Safety regulations of food and water implemented in the first year following the Fukushima nuclear accident

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An earthquake and tsunami of historic proportions caused massive damage across the northeastern coast of Japan on the afternoon of 11 March 2011, and the release of radionuclides from the stricken reactors of the Fukushima nuclear power plant 1 was detected early on the next morning. High levels of radioiodines and radiocesiums were detected in the topsoil and plants on 15 March 2011, so sampling of food and water for monitoring surveys began on 16 March 2011. On 17 March 2011, provisional regulation values for radioiodine, radiocesiums, uranium, plutonium and other transuranic α emitters were set to regulate the safety of radioactively contaminated food and water. On 21 March 2011, the first restrictions on distribution and consumption of contaminated items were ordered. So far, tap water, raw milk, vegetables, mushrooms, fruit, nut, seaweeds, marine invertebrates, coastal fish, freshwater fish, beef, wild animal meat, brown rice, wheat, tea leaves and other foodstuffs had been contaminated above the provisional regulation values. The provisional regulation values for radioiodine were exceeded in samples taken from 16 March 2011 to 21 May 2011, and those for radiocesiums from 18 March 2011 to date. All restrictions were imposed within 318 days after the provisional regulation values were first exceeded for each item. This paper summarizes the policy for the execution of monitoring surveys and restrictions, and the outlines of the monitoring results of 220,411 samples and the enforced restrictions predicated on the information available as of 31 March 2012.

Keywords: food safety regulation; Fukushima nuclear accident; provisional regulation value; provisional tolerance value; internal radiation exposure

1. THE FUKUSHIMA NUCLEAR ACCIDENT AND RADIONUCLIDE RELEASE

A magnitude 9.0 earthquake occurred off the northeastern coast of Japan on 11 March 2011, triggering an ensuing deadly tsunami with waves reaching as high as 40.5 m. This disaster caused massive destruction across a wide area: there have been 15,854 confirmed fatalities with 3089 people missing as of 28 March 2012 [1].

On 11 March 2011, a nuclear emergency situation was declared due to the accident at the Fukushima nuclear power plant (NPP) 1 (referred to hereafter as the Fukushima accident), and Nuclear Emergency Response Headquarters (NERHQ) were established. All operating nuclear reactors underwent automatic shutdown upon the quake, and the emergency diesel generators successfully started to supply power for nuclear fuel cooling systems. However, the tsunami swamped the reactors afterwards, and the generators became inoperable. Elevation of temperature and pressure inside the reactors resulted in a partial meltdown and hydrogen explosions. Eventually, radionuclides were discharged from the stricken reactors. A preliminary estimate made by the Nuclear and Industrial Safety Agency of Japan (NISA) indicated that 160 PBq of 131I, 18 PBq of 134Cs and 15 PBq of 137Cs were spewed into the atmosphere between 11 and 16 March 2011 [2]. The radioactivity dispersed across the whole northern hemisphere [3–5]. The Tokyo Electric Power Company (TEPCO) estimated the outflow of contaminated water into the open sea as follows: 520 tons of water containing 4.7 PBq (a total level of 131I, 134Cs and 137Cs) between 1 and 6 April 2011, 10,393 tons of water containing 150 GBq
between 4 and 10 April 2011 and 250 tons of water containing 20 TBq on 11 May 2011 [6]. On 12 April 2011, the Fukushima accident was provisionally rated as Level 7 on the International Nuclear and Radiological Event Scale [7], the same level as the Chernobyl nuclear accident in 1986.

Following the declaration of a nuclear emergency situation, NERHQ defined evacuation zones, the ranges of which were expanded depending on the situation. On 12 March 2011, a central circle of 20 km radius from the Fukushima NPP1 was designated as the ‘stay-away evacuation’ zone. On 15 March 2011, its surrounding annular area between 20 and 30 km was designated as the ‘indoor evacuation’ zone, and large-scale atmospheric radionuclide releases occurred. On 16 March 2011, NERHQ instructed evacuees under 40 years of age leaving the stay-away evacuation zone to take pills or syrup of stable iodine to reduce health risks to the thyroid [6]. Upon this instruction, stable iodine (1.51 million pills for 750 000 people and 61.1 kg powder for 120 000–180 000 people) was distributed in Fukushima Prefecture on 16 March 2011, but no evacuees actually took it because the evacuation had already been completed. As an exception, the local governments of Futaba, Tomioka, Miharu towns and Iwaki City of Fukushima Prefecture had distributed the stable iodine pills without awaiting the instructions by NERHQ, and some of those pills were taken (precise information unavailable). Surveys of 1149 children living in Iwaki City, Iitate Village and other areas of Fukushima Prefecture were conducted late in March 2011 to examine the levels of dose posed by radioiodines, among which a maximum level detected was a committed equivalent dose to the thyroid of 35 mSv. On 22 April 2011, the indoor evacuation zone was revised to the ‘evacuation prepared’ zone (also translated as ‘evacuation-prepared area in case of emergency’), where residents should be ready for evacuation to the outside of this zone in case of emergency or for indoor evacuation, but this excluded the area beyond the 20-km radius where citizens could be exposed to $>20$ mSv during the course of the next year, which was designated as the ‘planned evacuation’ zone (also translated as ‘deliberate evacuation area’).

