64, 67	1.7	2.2	1.2
Milk	71, 73	83.2	259.7	174.8
Milk and dairy products	72, 74	7.8	24.4	16.4
Mushrooms	46	16.5	13.2	8.6
Algae	47	10.9	8.7	5.8

D. Domestic production

29. Much of the food consumed in Japan is imported from overseas. It was therefore important to take into account the fraction of food that is domestically produced. Data for food production in Japan were provided in the form of food balance sheets by MHLW [MHLW, 2010]. The data relate to food production and imports in 2010. The production data were used to calculate the percentages of domestically produced food in each category, see table 2. The numbers were rounded to avoid the impression of unrealistically high precision.

Table 2. Percentage of domestically produced marketed food in Japan

Food category	*Sub-classifications (see attachment C-8 and supplement B)*	*Marketed food domestically produced (%)*
Leafy vegetables	27, 30, 34, 37	80
Root vegetables	13–16, 26	80
Other vegetables	25, 28, 29, 31–33, 35, 38	80 [a]
Soya and soya products	18–22	10
Rice and rice products	1, 2	100
Wheat and wheat products	3, 4, 6–9	10
Other cereals	10–12	1
Fresh and processed fruits	39, 40, 42, 43	40
Juices	36, 45	40 [a]
Marine and migratory fish	48–52, 60	50
Crustaceans and molluscs	53–59	50 [a]
Eggs	70	100
Beef/cattle	61	40
Pork (excluding wild boar)	62, 63	50
Poultry	65, 66	70
Other meat	64, 67	40 [a]
Milk	71, 73	100
Other dairy products	72, 74	50
Mushrooms	46	90
Algae	47	unknown

[a] *Estimates based on related groups.*

E. Activity concentrations of radionuclides in food

30. In order to estimate the concentrations of radionuclides in terrestrial foodstuffs following deposition on the ground, a dynamic food chain model is required, so that the time dependence of the concentrations can be determined. The model should also be able to take into account the time of year when the accidental releases occurred and Japanese agricultural practices. In the absence of a Japanese-specific model, the Committee decided to use the FARMLAND model [Brown and Simmonds, 1995] to estimate the activity concentrations of key radionuclides in various foodstuffs as a function of time on the basis of estimated or measured deposition densities on the ground. This model was used to calculate the food transfer factors ($Food_{TF}$) — the activity concentration per unit deposition density — for a number of foodstuffs, including cereals, leafy green vegetables, root vegetables, orchard fruit, soft fruit, cow milk, meat and liver, and sheep meat and liver.

31. The FARMLAND model is based on general agricultural practices and soil types in a temperate climate to reflect conditions in northern Europe. The model was adapted as far as possible to Japanese agricultural practices and conditions. Several scientific papers studying the transfer of radionuclides from soil to plants in Japanese conditions were reviewed and the results compared with the existing parameters in the FARMLAND model to obtain Japanese-specific transfer factors for use in the model (see supplement C). The FARMLAND model simulates the deposition of radionuclides from air to soil and to plants that are growing at the time of deposition. The model takes into account weathering from the surface of plants, translocation from the surface of plants to internal tissues (plus seeds, fruits and tubers, as

appropriate) and also the uptake of radionuclides from soil via the roots. The model was run to allow for fallow periods in Japan. Account was also taken of whether animals were grazing outdoors at the time of the accident or being given stored feed. Full details of the agricultural practices assumed and the parameters used in the FARMLAND model are given in supplement C.

32. The parameters in the FARMLAND model were also compared with the values given in the compilation of data for modelling the transfer of radionuclides in both terrestrial and freshwater environments published by IAEA [IAEA, 2009; IAEA, 2010].

33. A key food produced and consumed in Japan and neighbouring countries is rice and it was recognized that the cereal component of the FARMLAND model may not adequately reflect the agricultural conditions for rice. Particularly important is the fact that rice is usually grown in flooded, paddy fields. The physical and chemical conditions of the soil are different from those assumed in the FARMLAND model. One of the existing models for radionuclide transfer to rice that was considered in the review was the model, ECOREA-RICE, developed in the Republic of Korea [Keum et al., 2004]. Although it was not possible to obtain sufficient data to fully implement it, it was noted that the ECOREA-RICE model does share a similar structure with the cereal component of the FARMLAND model. The results from the two models were compared to give confidence in the use of the cereal component of the FARMLAND model adapted for rice. The importance of specific consideration being given to rice is highlighted in a paper by Uchida et al. [Uchida et al., 2007] which states that a “safety assessment for people who live in Japan should consider rice and vegetables as critical food”.

34. The addition of a rice component to the FARMLAND model was the most significant adaptation made in the dose assessment; the structure of the cereal component was retained but with revised transfer rates based on the findings of Uchida et al [Uchida et al., 2007; Uchida et al., 2009]. Data were available for the majority of radionuclides of interest.

35. The adapted FARMLAND model was used for the assessment of doses from ingestion for Japan and the limited assessment for nearby countries. Priority was given to the assessment of doses from ingestion of the radionuclides that are expected to give the most significant doses, namely ^{131}I, ^{134}Cs and ^{137}Cs.

36. The results obtained from the FARMLAND model for Japanese conditions and for a release on 12 March 2011 are presented in supplement D.

F. Food restrictions

37. Doses both with and without restrictions on the supply of foodstuffs being taken into account were estimated. It was understood that no restrictions on the supply of foodstuffs were applied in countries outside Japan (other than in restricting imports from Japan).

38. The levels used to apply restrictions on the supply of foodstuffs in Japan from March 2011 until April 2012 are given in table 3. These were taken from the MHLW website [MHLW, 2011].

Table 3. Activity concentrations of radionuclides at which restrictions on the supply of foodstuffs were introduced in Japan March 2011 through March 2012

Provisional regulation values of radioactive material in foodstuffs in accordance with the Food Sanitation Act

Radionuclide	*Foodstuff*	*Activity concentration (Bq/kg)*
Radioiodine Representative radionuclides among mixed radionuclides: ^{131}I)	Drinking water Milk, dairy products[a]	300
	Vegetables (except root vegetables and tubers) Fishery products	2 000
Radiocaesium	Drinking water Milk, dairy products	200
	Vegetables Grain Meat, eggs, fish, etc.	500
Uranium	Infant foods Drinking water Milk, dairy products	20
	Vegetables Grain Meat, eggs, fish, etc.	100
Alpha-emitting isotopes of plutonium and transuranic elements （Total activity concentration of ^{238}Pu,^{239}Pu, ^{240}Pu, ^{242}Pu, ^{241}Am, ^{242}Cm, ^{243}Cm, ^{244}Cm)	Infant foods Drinking water Milk, dairy products	1
	Vegetables Grain Meat, eggs, fish, etc.	10

[a] *Guidance was provided so that materials with activity concentrations exceeding 100 Bq/kg were not used in milk supplied for direct consumption or used in making powdered milk for babies.*

39. The values given above for radiocaesium were updated from 1 April 2012 and the following information was taken from an English translation of a MHLW document [MHLW, 2011].

Table 4. Activity concentrations of radiocaesium at which restrictions on supply of foodstuffs applied from 1 April 2012

Foodstuff category	*Activity concentration (Bq/kg)*
Drinking water	10
Milk	50
General foods	100
Infant foods	50

40. In the regions of Japan with the highest deposition densities, extensive remediation work was under way or planned at the time that this report was being prepared to reduce exposures. The effectiveness of this work remains to be determined.

G. Dose calculations

41. The dose calculations were performed using a Python™ script implemented in the ArcGIS® software of Esri [Esri, 2014; Python, 2014]. Levels of deposition density of radionuclides from both measurements and the atmospheric dispersion modelling were used in a form which was converted to an ArcGIS® feature class. The script tested whether the activity concentrations in food exceeded the threshold for the restrictions on the supply of foodstuffs and subsequently doses were calculated using equations 1 and 2.

42. The results of these calculations gave the estimated doses from ingestion of terrestrial food as a function of the type of food and radionuclide and the total doses from all types of food and radionuclides. Two sets of doses were estimated. The first set was based on the deposition densities of radionuclides on the ground, estimated from the atmospheric dispersion modelling (attachment C-9). The second set was based on the deposition densities of radionuclides on the ground obtained from the monitoring data (attachments C-1 and C-2). The activity concentrations of radionuclides in food estimated from the atmospheric dispersion modelling were compared with the measured levels where data were available for validation purposes.

V. DOSES FROM THE INGESTION OF AQUATIC FOOD AND DRINKING WATER

A. Individual doses from aquatic food

43. The measurements of activity concentration of radionuclides in food in the FAO/IAEA/MAFF database included values for both marine and freshwater fish and these provided part of the input for the assessment of dose in the first year following the accident. Extensive restrictions were introduced on the supply of fish caught in Fukushima Prefecture and these were taken into account as for other food by including the data only for food that was marketed.