On 16 June 2011, the ‘evacuation recommended’ spots were designated in areas where citizens could potentially be exposed to a cumulative dose of $>20$ mSv in the first year after 11 March 2012. On 30 September 2011, the designation of the evacuation prepared zone was lifted. Thus, the stay-away evacuation zone (also translated as ‘restricted area’), planned evacuation zone and evacuation recommended spots (part of Minami-Soma City, Date City and Kawauchi Village) were effective as of 31 March 2012.

On 17 April 2011, TEPCO provided a two-stage timeline hoping to achieve stable cooling of the reactors by July 2011 and its cold shutdown by October 2011 to January 2012 [8]. NERHQ reported the achievement of stable cooling on 17 July 2011 [9], and declared cold shutdown on 16 December 2011 [10]. The scale of radionuclide releases from reactor units 1–3 of the Fukushima NPP1 that started on the early morning of 12 March 2011 is decreasing steadily but is still continuing, such that estimated release rates of radioisotopes (a total level of $^{134}\text{Cs}$ and $^{137}\text{Cs}$) were 800 TBq/h on 15 March 2011, 1 GBq/h between 20 and 26 June 2011, 100 MBq/h between 3 and 13 October 2011, and 60 MBq/h from 26 November 2011 to 6 December 2011 [10].

For citizens, ingestion of radioactively contaminated food and water is the most significant route of radionuclide intake, leading to internal radiation exposure [11]. On 15 March 2011, high levels of radioiodines and radioisotopes were detected in the topsoil and plants, and thereby the Nuclear Safety Commission of Japan (NSC) advised that monitoring surveys of food and water should begin immediately. On the next day, samples for such surveys started being collected. On 17 March 2011, the Ministry of Health, Labour and Welfare of Japan (MHLW) set regulatory limits for radioactively contaminated food and water stipulated as ‘provisional regulation values’ (PRVs), and directed that food and water contaminated above the PRVs should not be consumed [12]. PRVs were initially exceeded in tap water, raw milk and leafy vegetables, and their distribution and consumption have been restricted since 21 March 2011. Subsequently, PRVs were additionally set on 5 April 2011, and various other foodstuffs also became contaminated above the PRVs. This paper aims to share the information on the aspect of food safety regulations implemented following the Fukushima accident internationally, with a belief that experiences and lessons learned should help improve the nuclear or radiological emergency preparedness worldwide and serve as a foundation for discussing the optimization of future radiation protection strategies. Here we describe the policy carried out for the execution of monitoring surveys of food and water and restrictions on distribution and consumption of contaminated items, and the outlines of the monitoring results and the enforced restrictions on the basis of the information available as of 31 March 2012.

2. SETTING OF PROVISIONAL REGULATION VALUES

MHLW set PRVs on 17 March 2011 without being assessed by the Food Safety Commission of Japan (FSCJ). The FSCJ was therefore requested to assess the validity of the PRVs on 20 March 2011, and issued a report dated 29 March 2011 [13], guaranteeing that the ongoing measures predicated on PRVs were effective enough to ensure safety [14]. On 4 April 2011, MHLW hence decided to use PRVs for the meantime [15, 16]. Although the PRV for radioiodine in water and milk ingested by infants was adopted from the ‘guideline level’ indicated by the Codex Alimentarius Commission (CAC) in 1995 [17], other
values set on 17 March 2011 were adopted from the preset ‘index values’ that NSC had provided as evaluation criteria to launch discussion on whether NERHQ needs to restrict the consumption of food and water [18]. Index values for radiiodine were defined in water and two food categories (i.e. milk, and vegetables except corns, tubers and edible roots), and those for other radionuclide groups (i.e. radioce- siums, uranium, plutonium and other transuranic α emitters) were defined in water and four food categories (i.e. all food). The intervention level (IL) considered in each category of food and water was a committed equivalent dose to the thyroid of 11.1 mSv/year for radioiodine, and a committed effective dose of 1 mSv/year for other radionuclide groups (e.g. radioce- siums). Index values (i.e. derived IL) were set not to exceed IL in any age groups of infants (0–1 year of age), children (1–6 years) and adults (≥17 years), and the same index values were thus given to these three age groups. Index values were calculated as radioactive concentrations of indicator radionuclides (131I for radioi- dine, 134Cs and 137Cs for radioce- siums) by postulating the relative radioactive concentration of coexisting radionuclides (i.e. 132I, 133I, 134I, 135I and 132Te for 131I; 89Sr and 90Sr for 134Cs and 137Cs). Thus, surveys of food and water were conducted to monitor levels of these indicator radio- nuclides. On 5 April 2011, the PRV for radioiodine in aquatic products was additionally set by adopting the value used for vegetables [19], as radioiodines at levels of concern were detected in konago fish sampled on 1 April 2011 (Section 4.4). The PRVs (listed in Table 1) were not revised after that, and were effective until 31 March 2012. New regulation values came into effect on 1 April 2012 (Section 5). Further details of the logic and issues behind PRVs have been described previously [20]. Throughout this paper, Bq/kg-wet was referred to as Bq/kg unless otherwise specified.

3. POLICY ON THE EXECUTION OF MONITORING SURVEYS AND RESTRICTIONS

3.1. Potable tap water

On 19 March 2011, MHLW notified local government au- thorities and regional water suppliers that tap water contam- inated above the PRV should not be consumed, but can be consumed even by infants if its replacements are unob- tainable [21]. It was also documented that such water can be safely used in daily life (e.g. for washing hands, bathing and laundry), because the estimated committed effective dose to be received was of the order of nSv/day [21].

3.1.1. Monitoring surveys

On 4 April 2011, MHLW provided five directives to regional water suppliers [22]. (i) Conduct surveys especially in Fukushima Prefecture and the neighboring areas (Miyagi, Yamagata, Niigata, Ibaraki, Tochigi, Gunma, Saitama, Kanagawa, Chiba and Tokyo prefectures) on account of the monitoring results in tap water and the atmosphere as well as the distance from the Fukushima NPP1 (Tokyo Metropolis was translated as Tokyo Prefecture for simplicity throughout this paper). (ii) Monitor levels of 131I, 134Cs and 137Cs for the time being. (iii) Take water samples from faucets or water filter plants. (iv) Perform surveys more than once a week, but do them every day when radioactivity levels are above or be- coming close to the PRVs. (v) Increase the frequency of surveys depending on the effects of rainfall in water filter plants whose source of water is rivers.

On 30 June 2011, MHLW revised part of the aforementioned directives considering the following viewpoints [23]. First of all, the scale of radionuclide releases from the Fukushima NPP1 was becoming smaller (see Section 1). Second, rainfall had not increased the radioactive fallout by much recently. Third, the PRVs for radioiodine were exceeded in tap water sampled on 29 March 2011 or later, and no samples exceeded PRV for radioce- siums (see Section 4.1). Fourth, the groundwater may not have been contaminated with radioce- siums, because cesium is absorbed in the topsoil and does not readily penetrate underground. ‘Perform surveys more than once a week’ in directive iv was therefore changed to ‘Perform surveys more than once a week when the source of water is surface water or groundwater affected by surface water, and do more than once a month if the source is groundwater that is not affected by surface water’. Thus, further restrictions on water consumption seem very unlikely to be necessary unless additional large-scale atmospheric releases of radio- nuclides occur. However, the first rainy season after the Fukushima accident has arrived, and it would be prudent to carry out surveys periodically over a wide area for the next few months. Some water suppliers have found it difficult to conduct surveys, because availability of germanium semi- conductor detectors was limited. Surveys should be per- formed with more reasonable and effective systems. For instance, if raw water sampled at representative monitoring spots in each river basin is subjected to surveys, multiple water suppliers in the basin can share the monitoring results for water quality management. Among the areas listed in directive i, surveys are unnecessary in minor islands that are geographically isolated from the main island and use an independent water source, if such a survey system works in basin units. Last, directive iii was changed to ‘Water should be sampled from water filter plants rather than faucets’ for better management of water quality in water filter plants.

3.1.2. Consumption restrictions

MHLW is to request water suppliers to enforce consump- tion restrictions and make these public when the mean radi- ation level in the last 3 days exceeds the PRV, or when a single monitoring datum obtained on a certain day is ‘far
above’ the PRV. On the other hand, water suppliers are to lift restrictions, not only when the mean level in the last 3 days falls below the PRV, but also when there has been a tendency toward decreasing levels. This policy was documented on 4 April 2011 [22], and has not been revised after that. Here, it should be noted that concrete threshold radioactive concentrations for ‘the single datum far above the PRV’ have not been defined, so quantitatively consistent decisions cannot be made to order restrictions.

### 3.2. Food

NERHQ issued the initial notice for policy on surveys and restrictions on 4 April 2011 [24]. Thereafter, radioiodine levels became low, whereas radiocesium levels remained high. Taken together, food in various categories contaminated above the PRVs started to be detected in various areas. Therefore, the policy underwent two revisions, where the second and third versions were issued on 27 June 2011 and 4 August 2011, respectively [25, 26].

The initial target local governments assigned for surveys were Fukushima, Ibaraki, Tochigi, Gunma, Miyagi, Yamagata, Niigata, Nagano, Saitama, Chiba and Tokyo prefectures. Kanagawa, Yamanashi and Shizuoka prefectures were then included in the second version, and Iwate, Akita and Aomori prefectures were further added in the third version. Thus, the current target local governments assigned consist of 17 prefectures (see Fig. 1 for locations of each prefecture).