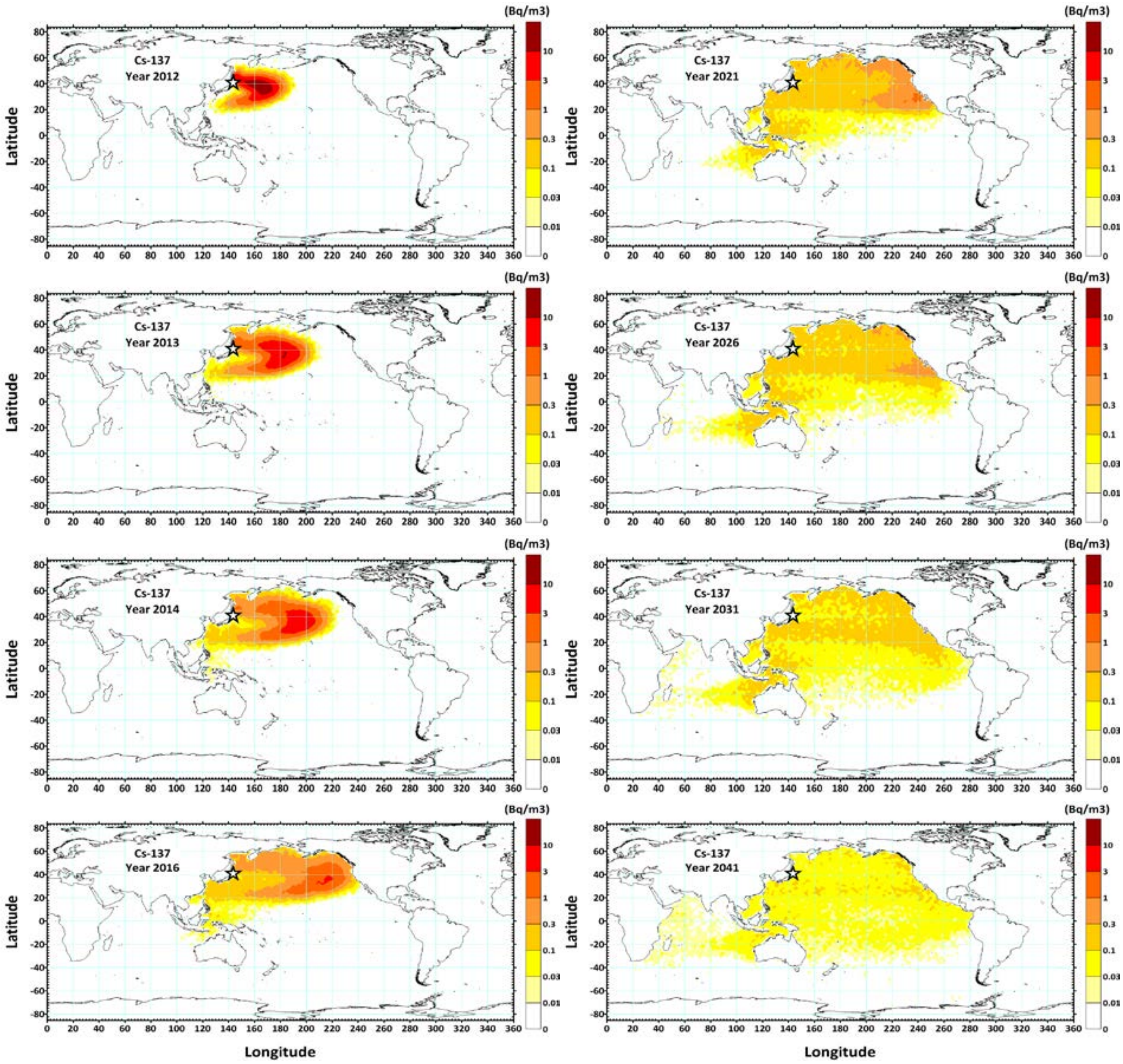
44. In order to estimate doses from the ingestion of marine food in future years, activity concentrations of radionuclides in key marine foodstuffs were estimated from predicted activity concentrations in seawater for 2, 5 and 10 years following the accident. These predictions were based on work by Nakano and Povinec [Nakano and Povinec, 2012]. Concentration factors were used to estimate the activity concentration in aquatic food (marine algae, fish and shellfish) from the predicted activity concentrations in seawater. It was assumed that all marine food consumed would be obtained from the northern Pacific Ocean, which is likely to be cautious as a fraction of the seafood consumed is probably imported from areas with lower activity concentrations. Some seafood harvested close to the FDNPS could have higher activity concentrations than estimated here, but because these foods are monitored and restrictions applied, no account was taken of these activity concentrations in the assessment of doses from intakes of these foods. Doses were also estimated for 20 and 50 years after the accident on the basis of observations of the decrease in ^{137}Cs concentrations with time following the fallout from the atmospheric testing of nuclear weapons in the late 1950s and early 1960s [Aoyama et al., 2012].

45. The data on intake of fish, shellfish and marine algae given in table 1 were used to assess the doses from ingestion. The dose coefficients for ingestion were taken from ICRP [ICRP, 2012, Publication 119] and are given in supplement A. Doses in the second and

subsequent years after the accident were assumed to be due to ^{134}Cs and ^{137}Cs only. The activity concentrations in the sea were available only for ^{137}Cs but it is known that initially those of ^{134}Cs and ^{137}Cs were approximately the same. Therefore, the ^{134}Cs concentrations were based on those of ^{137}Cs, with allowance being made for the differences in the half-lives of the two radionuclides.

46. The results of modelling of the dispersion of ^{137}Cs that were used as input to the dose assessment are shown in figure I. Details about the methodologies for the simulation are described in [Nakano and Povinec, 2012].

Figure I. Estimated distributions of ^{137}Cs in surface seawater from 2012 to 2041
(Modified after [Nakano and Povinec, 2012])



47. *Two years after the accident.* Radiocaesium released from FDNPS was estimated to have reached about two thirds of the northern Pacific Ocean by November 2012 (20 months after the accident). In general, the activity concentration of ^{137}Cs was estimated to be below 0.4 Bq/m^3; all concentrations were estimated to be below 0.7 Bq/m^3. Therefore, two years after the accident, an activity concentration of ^{137}Cs of 0.4 Bq/m^3 was considered to be representative for seawater of the northern Pacific Ocean. However, because of biological

processes, the concentration of radiocaesium in fish is known to decrease more slowly than its concentration in seawater. Activity concentrations of ^{134}Cs and ^{137}Cs in seawater of 0.35 and 0.7 Bq/m^3, respectively, were cautiously assumed for estimating doses from ingestion of seafood two years after the accident.

48. *Five years after the accident.* By November 2016 (5.5 years after the accident), the radiocaesium was predicted to have reached most of the northern Pacific Ocean, including the North American coast above latitude 30°N. In general, the activity concentrations of ^{137}Cs were predicted to be below 0.1 Bq/m^3. Only a limited area was predicted to have activity concentrations between 0.1 and 0.2 Bq/m^3 and areas of negligible size were predicted to have activity concentrations of more than 0.2 Bq/m^3. Activity concentrations of ^{134}Cs and ^{137}Cs in seawater of 0.037 and 0.2 Bq/m^3, respectively, were cautiously assumed in order to estimate doses from the ingestion of seafood 5 years after the accident.

49. *Ten years after the accident.* By November 2019 (8.5 years after the accident), the radiocaesium was predicted to have reached all of the northern Pacific Ocean. The activity concentrations of ^{137}Cs were predicted to be generally below 0.1 Bq/m^3, with only very few areas with concentrations greater than this. The estimate of doses at 10 years after the accident from the ingestion of seafood was based cautiously on an activity concentration of ^{137}Cs in seawater of 0.1 Bq/m^3. The activity concentration of ^{134}Cs was assumed to be negligible 10 years after the accident.

50. *Twenty and 50 years after the accident.* The overall decrease in the concentration of ^{137}Cs in the northern Pacific Ocean was assumed to be exponential with a half-life of about 20 years on the basis of long-term observations of the ^{137}Cs concentrations resulting from the testing of nuclear weapons in the atmosphere [IAEA, 2005]. Thus, 20 and 50 years after the accident, the activity concentrations of ^{137}Cs in seawater were assumed to be 0.07 and 0.025 Bq/m^3, respectively. These values were used to estimate the doses from the ingestion of seafood 20 and 50 years, respectively, after the accident.

51. The concentration factors used to estimate activity concentrations of radiocaesium in different types of seafood are given in table 5.

Table 5. Concentration factors used for marine foodstuffs [IAEA, 2004]

Foodstuff category	*Concentration factor (L/kg fresh food)*
Macroalgae	50
Marine fish	100
Crustaceans	50[a]
Molluscs	60

[a] *Because the data on food intake (table 1) did not distinguish between crustaceans and molluscs, a single concentration factor of 60 L/kg for both was assumed in the assessment.*

B. Individual doses from ingestion of drinking water

52. Following the accidental releases from FDNPS, elevated levels of some radionuclides were measured in drinking water supplies at some locations for limited periods of time. These measurements were used to estimate the doses to representative individuals from the ingestion of radionuclides in drinking water. Only a limited set of measurements were above the limits of detection and in order to investigate the likely range in doses, three approaches were considered. In the first, all activity concentrations listed as below the limits of detection were

assumed to be zero; in the second, all activity concentrations listed as below the limits of detection were assumed to be 5 Bq/L (the detection limits ranged between 5 and 15 Bq/L); in the third, if subsequent measurements were also reported to be below the limits of detection, the activity concentrations were assumed to be zero but if they were reported to be above the limits of detection, they were assumed to be 5 Bq/L. In all cases, data points listed as N/A were treated as zero. In addition, all activity concentrations less than the limits of detection for ^{131}I and ^{132}I were assumed to be zero if the measurements were made more than 80 days after the accident. The intakes of drinking water given by the World Health Organization (WHO) were used to estimate doses. There were relatively few instances where measurable levels of radionuclides were found in drinking water and these lasted for only a short time. Drinking water was therefore not a significant source of long-term exposure of the Japanese population and no attempt was made to model the doses from drinking water beyond the first year. Supplement E gives further information on the methodology adopted for the drinking water pathway.

VI. COMMENTARY ON UNCERTAINTIES

53. The important sources of uncertainty in the dose assessment were identified and assessed both quantitatively and qualitatively. The use of different methods to assess doses from ingestion also provided insight as to the possible magnitude of uncertainty in the assessment. Consideration was also given to the limitations of the FAO/IAEA/MAFF food database regarding the frequency of sampling, the spatial distribution of samples and how this varied with time, plus the type of food items collected. Some sensitivity analyses were carried out on the modelled results to determine the doses that might have been received if food had been consumed in the first few days after the accident before the restrictions were introduced.

Supplement A. Dose coefficients

A1. The list of radionuclides corresponds to that included in the source term used in the WHO assessment of dose arising from the FDNPS accident [WHO, 2012]. These dose coefficients were all taken from [ICRP, 2012, Publication 119]. The coefficients expressed in terms of equivalent doses to organs given by ICRP were assumed to be numerically equal to the coefficients expressed in terms of absorbed dose, because the doses of interest are due to low-LET radiation.

Table A1. Committed effective dose coefficients for ingestion for members of the public

Radionuclide	*Committed effective dose coefficient (Sv/Bq)*		
	Adults	*10-year-old*	*One-year-old*
Ruthenium-103	7.3×10^{-10}	1.5×10^{-9}	4.6×10^{-9}
Ruthenium-106	7.0×10^{-9}	1.5×10^{-8}	4.9×10^{-8}
Tellurium-127m	2.3×10^{-9}	5.2×10^{-9}	1.8×10^{-8}
Tellurium-129m	3.0×10^{-9}	6.6×10^{-9}	2.4×10^{-8}
Tellurium-131m	1.9×10^{-9}	4.3×10^{-9}	1.4×10^{-8}
Tellurium-132	3.8×10^{-9}	8.3×10^{-9}	3.0×10^{-8}
Iodine-131	2.2×10^{-8}	5.2×10^{-8}	1.8×10^{-7}
Iodine-132	2.9×10^{-10}	6.2×10^{-10}	2.4×10^{-9}
Iodine-133	4.3×10^{-9}	1.0×10^{-8}	4.4×10^{-8}
Iodine-135	9.3×10^{-10}	2.2×10^{-9}	8.9×10^{-9}
Xenon-133	-	-	-
Caesium-134	1.9×10^{-8}	1.4×10^{-8}	1.6×10^{-8}
Caesium-137	1.3×10^{-8}	1.0×10^{-8}	1.2×10^{-8}
Barium-137m	-	-	-
Barium-140	2.6×10^{-9}	5.8×10^{-9}	1.8×10^{-8}
Cerium-141	7.1×10^{-10}	1.5×10^{-9}	5.1×10^{-9}
Cerium-144	5.2×10^{-9}	1.1×10^{-8}	3.9×10^{-8}

Table A2. Committed absorbed dose coefficients for the thyroid for ingestion for members of the public

Radionuclide	*Committed absorbed dose coefficient for the thyroid (Sv/Bq)*		
	Adults	*10-year-old*	*One-year-old*
Ruthenium-103	6.7×10^{-11}	1.3×10^{-10}	4.1×10^{-10}
Ruthenium-106	1.4×10^{-9}	2.8×10^{-9}	8.7×10^{-9}
Tellurium-127m	3.1×10^{-9}	7.7×10^{-9}	3.4×10^{-8}
Tellurium-129m	4.6×10^{-9}	1.1×10^{-8}	5.1×10^{-8}
Tellurium-131m	1.8×10^{-8}	4.5×10^{-8}	1.5×10^{-7}
Tellurium-132	3.1×10^{-8}	7.5×10^{-8}	3.2×10^{-7}
Iodine-131	4.3×10^{-7}	1.0×10^{-6}	3.6×10^{-6}
Iodine-132	3.4×10^{-9}	8.3×10^{-9}	3.5×10^{-8}
Iodine-133	8.2×10^{-8}	2.0×10^{-7}	8.6×10^{-7}
Iodine-135	1.6×10^{-8}	3.9×10^{-8}	1.7×10^{-7}
Xenon-133	-	-	-
Caesium-134	1.8×10^{-8}	1.4×10^{-8}	1.6×10^{-8}
Caesium-137	1.3×10^{-8}	9.7×10^{-9}	1.1×10^{-8}
Barium-137m	-	-	-
Barium-140	8.7×10^{-11}	4.2×10^{-10}	8.3×10^{-10}
Cerium-141	3.0×10^{-13}	8.6×10^{-13}	4.5×10^{-12}
Cerium-144	1.2×10^{-11}	2.2×10^{-11}	6.8×10^{-11}

Table A3. Committed absorbed dose coefficients for the colon for ingestion for members of the public

Radionuclide	*Committed absorbed dose coefficient for the colon (Sv/Bq)*		
	Adults	*10-year- old*	*One-year-old*
Ruthenium-103	4.3×10^{-9}	9.2×10^{-9}	2.9×10^{-8}
Ruthenium-106	4.5×10^{-8}	1.0×10^{-7}	3.3×10^{-7}
Tellurium-127m	6.2×10^{-9}	1.4×10^{-8}	4.6×10^{-8}
Tellurium-129m	1.4×10^{-8}	3.2×10^{-8}	1.1×10^{-7}
Tellurium-131m	5.9×10^{-9}	1.3×10^{-8}	4.0×10^{-8}
Tellurium-132	1.3×10^{-8}	2.7×10^{-8}	8.5×10^{-8}
Iodine-131	1.2×10^{-10}	2.8×10^{-10}	1.5×10^{-9}
Iodine-132	4.6×10^{-11}	8.9×10^{-11}	2.5×10^{-10}
Iodine-133	1.1×10^{-10}	2.3×10^{-10}	7.8×10^{-10}
Iodine-135	7.3×10^{-11}	1.5×10^{-10}	4.1×10^{-10}
Xenon-133	-	-	-
Caesium-134	2.1×10^{-8}	1.7×10^{-8}	2.4×10^{-8}
Caesium-137	1.5×10^{-8}	1.3×10^{-8}	2.3×10^{-8}
Barium-137m	-	-	-
Barium-140	1.7×10^{-8}	3.5×10^{-8}	1.2×10^{-7}
Cerium-141	5.5×10^{-9}	1.2×10^{-8}	4.0×10^{-8}
Cerium-144	4.2×10^{-8}	9.2×10^{-8}	3.1×10^{-7}

Supplement B. Food categories and related data

B1. Table B1 gives the subcategories used in this assessment, and the corresponding classifications used by the Ministry of Health, Labour and Welfare (MHLW) as shown in table B4 below. The tables in this supplement use data provided to the Committee by the Japanese authorities as indicated and are considered to be primary data as described in table A1 of appendix A of annex A.

Table B1. Categories of food used in this assessment and the corresponding MHLW classifications

Category	*Description*	*MHLW classification*
Leafy vegetables	Leafy vegetables, cabbage, Chinese cabbage, spinach	27, 30, 34, 37
Root vegetables	Potatoes, starch/starch products, sweet potatoes, carrots	13–16, 26
Other vegetables	All other vegetables (excluding vegetable juices)	25, 28, 29, 31–33, 35, 38
Soya and soya products	Soybean/soybean products, other pulses and their products	18–22
Rice and rice products	Rice/rice products	1, 2
Wheat and wheat products	Wheat/wheat products	3, 4, 6–9
Other cereals	Other cereals/other cereal products (e.g. buckwheat, corn)	10–12
Fresh and processed fruits	Fruits	39, 40, 42, 43
Juices	Fruit juices, vegetable juices	36, 45
Marine and migratory fish	Raw fish, fish ham and sausage	48–52,60
Crustaceans and molluscs	Shellfish, prawn, shrimp, crab, squid, octopus, most processed seafood	53–59
Poultry eggs	Poultry eggs	70
Other eggs	Other eggs	
Beef/cattle	Beef	61
Pork (excluding wild boar)	Pork	62, 63
Poultry	Chicken and other poultry	65, 66
Other meat	Offal, other animal meat	64, 67
Milk	Milk, fermented milk	71, 73
Other dairy products	Other dairy products	72, 74
Mushrooms	Mushrooms	46
Algae	Algae	47

Table B2. Percentage of each food category produced in Japan (taken from table B5) and the food categories included in the FARMLAND model

Category	*Domestic production (%)*	*FARMLAND model*
Leafy vegetables	80	Leafy green vegetables
Root vegetables	80	Potatoes
Other vegetables	80 [a]	Leafy green vegetables
Soya and soya products	10	-
Rice and rice products	100	Rice
Wheat and wheat products	10	Cereal
Other cereals	1	Cereal
Fresh and processed fruits	40	Orchard fruit
Juices	40 [a]	-
Marine and migratory fish	50	-
Crustaceans and molluscs	50 [a]	-
Eggs	100	-
Beef/cattle	40	Beef
Pork (excluding wild boar)	50	Pork (based on cereal feed)
Poultry	70	Chicken meat (based on cereal feed)
Other meat	40 [a]	Cow liver
Milk	100	Cow milk
Other dairy products	50	Cow milk
Mushrooms	90	-
Algae	unknown	-

[a] *Estimates based on related groups.*

Table B3. Food excluded from the categories

Food excluded	*MHLW small classifications*	*Justification*
Japanese buns	5	
Sugar and sweetener	17	Heavily processed before reaching consumer
Other pulses and its products	23	
Nuts and seeds	24	
Bananas	41	
Jams	44	
Whale meat	68	Intake very small
Other meat, processed products	69	Category not well defined, intake negligible
Others (milk)	75	
Fats and oils	76–80	Heavily processed before reaching consumer
Confectioneries	81–85	Heavily processed before reaching consumer
Beverages	86–91	Mainly containing water (especially highest consumed types such as tea and coffee)
Seasonings and spices	92–98	Heavily processed before reaching consumer

Table B4. Japanese Ministry of Health, Labour and Welfare food classification numbers

Food categories	*Small classification number*
Cereals	**1–12**
Rice/rice products	1, 2
Rice	1
Rice products	2
Wheat/wheat products	3–9
Flour	3
Bread (except Japanese buns)	4
Japanese buns	5
Udon (Japanese noodles)/Chinese noodles	6
Precooked Chinese noodles	7
Pasta	8
Other wheat products	9
Other cereals/other cereal products	10–12
Buckwheat/buckwheat products	10
Corn/corn products	11
Others	12
Potatoes and starches	**13–16**
Potatoes/Potato products	13–15
Sweet potatoes/sweet potato products	13
Potatoes/potato products	14
Others	15
Starch/starch products	16
Sugar and sweetener	**17**
Pulses	**18–23**
Soybean/soybean products	18–22
Soybeans (whole beans and its products)	18
Tofu (bean curd)	19
Age (fried tofu)	20
Natto (fermented soybeans)	21
Other soybean products	22
Other pulses and its products	23
Nuts and seeds	**24**

Food categories	*Small classification number*
Vegetables	**25–38**
Green and yellow vegetables	25–29
Tomatoes	25
Carrot	26
Spinach	27
Sweet peppers	28
Others	29
Other vegetables	30–35
Cabbage	30
Cucumber	31
Daikon (Japanese white radish)	32
Onion	33
Chinese cabbage	34
Others	35
Vegetable juices	36
Pickles	37, 38
Leaf vegetables	37
Japanese white radish and others	38
Fruits	**39–45**
Fruits	39–43
Strawberry	39
Citrus fruits	40
Banana	41
Apple	42
Others	43
Jams	44
Fresh fruit/fruit juice beverages	45
Mushrooms	**46**
Algae	**47**
Fish and shellfish	**48–60**
Raw fish and shellfish	48–55
Mackerels, sardines	48
Salmon, trout	49
Sea breams, flatfish	50
Tuna, marlins and swordfish	51
Other raw fish	52
Shellfish	53
Squid, octopus	54
Prawn, shrimp, crab	55

Food categories	*Small classification number*
Seafood, processed products	56–60
Seafood (salted, semi-dried and fully-dried)	56
Seafood (canned)	57
Seafood (tsukudani)	58
Seafood (fish paste)	59
Fish ham and sausage	60
Meat	**61–69**
Animal meat	61–64
Beef	61
Pork	62
Ham and sausage	63
Others	64
Chicken and poultry	65, 66
Chicken	65
Other poultry	66
Offal	67
Others	68, 69
Whale	68
Other, processed products	69
Eggs	**70**
Milk	**71–75**
Milk and dairy products	71–74
Milk	71
Cheese	72
Fermented milk and lactic acid	73
Other dairy products	74
Others	75
Fats and oils	**76–80**
Butters	76
Margarines	77
Vegetable fats and oils	78
Animal fats	79
Others	80
Confectioneries	**81–85**
Traditional confectioneries	81
Cakes and pastries	82
Biscuits	83
Candies	84
Others	85