The initial priority target food categories were leafy vegetables (particularly, vegetables cultivated outdoors) and milk. Added in the second version were aquatic products, other vegetables and major food items consumed by people. Table 1.

| Radionuclide group                  | Category of food and water                              | Provisional regulation value (Bq/kg) |
|-------------------------------------|--------------------------------------------------------|-------------------------------------|
| Radioiodine                         | Water and beverages                                     | 300 (100 for infants)               |
|                                     | Milk                                                    |                                      |
|                                     | Vegetables except corms, tubers and roots               | 2000                                 |
|                                     | Aquatic products                                        |                                      |
| Radiocesium                         | Water and beverages                                     | 200                                  |
|                                     | Milk                                                    |                                      |
|                                     | Vegetables                                              | 500                                  |
|                                     | Cereals                                                 |                                      |
|                                     | Meat, eggs, aquatic products and other foodstuffs       |                                      |
| Uranium                             | Infant food                                             | 20                                   |
|                                     | Water and beverages                                     |                                      |
|                                     | Milk                                                    |                                      |
|                                     | Vegetables                                              | 100                                  |
|                                     | Cereals                                                 |                                      |
|                                     | Meat, eggs, aquatic products and other foodstuffs       |                                      |
| Plutonium and other transuranic α emitters | Infant food                                             | 1                                    |
|                                     | Water and beverages                                     |                                      |
|                                     | Milk                                                    |                                      |
|                                     | Vegetables                                              | 10                                   |
|                                     | Cereals                                                 |                                      |
|                                     | Meat, eggs, aquatic products and other foodstuffs       |                                      |

Table 1. Provisional regulation values effective until 31 March 2012

The provisional regulation value for radioiodine in seafood was set on 5 April 2011, whereas other values were set on 17 March 2011. These provisional regulation values were effective until 31 March 2012, and new regulation values become effective on 1 April 2012.

‘Milk’ here includes cow’s milk, powdered milk, human mother’s breast milk, daily products and related others. ‘Vegetables’ include mushrooms, fruit, edible algae (seaweeds), corms, tubers and roots in addition to vegetables. ‘Cereals’ include grains, rice and pulses. ‘Meat’ includes poultry. ‘Aquatic products’ include fish, shellfish and other fishery products. ‘Other foodstuffs’ refer to all foods that do not fall under any categories of milk, vegetables, cereals, meats, eggs and aquatic products. Note that the provisional regulation values for radioiodine have not been set in cereals, meat, eggs, corms, tubers, roots and the category of ‘other foodstuffs’.

The provisional regulation values were expressed as radioactive concentrations of indicator radionuclide (131I) by postulating the relative radioactive concentrations of coexisting radionuclides (132I, 133I, 134I, 135I and 132Te).

The provisional regulation values were expressed as total radioactive concentrations of indicator radionuclides (134Cs and 137Cs) by postulating the relative radioactive concentrations of coexisting radionuclides (89Sr and 90Sr).

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*a* The provisional regulation values were expressed as radioactive concentrations of an indicator radionuclide (131I) by postulating the relative radioactive concentrations of coexisting radionuclides (132I, 133I, 134I, 135I and 132Te).

*b* The provisional regulation values were expressed as total radioactive concentrations of indicator radionuclides (134Cs and 137Cs) by postulating the relative radioactive concentrations of coexisting radionuclides (89Sr and 90Sr).
the Japanese citizens (e.g. rice, tea, milk, potatoes, vegetables, fruit, aquatic products, mushrooms, pork, poultry, beef and edible algae). Beef was added in the third version. Regarding the frequency of surveys and criteria for commencement and removal of restrictions, the initial notice contained six directives. (i) Target local governments should conduct monitoring surveys basically once a week. (ii) Frequency of monitoring surveys is subject to change when detected radioactivity levels are above or becoming close to the PRVs. (iii) Based on the weekly summarized monitoring results, NERHQ is to order distribution restrictions. However, consumption should be restricted soon after the detection of 'very highly' contaminated food, irrespective of the number of samples above PRVs. NERHQ is to instruct such restrictions for each foodstuff according to Article 20, Item 3 of the Act on Special Measures Concerning Nuclear Emergency Preparedness. The unit for the enforcement of restrictions is basically each whole prefectural area, but can be municipalities (subareas divided within the prefecture, e.g. city, town or village) if applicable. Monitoring surveys should be performed weekly in each area where restrictions are ongoing. (iv) The local government is to request NERHQ to remove the restrictions when the monitoring result falls below the PRV three times consecutively. (v) NERHQ is to remove restrictions basically for each foodstuff, but a distinction between food items cultivated indoors and outdoors is not practical. (vi) The unit for withdrawal of restriction is each municipality. After removal of restrictions, monitoring surveys should be conducted periodically for as long as radionuclide releases

Fig. 1. Locations of 17 prefectures assigned as target local governments for food monitoring surveys. An upper left map shows part of Japan, and a lower right map shows the eastern half of the main island of Honshu. Only names of assigned 17 prefectures (details described in Section 3.2) are indicated in the lower right map. Of these, the gray-colored area emphasizes prefectures in which restrictions on distribution and/or consumption of food and/or water were imposed. An asterisk denotes the location of the Fukushima nuclear power plant 1.
from the Fukushima NPP1 continue. Parts of the directives were revised in the second version as follows, with no further changes in the third version. Directive i was changed to ‘Target local governments should start monitoring surveys at 3 days prior to the first shipment of foodstuffs whose shipment period is limited, or conduct surveys basically once a week for other foodstuffs’. Directive iv was changed to ‘when weekly obtained monitoring results fall below the PRV for radioiodine three times consecutively, or when all monitoring results obtained in the last month from three or more different sites of each city, town and village within the restricted area fall below the PRV for radiocesiums’.