Food categories	*Small classification number*
Beverages	**86–91**
Alcoholic beverages	86–88
Sake	86
Beer	87
Wines and spirits	88
Other beverages	89–91
Teas	89
Coffees and cocoas	90
Others	91
Seasonings and spices	**92–98**
Seasonings	92–97
Sources	92
Soy sauces	93
Salts	94
Mayonnaise	95
Miso (soybean paste)	96
Other seasonings	97
Spices and others	98

Table B5. Food supply balance sheet for Japan in 2010 [MAFF, 2012]

Item			*Quantity (10^6 kg)*						*Domestic supply (%)*	
			Domestic production	*Foreign trade*		*Stock variation*	*Domestic supply*	*Supply less variation*		
				Imported	*Exported*				*Imported*	*Domestic*
1.		Cereal grains	9 317	26 037	201	-- 17	35 170	35 153	74	26
	a.	Husked rice (brown rice)	8 554	831	201	-- 240	9 424	9 184	9	91
	b.	Wheat	571	5 473	0	-- 340	6 384	6 044	91	9
	c.	Barley	161	1 902	0	-- 35	2 098	2 063	92	8
	d.	Maize (corn)	0	16 047	0	531	15 516	16 047	100	0
	e.	Sorghum	0	1 473	0	47	1 426	1 473	100	0
	f.	Others	31	311	0	20	322	342	91	9
2.		Vegetables	15 201	7 555	9	30	22 717	22 747	33	67
	a.	Fruiting vegetables	3 187	1 357	0	0	4 544	4 544	30	70
		Fruit-like vegetables	735	65	0	0	800	800	8	92
	b.	Leafy and stem vegetables	5 680	911	0	0	6 591	6 591	14	86
	c.	Root and tuber vegetables	6 017	1 539	9	0	7 547	7 547	20	80
		Sweet potatoes	864	65	2	0	927	927	7	93
		Potatoes	2 290	959	2	0	3 247	3 247	30	70
		Others	2 863	515	5	0	3 373	3 373	15	85
	d.	Pulses	317	3 748	0	30	4 035	4 065	92	8
		Soybeans	223	3 456	0	37	3 642	3 679	94	6
		Others	94	292	0	- 7	393	386	76	24

Item			Quantity (10^6 kg)						Domestic supply (%)	
			Domestic production	Foreign trade		Stock variation	Domestic supply	Supply less variation		
				Imported	Exported				Imported	Domestic
3.	Fruits		2 960	4 756	42	- 45	7 719	7 674	62	38
	a.	Satsuma or satsuma mandarin	786	0	2	- 44	828	784	0	100
	b.	Apples	787	592	23	- 1	1 357	1 356	44	56
	c.	Others	1 387	4 164	17	0	5 534	5 534	75	25
4.	Meat		3 215	2 588	13	21	5 769	5 790	45	55
	a.	Beef	512	731	1	24	1 218	1 242	59	41
	b.	Pork	1 277	1 143	1	3	2 416	2 419	47	53
	c.	Chicken	1 417	674	11	- 7	2 087	2 080	32	68
	d.	Others	6	40	0	0	46	46	87	13
	e.	Whale	3	0	0	1	2	3	0	100
5.	Chicken eggs		2 506	114	1	0	2 619	2 619	4	96
6.	Cattle milk and milk products		7 631	3 528	24	- 231	11 366	11 135	32	68
	a.	Marketed for direct consumption	4 180	0	3	0	4 177	4 177	0	100
	b.	Marketed for further processing	3 451	3 528	21	- 231	7 189	6 958	51	49
		i) Evaporated milk and sweetened condensed milk	37	1	0	- 3	41	38	3	97
		ii) Condensed skimmed milk	5	0	0	0	5	5	0	100
		iii) Whole milk powder	14	0	0	0	14	14	0	100
		iv) Skimmed milk powder	149	3	0	- 11	163	152	2	98
		v) Powdered infant formula	25	0	0	0	25	25	0	100
		vi) Cheeses	46	199	0	0	245	245	81	19
		vii) Butter	70	2	0	- 12	84	72	3	97

Item			Quantity (10^6 kg)						Domestic supply (%)	
			Domestic production	Foreign trade		Stock variation	Domestic supply	Supply less variation		
				Imported	Exported				Imported	Domestic
7.	Fishes and shellfishes		4 166	3 268	702	- 33	6 765	6 732	49	51
	a.	Fresh, chilled or frozen	2 220	1 138	599	11	2 748	2 759	41	59
	b.	Salted, dried or smoked	1 727	2 027	96	- 43	3 701	3 658	55	45
	c.	Canned	219	103	7	- 1	316	315	33	67
8.	Seaweeds		106	47	2	0	151	151	31	69
9.	Starches		2 580	129	0	- 52	2 761	2 709	5	95
10.	Sugar									
	a.	Raw sugar	175	1 250	0	- 109	1 534	1 425	88	12
	b.	Refined sugar	2 023	406	1	- 25	2 453	2 428	17	83
	c.	Brown sugar	23	11	0	5	29	34	32	68
	d.	Molasses	106	121	6	- 6	227	221	55	45
11.	Fats and oils		1 980	929	14	- 25	2 920	2 895	32	68
	a.	Vegetable oils and fats	1 657	846	12	- 22	2 513	2 491	34	66
	a.	i)Soybean	468	18	3	- 6	489	483	4	96
		ii)Rapeseed	993	9	1	21	980	1 001	1	99
		iii)Coconut	0	47	0	- 5	52	47	100	0
		iv)Others	196	772	8	- 32	992	960	80	20
	b.	Animal oils and fats	323	83	2	- 3	407	404	21	79
		i)Fish and fin whale	60	21	1	- 16	96	80	26	74
		ii)Cattle fat and tallow	73	59	0	- 1	133	132	45	55
		iii)Others	190	3	1	14	178	192	2	98

Item			Quantity (10^6 kg)						Domestic supply (%)	
			Domestic production	Foreign trade		Stock variation	Domestic supply	Supply less variation		
				Imported	Exported				Imported	Domestic
12.	Fermented soybean paste		467	8	10	2	463	465	2	98
13.	Soy sauce		845	1	18	- 1	829	828	0	100
14.	Others		2 337	2 346	0	6	4 677	4 683	50	50
		Mushrooms	464	73	0	0	537	537	14	86
		Alcoholic Beverages	8 755	516	56	397	8 818	9 215	6	94

Supplement C. Model parameters and agricultural practices used in the FARMLAND model

A. The FARMLAND model modified for Japanese conditions

C1. The FARMLAND model [Brown and Simmonds, 1995] was used for the assessment of activity concentrations in food resulting from deposition of radionuclides on the ground. Although no Japanese-specific model of the transfer of radionuclides through the food chain was available, several changes to the FARMLAND model were implemented to adapt it more closely to the Japanese conditions.

C2. The dates of sowing and harvesting of crops in the modified FARMLAND model were based on data provided by the Japanese experts. Where insufficient data were available, the default values in the FARMLAND model were used. Table C1 is a summary of the growing and harvesting dates assumed for the crops.

Table C1. Agricultural practices for crops grown in Japan

FARMLAND crop	*Start of growing season*	*Start or end of harvest*
Cereal	1 Feb.	1 June (start)
Leafy green vegetables	Growing all year round, continuous cropping	
Orchard fruit	1 Apr.	15 Sept. (start)
Soft fruit	1 Apr.	31 Oct. (end)
Root vegetables	1 Feb.	15 Nov. (end)
Potatoes	1 Feb.	15 Nov. (end)
Pasture	Growing all year round, silage harvested 15 Sept.	
Rice	1 June	1 Oct. (start)

C3. The animal husbandry practices assumed for the animal component of the FARMLAND model are summarized in table C2. In the absence of other information, it was assumed that pigs and chickens were kept indoors and were fed solely on grain grown domestically (activity concentrations taken from the cereal component of the model).

Table C2. Animal husbandry practices for animals reared in Japan

FARMLAND animal	*Husbandry practices*
Cows	Indoors, fed stored grass silage from 1 Nov.–15 Apr. Outdoors, grazing pasture from 15 Apr.–1 Nov.
Sheep	Outdoors, grazing pasture all year round
Pigs	Indoors, fed grain all year round
Chickens	Indoors, fed grain all year round

C4. Available literature on the transfer of radionuclides to plants in Japan was reviewed to inform the choice of soil-to-plant concentration ratios [Ban-Nai et al., 1995; Ban-Nai et al., 1999; Ban-nai and Muramatsu, 2002, 179; Ban-Nai and Muramatsu, 2003; IAEA, 2010; Uchida and Tagami, 2007; Uchida et al., 2007; Uchida et al., 2007; Uchida et al., 2009]. The default concentration ratios were revised where there was sufficient evidence to support a different value. The final values used are presented in table C3.

Table C3. Soil-to-plant concentrations ratios

Crop	*Concentration ratio, caesium*	*Concentration ratio, iodine*
Cereal	1×10^{-2}	5×10^{-4}
Leafy green vegetables	1×10^{-2}	1×10^{-3}
Orchard fruit	3×10^{-3}	2×10^{-2}
Soft fruit	3×10^{-3}	2×10^{-2}
Root vegetables	7×10^{-3}	2×10^{-2}
Potatoes	6×10^{-3}	2×10^{-2}
Pasture	3×10^{-2}	2×10^{-2}
Rice	5×10^{-3}	2×10^{-3}

C5. Default values were used for other parameters in the FARMLAND model, such as soil density, plant interception factors and weathering half-lives. Discussion of these is included in [Brown and Simmonds, 1995] and tables C4–C7 contain the details of these parameters.

Table C4. Soil migration rate constants

Soil model	*Depth*	*Rate constant (per day)*
Well-mixed soil [a]	From 0–30 cm to deeper soil	1.90×10^{-5}
Undisturbed land [b]	From 0–1 cm to 1–5 cm	6.65×10^{-4}
	From 1–5 cm to 5–15 cm	1.72×10^{-4}
	From 5–15 cm to 15–30 cm	1.07×10^{-4}
	From 15–30 cm to 5–15 cm	4.03×10^{-6}
	From 15–30 cm to deeper soil	3.80×10^{-5}

[a] *Applies to all crop models except pasture and hay/silage.*
[b] *Applies to pasture and hay/silage models.*

Table C5. Element-independent parameter values used in the FARMLAND model for crops

Parameter	*Green vegetables*	*Cereal/rice*	*Pasture*	*Hay/silage*	*Root vegetables /potatoes*	*Orchard fruit*	*Soft fruit*
Yield, fresh weight (kg/km^2)	1×10^6	4×10^5	5×10^5	1×10^6	3×10^6	1.69×10^6	1.31×10^6
Dry matter content of crops (%)	20	90	20	20	20	16	10
Interception factor	0.3	0.3 whole plant 0.012 grain	0.25	0.62	0.4	0.74 plant 0.007 fruit	0.74 plant 0.003 fruit
Half-life on plant surface (days)	14	14 plant 14.4 grain	14 summer 28 winter	14	14	14 plant 14 fruit	14 plant 14 fruit
Soil on plant surface (% of dry plant weight)	0.1 [a]	0.01 [a]	4	4	0.1 [a]	0	0.1 [a]
Depth of soil (cm)	30	30	15	15	30	30	30
Mass of soil per cm depth (kg/km^2)	1.5×10^7	1.5×10^7	1.5×10^7	1.5×10^7	1.5×10^7	1.5×10^7	1.5×10^7
Soil density (g/cm^3)	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Fraction of activity retained after preparation [b]	0.2	0.1	-	-	1.0	1.0	1.0

[a] *Before preparation and processing.*
[b] *Applies to surface contamination only.*

Table C6. Element-independent parameter values used in the FARMLAND model for animals

The values are appropriate for the United Kingdom

Parameter	*Cattle* [a]	*Cattle* [b]	*Sheep* [a]	*Sheep* [b]
Mean life (years)	6	6	1	1
Weight of muscle (kg)	230 [c]	360 [d]	18 [c]	30 [d]
Weight of liver (kg)	6	6	0.8	1
Daily milk production (L)	10	10	-	-
Number of animals (km^{-2})	400	400	500	500

[a] *Simple model used for all elements other than strontium, caesium and iodine.*
[b] *Complex model used for strontium, caesium and iodine.*
[c] *This is the carcass weight; the weight of lean meat is 150 kg for cattle and 15 kg for sheep.*
[d] *This is the weight of all soft tissues; the weight of lean meat is 150 kg and 15 kg for sheep.*

Table C7. Summary of animal intakes

Animal	*Pasture (kg/d dry mass)*	*Silage (kg/d dry mass)*	*Grain (kg/d fresh mass)*	*Water (L/d)*	*Soil (% dry matter intake)*	*Air (m^3/s)*
Cattle	13	15.5	-	55	4	1.5×10^{-3}
Sheep	1.5	1.5	-	4	20	1.0×10^{-4}
Pigs	-	-	1.0	7	-	6.2×10^{-4}
Chickens	-	-	Layers 0.1 Table 0.05	0.23	-	1.3×10^{-5}

B. Rice model

C6. In view of the large quantity of rice grown in Japan and its importance in the diet of the Japanese population, this food was specifically included in the assessment. Since a rice component did not exist in the FARMLAND model, a modified cereal model was used with the specific soil-to-plant concentration ratios and harvest times applicable for rice included (see tables C1 and C3).

Supplement D. Transfer factors for Japanese food used in the FARMLAND model

D1. The FARMLAND model was implemented for Japanese growing conditions for a release on 12 March and normalized for a deposition density of 1 Bq/m^2. Tables D1–D12 present the output results from these models. The values are given to two decimal places for use in the subsequent calculations of dose but this should not be taken to imply this degree of precision.

Table D1. Activity concentrations and time-integrated activity concentrations in leafy green vegetables

Time after release (days)	*Activity concentration (Bq/kg)*			*Time-integrated activity concentration ((Bq a)/kg)*		
	Iodine-131	*Caesium-134*	*Caesium-137*	*Iodine-131*	*Caesium-134*	*Caesium-137*
0	6.00×10^{-2}	6.00×10^{-2}	6.00×10^{-2}	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
7	2.39×10^{-2}	4.34×10^{-2}	4.37×10^{-2}	7.52×10^{-4}	9.83×10^{-4}	9.85×10^{-4}
14	9.53×10^{-3}	3.15×10^{-2}	3.19×10^{-2}	1.05×10^{-3}	1.70×10^{-3}	1.70×10^{-3}
30	1.18×10^{-3}	1.53×10^{-2}	1.57×10^{-2}	1.23×10^{-3}	2.68×10^{-3}	2.71×10^{-3}
60	2.45×10^{-5}	4.12×10^{-3}	4.33×10^{-3}	1.25×10^{-3}	3.38×10^{-3}	3.43×10^{-3}
90	5.35×10^{-7}	1.16×10^{-3}	1.25×10^{-3}	1.25×10^{-3}	3.57×10^{-3}	3.63×10^{-3}
180	1.97×10^{-10}	5.29×10^{-5}	6.17×10^{-5}	1.25×10^{-3}	3.65×10^{-3}	3.72×10^{-3}
270	8.28×10^{-13}	2.46×10^{-5}	3.10×10^{-5}	1.25×10^{-3}	3.65×10^{-3}	3.73×10^{-3}
365	3.17×10^{-15}	1.69×10^{-5}	2.30×10^{-5}	1.25×10^{-3}	3.66×10^{-3}	3.74×10^{-3}
730	2.03×10^{-18}	1.10×10^{-5}	2.06×10^{-5}	1.25×10^{-3}	3.67×10^{-3}	3.76×10^{-3}
1 095	1.30×10^{-21}	7.74×10^{-6}	1.98×10^{-5}	1.25×10^{-3}	3.68×10^{-3}	3.78×10^{-3}
1 825	5.41×10^{-25}	3.89×10^{-6}	1.86×10^{-5}	1.25×10^{-3}	3.69×10^{-3}	3.82×10^{-3}
3 650	5.62×10^{-30}	7.00×10^{-7}	1.60×10^{-5}	1.25×10^{-3}	3.70×10^{-3}	3.90×10^{-3}
5 475	5.84×10^{-35}	1.26×10^{-7}	1.38×10^{-5}	1.25×10^{-3}	3.70×10^{-3}	3.98×10^{-3}
1 825	5.87×10^{-43}	3.62×10^{-12}	4.81×10^{-6}	1.25×10^{-3}	3.70×10^{-3}	4.27×10^{-3}
21 900	$0.00 \times 10^{+00}$	1.19×10^{-13}	3.56×10^{-6}	1.25×10^{-3}	3.70×10^{-3}	4.32×10^{-3}
25 550	$0.00 \times 10^{+00}$	3.92×10^{-15}	2.63×10^{-6}	1.25×10^{-3}	3.70×10^{-3}	4.35×10^{-3}

Table D2. Activity concentrations and time-integrated activity concentrations in root vegetables

Time after release (days)	*Activity concentration (Bq/kg)*			*Time-integrated activity concentration ((Bq a)/kg)*		
	Iodine-131	*Caesium-134*	*Caesium-137*	*Iodine-131*	*Caesium-134*	*Caesium-137*
0	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
7	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
14	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
30	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
60	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
90	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
180	5.96×10^{-11}	3.16×10^{-4}	3.68×10^{-4}	9.13×10^{-8}	3.88×10^{-4}	4.29×10^{-4}
270	3.92×10^{-14}	3.04×10^{-4}	3.82×10^{-4}	9.13×10^{-8}	4.43×10^{-4}	4.95×10^{-4}
365	1.09×10^{-17}	2.78×10^{-4}	3.80×10^{-4}	9.13×10^{-8}	5.18×10^{-4}	5.95×10^{-4}
730	2.76×10^{-30}	7.80×10^{-5}	1.46×10^{-4}	9.13×10^{-8}	6.53×10^{-4}	8.02×10^{-4}
1 095	8.89×10^{-30}	5.56×10^{-5}	1.42×10^{-4}	9.13×10^{-8}	7.19×10^{-4}	9.47×10^{-4}
1 825	4.16×10^{-33}	2.80×10^{-5}	1.34×10^{-4}	9.13×10^{-8}	7.99×10^{-4}	1.22×10^{-3}
3 650	5.11×10^{-38}	5.02×10^{-6}	1.15×10^{-4}	9.13×10^{-8}	8.67×10^{-4}	1.84×10^{-3}
5 475	6.25×10^{-43}	9.01×10^{-7}	9.86×10^{-5}	9.13×10^{-8}	8.79×10^{-4}	2.38×10^{-3}
1 825	$0.00 \times 10^{+00}$	2.32×10^{-11}	3.39×10^{-5}	9.13×10^{-8}	8.82×10^{-4}	4.50×10^{-3}
21 900	$0.00 \times 10^{+00}$	7.61×10^{-13}	2.50×10^{-5}	9.13×10^{-8}	8.82×10^{-4}	4.79×10^{-3}
25 550	$0.00 \times 10^{+00}$	2.49×10^{-14}	1.84×10^{-5}	9.13×10^{-8}	8.82×10^{-4}	5.01×10^{-3}

Table D3. Activity concentrations and time-integrated activity concentrations in cereals

Time after release (days)	*Activity concentration (Bq/kg)*			*Time-integrated activity concentration ((Bq a)/kg)*		
	Iodine-131	*Caesium-134*	*Caesium-137*	*Iodine-131*	*Caesium-134*	*Caesium-137*
0	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
7	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
14	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
30	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
60	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
90	1.19×10^{-5}	2.56×10^{-2}	2.76×10^{-2}	5.18×10^{-7}	7.04×10^{-4}	7.58×10^{-4}
180	5.09×10^{-9}	2.36×10^{-2}	2.75×10^{-2}	8.96×10^{-7}	6.76×10^{-3}	7.55×10^{-3}
270	2.17×10^{-12}	2.17×10^{-2}	2.73×10^{-2}	8.96×10^{-7}	1.23×10^{-2}	1.43×10^{-2}
365	6.04×10^{-16}	1.99×10^{-2}	2.72×10^{-2}	8.96×10^{-7}	1.77×10^{-2}	2.14×10^{-2}
730	2.36×10^{-31}	1.11×10^{-5}	2.08×10^{-5}	8.96×10^{-7}	2.20×10^{-2}	2.74×10^{-2}
1 095	4.67×10^{-27}	7.86×10^{-6}	2.01×10^{-5}	8.96×10^{-7}	2.20×10^{-2}	2.74×10^{-2}
1 825	2.18×10^{-30}	3.96×10^{-6}	1.89×10^{-5}	8.96×10^{-7}	2.20×10^{-2}	2.74×10^{-2}
3 650	2.67×10^{-35}	7.12×10^{-7}	1.63×10^{-5}	8.96×10^{-7}	2.20×10^{-2}	2.75×10^{-2}
5 475	3.26×10^{-40}	1.28×10^{-7}	1.40×10^{-5}	8.96×10^{-7}	2.20×10^{-2}	2.76×10^{-2}
1 825	$0.00 \times 10^{+00}$	3.09×10^{-12}	4.89×10^{-6}	8.96×10^{-7}	2.20×10^{-2}	2.79×10^{-2}
21 900	$0.00 \times 10^{+00}$	1.02×10^{-13}	3.63×10^{-6}	8.96×10^{-7}	2.20×10^{-2}	2.79×10^{-2}
25 550	$0.00 \times 10^{+00}$	3.34×10^{-15}	2.69×10^{-6}	8.96×10^{-7}	2.20×10^{-2}	2.80×10^{-2}