The frequency of surveys and criteria for commencement and removal of restrictions should further follow the food category-specific policy. Such specific policies were initially given for milk and vegetables. Then, a specific policy was additionally given for fruit, aquatic products, tea leaves and wheat in the second version, and beef and rice in the third version. Outlines of the food category-specific policies instructed in the third version are described below.

3.2.1. Raw milk
Monitoring surveys should be carried out every 2 weeks. Samples should be taken from each daily plant or milk storage center. Restrictions of radioiodine-contaminated milk can be lifted when monitoring results fall below 100 Bq/kg of $^{131}$I three times successively (no criteria given to radiocesium-contaminated milk). Monitoring surveys should be conducted every 2 weeks if all monitoring results obtained in the last month after removal of restrictions fall below the PRVs for both radioiodine and radiocesiums.

3.2.2. Vegetables and fruit
Monitoring surveys should begin at 3 days prior to the first shipment, and then be conducted monthly if excess radioactivity is not detected. Foodstuffs cultivated outdoors and indoors can be restricted separately if controllable. If the shipment of a target foodstuff is completed prior to the removal of restrictions, restrictions can be removed depending on the monitoring results to be obtained at 3 days prior to the first shipment in the next shipment season. Monitoring surveys should be performed once a month if all monitoring results obtained in the last month after removal of restrictions fall below the PRVs for both radioiodine and radiocesiums.

3.2.3. Aquatic products
Major items of freshwater fish (e.g. yamame, wakasagi and ayu) and migratory fish (e.g. bonito, sardine, mackerel, Pacific saury and salmon) should be sampled at major fishing zones. For coastal fish, major items should be selected as samples considering their particular habitat. Hatchery-reared fish and natural fish should be monitored separately. Frequency of monitoring surveys should be once a week after the start of a fishing season, but can be reduced (e.g. to every 2 weeks) if the monitoring results have consistently fallen below the PRVs in the last month. Hatchery-reared fish and natural fish can be restricted separately. Restrictions can be lifted when all monitoring results of freshwater fish obtained weekly in the last month at several fishing zones, or those of coastal fish and migratory fish obtained at three or more different spots in the last month fall below the PRVs. If fish items cannot be sampled prior to withdrawal of restrictions (e.g. due to migration of fish or completion of the fishing season), restrictions can be withdrawn according to the monitoring results to be obtained by the first fishing in the next season.

3.2.4. Tea leaves
In each plucking period (e.g. for the first or second plucked tea), monitoring surveys of dried tea leaves should start to be conducted at 3 days prior to the first shipment and should be continued during the initial shipment period. Restrictions can be removed in the next plucking period or later when all monitoring results obtained from three or more different sites of each city, town and village within the restricted area fall below the PRV for radiocesiums. Monitoring results in each plucking period should be reported after removal of restrictions.

3.2.5. Beef
The distribution of beef from cattle fed with highly contaminated rice straw has been restricted (see Section 4.5.2). The local government is to request NERHQ to partially remove such restrictions, assuming thorough husbandry management and the following safety management. In specified target areas, all cattle should be subjected to monitoring surveys. Of these, cattle with radioactivity levels below the PRVs can be sold. In other areas, each cattle farmer should conduct monitoring surveys of one or more cattle for the first shipment. If the radioactivity level in the farmer’s cattle is far below the PRVs, the farmer can ship and slaughter cattle. Monitoring surveys should be conducted periodically thereafter. Upon request from the local government, NERHQ is to instruct such partial removal of distribution restrictions.

3.2.6. Wheat and barley
Japan Agricultural Cooperatives or relevant associations generally collect and sell most wheat and barley, so that safety can be verified in each lot that corresponds to wheat or barley in a silo or ~300-ton unit stored in a warehouse. Local governments should conduct monitoring surveys of all lots when the ambient dose rate at the time of heading or flowering exceeds 0.1 µSv/h (after rounding off to one
decimal place), or when radiocesium levels in agricultural soil sampled at a depth of 15 cm from the surface layer exceed 1000 Bq/kg. In other areas, all lots should be monitored if the first lot has excess radioactivity. Lots exceeding the PRVs cannot be sold according to the Food Sanitation Act, but its distribution restrictions are not to be imposed according to the Act on Special Measures Concerning Nuclear Emergency Preparedness.

3.2.7. Rice

The policy indicated by the Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF) on 3 August 2011 [27] is summarized below, along with that of NERHQ on 4 August 2011 [26].