Table D4. Activity concentrations and time-integrated activity concentrations in potatoes

Time after release (days)	*Activity concentration (Bq/kg)*			*Time-integrated activity concentration ((Bq a)/kg)*		
	Iodine-131	*Caesium-134*	*Caesium-137*	*Iodine-131*	*Caesium-134*	*Caesium-137*
0	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
7	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
14	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
30	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
60	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
90	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
180	5.96×10^{-11}	1.96×10^{-4}	2.28×10^{-4}	9.13×10^{-8}	3.59×10^{-4}	3.96×10^{-4}
270	3.92×10^{-14}	1.94×10^{-4}	2.45×10^{-4}	9.13×10^{-8}	3.85×10^{-4}	4.28×10^{-4}
365	1.09×10^{-17}	1.78×10^{-4}	2.43×10^{-4}	9.13×10^{-8}	4.34×10^{-4}	4.92×10^{-4}
730	2.76×10^{-30}	6.91×10^{-6}	1.29×10^{-5}	9.13×10^{-8}	4.83×10^{-4}	5.64×10^{-4}
1 095	8.89×10^{-30}	4.92×10^{-6}	1.26×10^{-5}	9.13×10^{-8}	4.89×10^{-4}	5.77×10^{-4}
1 825	4.16×10^{-33}	2.48×10^{-6}	1.19×10^{-5}	9.13×10^{-8}	4.96×10^{-4}	6.02×10^{-4}
3 650	5.11×10^{-38}	4.46×10^{-7}	1.02×10^{-5}	9.13×10^{-8}	5.02×10^{-4}	6.57×10^{-4}
5 475	6.25×10^{-43}	8.01×10^{-8}	8.77×10^{-6}	9.13×10^{-8}	5.03×10^{-4}	7.04×10^{-4}
1 825	$0.00 \times 10^{+00}$	1.83×10^{-12}	3.06×10^{-6}	9.13×10^{-8}	5.04×10^{-4}	8.93×10^{-4}
21 900	$0.00 \times 10^{+00}$	6.01×10^{-14}	2.27×10^{-6}	9.13×10^{-8}	5.04×10^{-4}	9.20×10^{-4}
25 550	$0.00 \times 10^{+00}$	1.98×10^{-15}	1.68×10^{-6}	9.13×10^{-8}	5.04×10^{-4}	9.40×10^{-4}

Table D5. Activity concentrations and time-integrated activity concentrations in orchard fruit

Time after release (days)	*Activity concentration (Bq/kg)*			*Time-integrated activity concentration (Bq a/kg)*		
	Iodine-131	*Caesium-134*	*Caesium-137*	*Iodine-131*	*Caesium-134*	*Caesium-137*
0	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
7	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
14	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
30	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
60	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
90	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
180	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
270	1.59×10^{-14}	1.75×10^{-5}	2.20×10^{-5}	7.06×10^{-13}	4.18×10^{-6}	5.08×10^{-6}
365	4.42×10^{-18}	1.60×10^{-5}	2.19×10^{-5}	7.06×10^{-13}	8.53×10^{-6}	1.08×10^{-5}
730	6.92×10^{-26}	3.37×10^{-6}	6.30×10^{-6}	7.06×10^{-13}	1.78×10^{-5}	2.50×10^{-5}
1 095	2.92×10^{-25}	2.38×10^{-6}	6.09×10^{-6}	7.06×10^{-13}	2.22×10^{-5}	3.43×10^{-5}
1 825	1.36×10^{-28}	1.20×10^{-6}	5.73×10^{-6}	7.06×10^{-13}	2.57×10^{-5}	4.62×10^{-5}
3 650	1.66×10^{-33}	2.16×10^{-7}	4.93×10^{-6}	7.06×10^{-13}	2.85×10^{-5}	7.28×10^{-5}
5 475	2.04×10^{-38}	3.88×10^{-8}	4.25×10^{-6}	7.06×10^{-13}	2.91×10^{-5}	9.57×10^{-5}
1 825	$0.00 \times 10^{+00}$	9.34×10^{-13}	1.48×10^{-6}	7.06×10^{-13}	2.92×10^{-5}	1.88×10^{-4}
21 900	$0.00 \times 10^{+00}$	3.07×10^{-14}	1.10×10^{-6}	7.06×10^{-13}	2.92×10^{-5}	2.00×10^{-4}
25 550	$0.00 \times 10^{+00}$	1.01×10^{-15}	8.13×10^{-7}	7.06×10^{-13}	2.92×10^{-5}	2.10×10^{-4}

Table D6. Activity concentrations and time-integrated activity concentrations in soft fruit

Time after release (days)	*Activity concentration (Bq/kg)*			*Time-integrated activity concentrations (Bq a/kg)*		
	Iodine-131	*Caesium-134*	*Caesium-137*	*Iodine-131*	*Caesium-134*	*Caesium-137*
0	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
7	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
14	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
30	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
60	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
90	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
180	6.01×10^{-11}	1.92×10^{-5}	2.25×10^{-5}	1.50×10^{-9}	1.19×10^{-5}	1.34×10^{-5}
270	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	1.50×10^{-9}	1.90×10^{-5}	2.19×10^{-5}
365	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	1.50×10^{-9}	1.90×10^{-5}	2.19×10^{-5}
730	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	1.50×10^{-9}	2.32×10^{-5}	2.85×10^{-5}
1 095	3.48×10^{-27}	2.46×10^{-6}	6.30×10^{-6}	1.50×10^{-9}	2.61×10^{-5}	3.49×10^{-5}
1 825	1.62×10^{-30}	1.24×10^{-6}	5.93×10^{-6}	1.50×10^{-9}	2.97×10^{-5}	4.71×10^{-5}
3 650	1.99×10^{-35}	2.23×10^{-7}	5.10×10^{-6}	1.50×10^{-9}	3.27×10^{-5}	7.46×10^{-5}
5 475	2.43×10^{-40}	4.01×10^{-8}	4.39×10^{-6}	1.50×10^{-9}	3.32×10^{-5}	9.83×10^{-5}
1 825	$0.00 \times 10^{+00}$	9.67×10^{-13}	1.53×10^{-6}	1.50×10^{-9}	3.33×10^{-5}	1.93×10^{-4}
21 900	$0.00 \times 10^{+00}$	3.18×10^{-14}	1.14×10^{-6}	1.50×10^{-9}	3.33×10^{-5}	2.07×10^{-4}
25 550	$0.00 \times 10^{+00}$	1.05×10^{-15}	8.41×10^{-7}	1.50×10^{-9}	3.33×10^{-5}	2.17×10^{-4}

Table D7. Activity concentrations and time-integrated activity concentrations in rice

Time after release (days)	*Activity concentration (Bq/kg)*			*Time-integrated activity concentration (Bq a/kg)*		
	Iodine-131	*Caesium-134*	*Caesium-137*	*Iodine-131*	*Caesium-134*	*Caesium-137*
0	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
7	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
14	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
30	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
60	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
90	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
180	2.34×10^{-11}	4.69×10^{-5}	5.47×10^{-5}	7.38×10^{-13}	1.03×10^{-6}	1.20×10^{-6}
270	9.99×10^{-15}	4.31×10^{-5}	5.44×10^{-5}	1.48×10^{-12}	1.21×10^{-5}	1.47×10^{-5}
365	2.77×10^{-18}	3.95×10^{-5}	5.41×10^{-5}	1.48×10^{-12}	2.29×10^{-5}	2.88×10^{-5}
730	8.62×10^{-28}	5.72×10^{-6}	1.07×10^{-5}	1.48×10^{-12}	4.34×10^{-5}	5.98×10^{-5}
1 095	4.33×10^{-27}	4.04×10^{-6}	1.03×10^{-5}	1.48×10^{-12}	5.07×10^{-5}	7.53×10^{-5}
1 825	2.02×10^{-30}	2.04×10^{-6}	9.73×10^{-6}	1.48×10^{-12}	5.66×10^{-5}	9.54×10^{-5}
3 650	2.47×10^{-35}	3.66×10^{-7}	8.38×10^{-6}	1.48×10^{-12}	6.14×10^{-5}	1.41×10^{-4}
5 475	3.03×10^{-40}	6.58×10^{-8}	7.21×10^{-6}	1.48×10^{-12}	6.23×10^{-5}	1.79×10^{-4}
1 825	$0.00 \times 10^{+00}$	1.59×10^{-12}	2.52×10^{-6}	1.48×10^{-12}	6.25×10^{-5}	3.36×10^{-4}
21 900	$0.00 \times 10^{+00}$	5.23×10^{-14}	1.87×10^{-6}	1.48×10^{-12}	6.25×10^{-5}	3.57×10^{-4}
25 550	$0.00 \times 10^{+00}$	1.72×10^{-15}	1.38×10^{-6}	1.48×10^{-12}	6.25×10^{-5}	3.73×10^{-4}

Table D8. Activity concentrations and time-integrated activity concentrations in sheep meat