In Japan, rice is the staple food, and its intake and production are greater than other foodstuffs. Rice can be stored for long periods of time, and there are various distribution systems (e.g. direct sales by farmers) unlike wheat and barley (Section 3.2.6). Considering these situations, ‘two-stage monitoring surveys’ composed of pre- and post-harvest surveys should be conducted for rice.

Pre-harvest surveys aim at setting target areas for post-harvest surveys according to the monitoring data obtained in rice at the piloerection stage. The local governments initially requested to conduct surveys were Fukushima, Ibaraki, Tochigi, Gunma, Chiba, Tokyo, Kanagawa, Miyagi, Yamagata, Niigata, Nagano, Saitama, Yamanashi and Shizuoka prefectures. On 4 August 2011, Iwate, Aomori and Akita prefectures were added. These local governments were requested to conduct surveys of rice at piloerection sampled in cultivated fields within 3 days before and less than 1 week pre-harvest. On the one hand, each municipality where radiocesium levels in soil exceed 1000 Bq/kg should perform surveys at least at one site. If radiocesium levels in rice at piloerection are above 200 Bq/kg, these areas are assigned as ‘priority target areas’. Here, a value of 200 Bq/kg was obtained by rounding down the half value (250 Bq/kg) of the PRV for radiocesiums in cereals including rice (500 Bq/kg). On the other hand, each municipality where the ambient dose rate is above 0.1 µSv/h (after rounding off to one decimal place) should perform surveys at about five different sites. If radiocesium levels in rice at piloerection are below 200 Bq/kg, these areas are assigned as ‘other target areas’. Such pre-harvest surveys have been instructed only for rice.

Post-harvest surveys aim to judge the necessity of distribution restrictions based on the monitoring data obtained in harvested rice. In the priority target areas, surveys of rice should be performed at about every 15 ha. If the PRV for radiocesiums is exceeded, restrictions should be imposed in each municipality. In each of the other target areas, surveys of rice should be performed at about seven different sites. If radiocesium levels are above 200 Bq/kg, these areas are switched to be priority target areas. Because there is only a single annual crop, restrictions for rice harvested in 2011 cannot be lifted throughout the year once enforced.

Taken together, it is noteworthy that prior to these two-stage monitoring surveys, restrictions on rice cultivation were imposed. In other words, there were three stages to prevent production and distribution of contaminated rice. On 8 April 2011, NERHQ issued the notice for policy on restrictions on planting and cultivation of rice [28]. The National Institute for Agro-Environmental Sciences (Ibaraki, Japan) had analyzed radiocesium levels in the soil of paddy fields and in harvested rice, and obtained a total of 564 data sampled at 17 different sites in Japan from 1959 to 2001. The data showed that transfer of radiocesiums from soil to rice does not depend on the types of soil. Based on these data, the index for transfer of radiocesiums from the soil of paddy fields to unpolished brown rice was set to 0.1. This was because some Japanese citizens daily consume brown rice, though polished rice should contain lower levels of radiocesiums. Given this index, the upper limits of radiocesium levels in soil were set to 5000 Bq/kg so as to avoid producing brown rice exceeding the PRV (500 Bq/kg). It was hence advised that rice should not be cultivated in areas where radiocesium levels in the soil of paddy fields are above 5000 Bq/kg. On 22 April 2011, NERHQ imposed restrictions on rice cultivation in the stay-away evacuation zone, planned evacuation zone, and evacuation prepared zone of Fukushima Prefecture [29].

On 30 August 2011, MAFF reported the distribution map of radiocesium levels in farmland soil, which was drawn predicated on the monitoring results of soil sampled either from paddy fields (sampled at 15 cm depth from the ground surface) or other farmland (at ≤30 cm deep) at 360 sites in Fukushima Prefecture and at a total of 220 sites in Miyagi, Tochigi, Gunma, Ibaraki and Chiba prefectures [30]. Because sampling dates varied, radiocesium levels were adjusted to those on 14 June 2011. Among zones where rice cultivation has been restricted (i.e. zones for the stay-away evacuation, planned evacuation and prepared evacuation in Fukushima Prefecture), the maximum level detected in the soil of paddy fields was 28 401 Bq/kg in Namie Town (planned evacuation zone). In other areas of Fukushima Prefecture, radiocesium levels in the soil of paddy fields were below 5000 Bq/kg, but soil of farmland for crops other than rice contained 5249–8571 Bq/kg of radiocesiums at nine sites in Date, Soma, Iwaki cities or Otama Village (n.b. cultivation restrictions have not been imposed for crops other than rice). The maximum levels detected in Tochigi, Miyagi, Chiba, Gunma and Ibaraki prefectures were 3971 (paddy field), 2215 (truck farm), 777 (truck farm), 688 (truck farm) and 632 (truck farm) Bq/kg, respectively. MAFF is planning to conduct additional surveys of farmland soil. In these surveys, the sampling scale will be enlarged to 3000 sites, and priority will be given to sites neighboring previously
surveyed sites where high levels of radioceasiums have been detected. Such surveys would be significant to plan the strategy for decontamination of farmland. Incidentally, the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT) has provided the distribution maps for levels of radioceasiums and radioiodines in soil on 30 August 2011 and 21 September 2011, respectively [31, 32]. These maps were drawn based on the monitoring results of soil other than farmland sampled on 6–14 June 2011 and 27 June to 8 July 2011 at 5 cm in depth from the ground surface, and were devoted to evaluation of the dose to citizens.