Time after release (days)	*Activity concentration (Bq/kg)*			*Time-integrated activity concentration (Bq a/kg)*		
	Iodine-131	*Caesium-134*	*Caesium-137*	*Iodine-131*	*Caesium-134*	*Caesium-137*
0	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
7	2.16×10^{-2}	1.81×10^{-1}	1.82×10^{-1}	2.74×10^{-4}	1.94×10^{-3}	1.95×10^{-3}
14	1.60×10^{-2}	2.72×10^{-1}	2.75×10^{-1}	6.41×10^{-4}	6.39×10^{-3}	6.44×10^{-3}
30	4.64×10^{-3}	3.07×10^{-1}	3.15×10^{-1}	1.06×10^{-3}	1.98×10^{-2}	2.01×10^{-2}
60	2.09×10^{-4}	1.65×10^{-1}	1.74×10^{-1}	1.18×10^{-3}	3.94×10^{-2}	4.05×10^{-2}
90	6.98×10^{-6}	6.88×10^{-2}	7.43×10^{-2}	1.19×10^{-3}	4.85×10^{-2}	5.02×10^{-2}
180	1.02×10^{-8}	7.93×10^{-3}	9.25×10^{-3}	1.19×10^{-3}	5.47×10^{-2}	5.70×10^{-2}
270	8.76×10^{-13}	4.50×10^{-3}	5.67×10^{-3}	1.19×10^{-3}	5.61×10^{-2}	5.87×10^{-2}
365	5.03×10^{-15}	3.59×10^{-3}	4.91×10^{-3}	1.19×10^{-3}	5.71×10^{-2}	6.01×10^{-2}
730	5.29×10^{-19}	1.73×10^{-3}	3.23×10^{-3}	1.19×10^{-3}	5.97×10^{-2}	6.40×10^{-2}
1 095	3.45×10^{-22}	8.89×10^{-4}	2.27×10^{-3}	1.19×10^{-3}	6.09×10^{-2}	6.67×10^{-2}
1 825	1.53×10^{-25}	2.61×10^{-4}	1.25×10^{-3}	1.19×10^{-3}	6.19×10^{-2}	7.01×10^{-2}
3 650	1.81×10^{-30}	1.41×10^{-5}	3.23×10^{-4}	1.19×10^{-3}	6.24×10^{-2}	7.36×10^{-2}
5 475	2.16×10^{-35}	7.85×10^{-7}	8.57×10^{-5}	1.19×10^{-3}	6.24×10^{-2}	7.44×10^{-2}
1 825	2.80×10^{-43}	6.06×10^{-12}	9.14×10^{-9}	1.19×10^{-3}	6.24×10^{-2}	7.48×10^{-2}
21 900	$0.00 \times 10^{+00}$	2.73×10^{-14}	6.44×10^{-10}	1.19×10^{-3}	6.24×10^{-2}	7.48×10^{-2}
25 550	$0.00 \times 10^{+00}$	1.22×10^{-16}	4.54×10^{-11}	1.19×10^{-3}	6.24×10^{-2}	7.48×10^{-2}

Table D9. Activity concentrations and time-integrated activity concentrations in sheep liver

Time after release (days)	*Activity concentration (Bq/kg)*			*Time-integrated activity concentration (Bq a/kg)*		
	Iodine-131	*Caesium-134*	*Caesium-137*	*Iodine-131*	*Caesium-134*	*Caesium-137*
0	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
7	2.16×10^{-2}	1.81×10^{-1}	1.82×10^{-1}	2.74×10^{-4}	1.94×10^{-3}	1.95×10^{-3}
14	1.60×10^{-2}	2.72×10^{-1}	2.75×10^{-1}	6.41×10^{-4}	6.39×10^{-3}	6.44×10^{-3}
30	4.64×10^{-3}	3.07×10^{-1}	3.15×10^{-1}	1.06×10^{-3}	1.98×10^{-2}	2.01×10^{-2}
60	2.09×10^{-4}	1.65×10^{-1}	1.74×10^{-1}	1.18×10^{-3}	3.94×10^{-2}	4.05×10^{-2}
90	6.98×10^{-6}	6.88×10^{-2}	7.43×10^{-2}	1.19×10^{-3}	4.85×10^{-2}	5.02×10^{-2}
180	1.02×10^{-8}	7.93×10^{-3}	9.25×10^{-3}	1.19×10^{-3}	5.47×10^{-2}	5.70×10^{-2}
270	8.76×10^{-13}	4.50×10^{-3}	5.67×10^{-3}	1.19×10^{-3}	5.61×10^{-2}	5.87×10^{-2}
365	5.03×10^{-15}	3.59×10^{-3}	4.91×10^{-3}	1.19×10^{-3}	5.71×10^{-2}	6.01×10^{-2}
730	5.29×10^{-19}	1.73×10^{-3}	3.23×10^{-3}	1.19×10^{-3}	5.97×10^{-2}	6.40×10^{-2}
1 095	3.45×10^{-22}	8.89×10^{-4}	2.27×10^{-3}	1.19×10^{-3}	6.09×10^{-2}	6.67×10^{-2}
1 825	1.53×10^{-25}	2.61×10^{-4}	1.25×10^{-3}	1.19×10^{-3}	6.19×10^{-2}	7.01×10^{-2}
3 650	1.81×10^{-30}	1.41×10^{-5}	3.23×10^{-4}	1.19×10^{-3}	6.24×10^{-2}	7.36×10^{-2}
5 475	2.16×10^{-35}	7.85×10^{-7}	8.57×10^{-5}	1.19×10^{-3}	6.24×10^{-2}	7.44×10^{-2}
1 825	2.80×10^{-43}	6.06×10^{-12}	9.14×10^{-9}	1.19×10^{-3}	6.24×10^{-2}	7.48×10^{-2}
21 900	$0.00 \times 10^{+00}$	2.73×10^{-14}	6.44×10^{-10}	1.19×10^{-3}	6.24×10^{-2}	7.48×10^{-2}
25 550	$0.00 \times 10^{+00}$	1.22×10^{-16}	4.54×10^{-11}	1.19×10^{-3}	6.24×10^{-2}	7.48×10^{-2}

Table D10. Activity concentrations and time-integrated activity concentrations in cow meat

Time after release (days)	*Activity concentration (Bq/kg)*			*Time-integrated activity concentration (Bq a/kg)*		
	Iodine-131	*Caesium-134*	*Caesium-137*	*Iodine-131*	*Caesium-134*	*Caesium-137*
0	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
7	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
14	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
30	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
60	4.91×10^{-5}	4.81×10^{-2}	5.07×10^{-2}	1.92×10^{-5}	3.11×10^{-3}	3.25×10^{-3}
90	9.59×10^{-7}	2.74×10^{-2}	2.97×10^{-2}	2.02×10^{-5}	6.16×10^{-3}	6.49×10^{-3}
180	1.15×10^{-9}	6.07×10^{-3}	7.09×10^{-3}	2.03×10^{-5}	9.51×10^{-3}	1.02×10^{-2}
270	2.65×10^{-13}	9.70×10^{-3}	1.22×10^{-2}	2.03×10^{-5}	1.09×10^{-2}	1.19×10^{-2}
365	1.39×10^{-16}	1.28×10^{-2}	1.75×10^{-2}	2.03×10^{-5}	1.40×10^{-2}	1.60×10^{-2}
730	2.97×10^{-20}	5.98×10^{-4}	1.12×10^{-3}	2.03×10^{-5}	1.74×10^{-2}	2.09×10^{-2}
1 095	2.64×10^{-23}	2.47×10^{-4}	6.31×10^{-4}	2.03×10^{-5}	1.78×10^{-2}	2.18×10^{-2}
1 825	1.31×10^{-26}	5.86×10^{-5}	2.80×10^{-4}	2.03×10^{-5}	1.80×10^{-2}	2.26×10^{-2}
3 650	1.60×10^{-31}	2.90×10^{-6}	6.62×10^{-5}	2.03×10^{-5}	1.81×10^{-2}	2.33×10^{-2}
5 475	1.94×10^{-36}	1.60×10^{-7}	1.74×10^{-5}	2.03×10^{-5}	1.81×10^{-2}	2.35×10^{-2}
1 825	1.96×10^{-44}	9.91×10^{-13}	1.93×10^{-9}	2.03×10^{-5}	1.81×10^{-2}	2.36×10^{-2}
21 900	$0.00 \times 10^{+00}$	4.42×10^{-15}	1.36×10^{-10}	2.03×10^{-5}	1.81×10^{-2}	2.36×10^{-2}
25 550	$0.00 \times 10^{+00}$	1.97×10^{-17}	9.52×10^{-12}	2.03×10^{-5}	1.81×10^{-2}	2.36×10^{-2}

Table D11. Activity concentrations and time-integrated activity concentrations in cow liver

Time after release (days)	*Activity concentration (Bq/kg)*			*Time-integrated activity concentration (Bq a/kg)*		
	Iodine-131	*Caesium-134*	*Caesium-137*	*Iodine-131*	*Caesium-134*	*Caesium-137*
0	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
7	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
14	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
30	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
60	4.91×10^{-5}	4.81×10^{-2}	5.07×10^{-2}	1.92×10^{-5}	3.11×10^{-3}	3.25×10^{-3}
90	9.59×10^{-7}	2.74×10^{-2}	2.97×10^{-2}	2.02×10^{-5}	6.16×10^{-3}	6.49×10^{-3}
180	1.15×10^{-9}	6.07×10^{-3}	7.09×10^{-3}	2.03×10^{-5}	9.51×10^{-3}	1.02×10^{-2}
270	2.65×10^{-13}	9.70×10^{-3}	1.22×10^{-2}	2.03×10^{-5}	1.09×10^{-2}	1.19×10^{-2}
365	1.39×10^{-16}	1.28×10^{-2}	1.75×10^{-2}	2.03×10^{-5}	1.40×10^{-2}	1.60×10^{-2}
730	2.97×10^{-20}	5.98×10^{-4}	1.12×10^{-3}	2.03×10^{-5}	1.74×10^{-2}	2.09×10^{-2}
1 095	2.64×10^{-23}	2.47×10^{-4}	6.31×10^{-4}	2.03×10^{-5}	1.78×10^{-2}	2.18×10^{-2}
1 825	1.31×10^{-26}	5.86×10^{-5}	2.80×10^{-4}	2.03×10^{-5}	1.80×10^{-2}	2.26×10^{-2}
3 650	1.60×10^{-31}	2.90×10^{-6}	6.62×10^{-5}	2.03×10^{-5}	1.81×10^{-2}	2.33×10^{-2}
5 475	1.94×10^{-36}	1.60×10^{-7}	1.74×10^{-5}	2.03×10^{-5}	1.81×10^{-2}	2.35×10^{-2}
1 825	1.96×10^{-44}	9.91×10^{-13}	1.93×10^{-9}	2.03×10^{-5}	1.81×10^{-2}	2.36×10^{-2}
21 900	$0.00 \times 10^{+00}$	4.42×10^{-15}	1.36×10^{-10}	2.03×10^{-5}	1.81×10^{-2}	2.36×10^{-2}
25 550	$0.00 \times 10^{+00}$	1.97×10^{-17}	9.52×10^{-12}	2.03×10^{-5}	1.81×10^{-2}	2.36×10^{-2}