Overall, the current policy on the enforcement of restrictions has provided clear criteria to remove the restrictions, but not to order them. Namely, concrete threshold values of radioactive concentrations for ‘highly contaminated’ and ‘very highly contaminated’ food have not been defined to restrict distribution and consumption, respectively, so quantitatively consistent decisions could not be made to impose restrictions.

4. OUTLINES OF MONITORING DATA AND ENFORCED RESTRICTIONS

As of 31 March 2012, MHLW reported the monitoring data of 137 337 food samples and 83 074 tap water samples taken since 19 and 21 March 2011, respectively [33]. Of these, the PRVs were exceeded in 1519 food samples and 68 tap water samples. Tables 2 and 3 list the dates when samples first or last exceeded the PRVs, and the maximum levels of radioiodine (131I) and radioceasiums (a total of 134Cs and 137Cs) in each item of food and water. Table 4 further lists timing and duration for each enforced restriction. Note that the number of days taken was conservatively counted including the initial day throughout this paper (e.g. the days from 16 March 2011 to 28 March 2011 were counted as 13 days, not 12 days).

4.1. Tap water

The PRVs for radioiodine were exceeded for ≤13 days (16–28 March 2011), whereas no samples exceeded the PRVs for radioceasiums. The maximum level detected was 965 Bq/kg of radioiodine in the sample obtained on 20 March 2011 in Fukushima Prefecture. All consumption restrictions began within 6 days (within 2 days except for Fukushima Prefecture) after radioiodine levels first exceeded 100 Bq/kg. Consumption by infants was restricted for 51 days in Iitate Village of Fukushima Prefecture (the water supplier voluntarily extended the period of restrictions for infants, so it took 44 days to lift restrictions after the PRVs were last exceeded), 4–12 days in other areas of Fukushima Prefecture and 1–4 days in other prefectures. Consumption by all age groups other than infants was restricted for 12 days only in Iitate Village. In Tochigi Prefecture, the PRVs were not exceeded during the restricted period.

The radioactivity levels in sludge from water filter plants are becoming lower. For example, in the Kanamachi plant of Tokyo Prefecture (the only plant in Tokyo from which tap water exceeded PRV), the levels of radioiodine and radioceasiums in mechanically dehydrated sludge were 88 400 and 14 650 Bq/kg on 28 March 2011, 60 and 7400 Bq/kg on 1 June 2011, <20 and 410 Bq/kg on 28 December 2011 and <20 and 670 Bq/kg in the second half of March 2012 (a mean of four samples taken on 15, 19, 22 and 26 March 2012; such approach has been taken since January 2012), respectively [34]. On 16 June 2011, NERHQ issued a notice for policy on the handling of radioceasium-contaminated sludge from water filter plants, sewage treatment plants, local drainage facilities and industrial water facilities [35]. Responding to this notice, radioceasium levels in 49 250 tons of dehydrated sludge from water filter plants were monitored in the target 14 prefectures on 16 June 2011 and 12 July 2011 [36]. Of these, 28% were at <100 Bq/kg (the level instructed in the notice allowing reuse of the sludge), 69% were at 100–8000 Bq/kg (the level for landfill disposal at leachate-controlled landfill sites if the sites will not be converted into a residence), 3% were at 8000–100 000 Bq/kg (the level for temporary storage at the sites), and none at >100 000 Bq/kg (the level for storage in shielded facilities at a distance away from the boundary of the site depending on radioactivity levels). Taken together, 76% of such sludge has been stored in each water filter plant and disposal methods have yet to be determined for 97%, while the rest has undergone landfill disposal or has been processed for reuse in cement ingredients, construction, agriculture, horticulture, etc. Another 54 631 tons of sludge have not been subjected to monitoring surveys, but most of it will not be moved outside the plants as they have sufficient storage space.

4.2. Raw milk

The PRVs for radioiodine were exceeded for ≤7 days (16–22 March 2011), while those for radioceasiums were exceeded only in one sample. The maximum level detected was 5300 Bq/kg of radioiodines in the sample obtained on 20 March 2011 in Fukushima Prefecture, and 420 Bq/kg of radioceasiums in the sample obtained on 19 March 2011 in Fukushima Prefecture. Distribution restrictions began within 6 days after radioiodine levels started exceeding 100 Bq/kg. In Fukushima Prefecture, the PRVs have not been exceeded since 23 March 2011, but restrictions are still ongoing. In Ibaraki Prefecture, no samples exceeded the PRVs during the restricted 19-day period.