Table D12. Activity concentrations and time-integrated activity concentrations in cow milk

Time after release (days)	*Activity concentration (Bq/kg)*			*Time-integrated activity concentration (Bq a/kg)*		
	Iodine-131	*Caesium-134*	*Caesium-137*	*Iodine-131*	*Caesium-134*	*Caesium-137*
0	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
7	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
14	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
30	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$	$0.00 \times 10^{+00}$
60	4.30×10^{-5}	8.24×10^{-3}	8.68×10^{-3}	4.69×10^{-5}	1.41×10^{-3}	1.46×10^{-3}
90	5.28×10^{-7}	2.11×10^{-3}	2.28×10^{-3}	4.76×10^{-5}	1.74×10^{-3}	1.81×10^{-3}
180	8.11×10^{-10}	6.63×10^{-4}	7.74×10^{-4}	4.77×10^{-5}	2.02×10^{-3}	2.12×10^{-3}
270	7.62×10^{-13}	2.61×10^{-3}	3.29×10^{-3}	4.77×10^{-5}	2.33×10^{-3}	2.51×10^{-3}
365	2.43×10^{-16}	2.59×10^{-3}	3.54×10^{-3}	4.77×10^{-5}	3.02×10^{-3}	3.41×10^{-3}
730	5.91×10^{-20}	1.09×10^{-4}	2.04×10^{-4}	4.77×10^{-5}	3.49×10^{-3}	4.11×10^{-3}
1 095	4.20×10^{-23}	4.61×10^{-5}	1.18×10^{-4}	4.77×10^{-5}	3.56×10^{-3}	4.26×10^{-3}
1 825	1.96×10^{-26}	1.11×10^{-5}	5.32×10^{-5}	4.77×10^{-5}	3.61×10^{-3}	4.42×10^{-3}
3 650	2.36×10^{-31}	5.53×10^{-7}	1.26×10^{-5}	4.77×10^{-5}	3.63×10^{-3}	4.56×10^{-3}
5 475	2.85×10^{-36}	3.05×10^{-8}	3.33×10^{-6}	4.77×10^{-5}	3.63×10^{-3}	4.59×10^{-3}
1 825	$0.00 \times 10^{+00}$	1.89×10^{-13}	3.69×10^{-10}	4.77×10^{-5}	3.63×10^{-3}	4.61×10^{-3}
21 900	$0.00 \times 10^{+00}$	8.43×10^{-16}	2.59×10^{-11}	4.77×10^{-5}	3.63×10^{-3}	4.61×10^{-3}
25 550	$0.00 \times 10^{+00}$	3.75×10^{-18}	1.82×10^{-12}	4.77×10^{-5}	3.63×10^{-3}	4.61×10^{-3}

Supplement E. Methodology for assessing doses from ingestion of radionuclides in drinking water

I. INTRODUCTION

E1. Following an accidental release of radionuclides to the environment, the ingestion of drinking water is one pathway through which radionuclides can enter the body. This applies to both releases to atmosphere and releases to water bodies. Following the releases from FDNPS, widespread monitoring of drinking water was carried out to determine the quantities of the key radionuclides contained in water. In order to reduce radiation exposures of the public, restrictions on the supply of drinking water were introduced in Japan, with the aim of ensuring that water with radionuclides above defined concentration levels was not distributed. Where feasible, the assessed effective doses from the ingestion of drinking water took into account these restrictions.

E2. Radionuclides released to atmosphere may deposit onto water surfaces and may also enter these water bodies via runoff from land. Radionuclides rapidly disperse and dilute in large water bodies. There are also natural and anthropogenic filtering systems that contribute to the rapid removal of radionuclides from drinking water supplies.

E3. The assessment of doses for the first year in Japan was based on the comprehensive set of measurement data collected by the Japanese authorities [MHLW, 2013]. The measured concentrations were combined with information on how much water people drink to estimate radiation doses. Doses were not estimated beyond the first year unless the monitoring results suggested that measurable levels of radionuclides were still present in drinking water at this time. No assessment was made for countries other than Japan.

E4. This supplement summarizes the methodology used for estimating effective doses to the public from ingestion of drinking water and the results obtained using this method.

II. METHODOLOGY

E5. The aim was to estimate the effective doses from drinking water to representative people living in specific locations. Within Fukushima Prefecture, an average effective dose was estimated for each district. For the rest of Japan, average effective doses were estimated for each prefecture.

(a) Basic data and parameters

E6. *Radionuclide content in drinking water.* The monitoring data for drinking water sources in Japan [MHLW, 2013] were summarized for the dose estimates. The spreadsheet contained information about the date and location of sampling, radionuclides to be tested, water supplier and the date when the results were published. Datasets of activity concentration in drinking water collected by MHLW from May 2011 to April 2012 were used.

E7. *Age groups*. Effective doses were estimated for three age groups—adults, 10-year-old children and one-year-old infants.

E8. *Intake rates*. Intake rates were taken from [WHO, 2012] and were 2 L, 1 L and 0.75 L daily for adults, 10-year-old children and one-year-old infants, respectively. It was assumed that all the water consumed by an individual was sourced from local water supplies and that no bottled water was consumed except when drinking water supplies were restricted by the Japanese authorities.

E9. *Dose coefficients.* Dose coefficients were taken from [ICRP, 2011].

E10. *Radionuclide*s. Data were available only for ^{131}I, ^{134}Cs and ^{137}Cs concentrations in drinking water for areas outside Fukushima Prefecture and these were therefore the only radionuclides considered in the dose assessment. For districts within Fukushima Prefecture, drinking water supplies were also tested for a number of other radionuclides. However, the only radionuclides detected in drinking water throughout the entire prefecture were ^{131}I, ^{132}I, ^{134}Cs and ^{137}Cs; therefore, these four radionuclides were the only radionuclides included in the dose assessment for these districts.

(b) Considerations in interpreting and using the data

E11. *Delays in beginning measurements*. The first day on which a drinking water sample was collected in Fukushima Prefecture was 16 March 2011. Sampling did not begin in some districts until late March or early April 2011. For each district or prefecture, the day on which the first intake of drinking water containing radionuclides was assumed to occur was determined by comparing the monitoring data with the data from the plume modelling.

E12. *Limits of detection.* The majority of results for concentrations of radionuclides in drinking water samples were reported as less than the detection limit. In most prefectures, there were no measurements above the detection limit for the entire year following the accident. In some cases, the detection limit was stated as being somewhere between 5 and 15 Bq/L. In other cases, a specific detection limit was provided (this was typically between 0.5 and 1 Bq/L). A brief analysis was done to investigate the impact on the estimated doses of using different values where a measurement was reported to be below the detection limit. The doses for two districts in Fukushima Prefecture (Iitate and Date) were calculated for three scenarios: in the first, activity concentrations reported as less than the detection limit were assumed to be zero; in the second, activity concentrations reported as less than the detection limit were assumed to be 5 Bq/L; and in the third, a variable approach was used, if subsequent measurements were also reported to be below the limits of detection, the activity concentrations were assumed to be zero, but if they were reported to be above the limits of detection, they were assumed to be 5 Bq/L.

E13. *Variation in sampling locations.* The activity concentrations of radionuclides in drinking water were measured on some samples taken directly from taps or wells. Other samples were taken at treatment plants. No data were available to determine whether there had been any reduction in activity concentrations during transport to consumers and therefore no correction was made to the data to account for this. This may have led to some overestimation of the actual doses.

E14. *Sampling bias.* It is likely that more sampling occurred in areas where there was a higher expectation of higher levels, or where higher levels had been found previously. Because no attempt was made to correct for this sampling bias, this may also have led to some overestimation of the doses from drinking water.

E15. *Drinking water restrictions.* In some locations, water drinking was restricted to prevent the intake of radionuclides in tap water. The majority of restrictions were intended to apply only for infants. The Japanese authorities supplied bottled water to all regions where restrictions were in place. Therefore, it was assumed in this assessment that all drinking water restrictions were adhered to and the doses from radionuclides in drinking water were zero when restrictions were in place.

E16. *Evacuation zones.* Evacuation zones have not been accounted for in these dose estimates, as there was not sufficient time for radionuclides to get into drinking water in many of the districts that were evacuated. However, the assumption that the doses prior to evacuation from drinking water in these districts were zero need to be verified, particularly for deliberate evacuation areas. For this reason, the excel spreadsheets used to calculate doses were set up to show the average weekly and/or monthly intakes of radionuclides for each district/prefecture.

E17. *Coverage of the data.* Some districts/prefectures had very few measurements made and some districts/prefectures did not have any measurements made from March 2011. For the districts within Fukushima Prefecture, the tables of measurement results give the total number of water samples used to estimate doses and the date that the first water sample was taken.

(c) Dose calculation

E18. For the districts within Fukushima Prefecture, weekly doses to the representative individuals were calculated from March 2011 to the end of May 2011. After this time, monthly doses were calculated because the concentrations of radionuclides in drinking water had fallen significantly and fewer measurements had been taken. For prefectures other than Fukushima Prefecture, monthly doses were calculated from March 2011 to March 2012. All monthly doses were based on calendar months.

E19. Datasets of activity concentration in drinking water collected by MHLW from May 2011 to April 2012 were used.

E20. Doses for each radionuclide were calculated as follows:

$$\text{Dose}_{\text{DW}}\,(\text{Sv}) = \sum_{\text{radionuclides}} \text{annual intake (Bq)} \times \text{dose coefficient}_{\text{ing}}$$

where the annual intake (AI) is determined by:

$$\text{Annual intake (Bq)} = \sum_{\text{weeks/months}} \text{average concentration (Bq/L)} \times \text{weekly or monthly intake (L)}$$

(d) Population-weighted average dose

E21. In addition to estimating effective doses and absorbed doses to the thyroid to the representative individual for each district within Fukushima Prefecture, a population-weighted average dose (PWD) was calculated for Fukushima Prefecture as a whole using the following equation:

$$\text{PWD} = \frac{\Sigma_{i=\text{district}}\,(\text{average dose}_i \times \text{population}_i)}{\Sigma_i\,\text{population}_i}$$

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