In the Chernobyl accident, the average thyroid dose to children and adolescents, which was almost entirely due to consumption of radioiodine-contaminated fresh milk in the
| Category* | Item | Area | Number of samplesb | 131I | 137I | 134Cs and 137Cs |
|-----------|------|------|-------------------|------|------|----------------|
|           |      |      |                   | First exceededc | Maximum levels in Bq/kg (sampling date) | Last exceededc | Duration (days)d | First exceededc | Maximum levels in Bq/kg (sampling date) | Last exceededc | Duration (days)d |
| Water and beverages | Tap water | Fukushima | 43 (8)f | 3.16.2011a | 965 (3.20.2011) | 3.28.2011 | 13 | n.e. | 3.19.2011 | 420 (3.19.2011) | 3.19.2011 | 1 |
|           |      | Chiba | 8 (2)f | 3.22.2011 | 370 (3.22.2011) | 3.25.2011 | 4 | n.e. |
|           |      | Ibaraki | 13 (0)f | 3.22.2011 | 298 (3.23.2011) | 3.24.2011 | 3 | n.e. |
|           |      | Tokyo | 2 (0)f | 3.22.2011 | 210 (3.22.2011) | 3.23.2011 | 2 | n.e. |
|           |      | Saitamaa | 1 (0)f | 3.22.2011 | 120 (3.22.2011) | 3.22.2011 | 1 | n.e. |
|           |      | Tochigi | 1 (0)f | 3.24.2011 | 110 (3.24.2011) | 3.24.2011 | 1 | n.e. |
| Milk | Raw milk | Fukushima | 18 (18)c | 3.16.2011a | 5300 (3.20.2011) | 3.22.2011 | 7 | 3.19.2011 | 420 (3.19.2011) | 3.19.2011 | 1 |
|           |      | Ibaraki | 5 (5)c | 3.19.2011 | 1700 (3.19.2011-3.21.2011) | 3.21.2011 | 3 | n.e. |
| Meat | Beef | Fukushima | 61 (7.8.2011)i | n.e. | 3.30.2011l | 3400 (6.30.2011) | 12.18.2011 | 264 |
|           |      | Tochigi | 10 (7.22.2011)j | n.e. | 4.15.2011l | 2200 (4.15.2011) | 7.19.2011 | 96 |
|           |      | Miyagi | 58 (7.22.2011)j | n.e. | 5.6.2011l | 1400 (7.7.2011) | 9.29.2011 | 147 |
|           |      | Iwate | 24 (7.22.2011)j | n.e. | 5.21.2011l | 2430 (7.26.2011) | 3.21.2012 | 307 |
|           |      | Yamagataa | 2 (7.24.2011)j | n.e. | 5.25.2011l | 590 (5.25.2011) | 6.3.2011 | 10 |
|           |      | Akita | 2 (7.22.2011)j | n.e. | 7.12.2011l | 781 (8.1.2011) | 8.1.2011 | 21 |
| Venison | | Tochigi | 5 | n.e. | 7.3.2011 | 1069 (7.3.2011) | 12.4.2011 | 155 |
|           |      | Fukushimaa | 1 | n.e. | 12.25.2011 | 1110 (12.25.2011) | 12.25.2011 | 1 |
| Wild boar meat | | Tochigi | 11 | n.e. | 7.16.2011 | 2490 (1.19.2012) | 1.27.2012 | 196 |
|           |      | Ibaraki | 8 | n.e. | 9.7.2011 | 1040 (9.7.2011) | 2.8.2012 | 155 |
| Wild moon bear meat | | Fukushima | 98 | n.e. | 9.5.2011 | 14600 (9.5.2011) | 3.4.2012 | 178 |
|           |      | Fukushima | 5 | n.e. | 8.15.2011 | 1850 (12.5.2011) | 12.25.2011 | 133 |
|           |      | Tochigi | 1 | n.e. | 8.20.2011 | 727 (8.20.2011) | 8.20.2011 | 1 |
| Wild bear meat | | Iwate | 1 | n.e. | 11.24.2011 | 600 (11.24.2011) | 11.24.2011 | 1 |
|           |      | Fukushimaa | 1 | n.e. | 11.10.2012 | 2030 (1.10.2012) | 1.10.2012 | 1 |
|           |      | Yamagataa | 1 | n.e. | 3.11.2012 | 560 (3.11.2012) | 3.11.2012 | 1 |
|           |      | Fukushimaa | 1 | n.e. | 11.20.2011 | 736 (11.20.2011) | 11.20.2011 | 1 |
| Cereals | Wheat | Fukushimaa | 1 | n.e. | 7.19.2011 | 630 (7.19.2011) | 7.19.2011 | 1 |
| Brown rice | | Fukushima | 311 | n.e. | 11.14.2011 | 1540 (12.22.2011) | 2.3.2012 | 82 |
| Other foodstuffs | Raw tea leaves | Kanagawa | 6j | n.e. | 5.9.2011 | 775 (5.11.2011) | 5.12.2011 | 4 |

Continued
| Category          | Item         | Area      | Number of samples | Number of samples above 100 Bq/kg of $^{131}$I | Number of samples above 300 Bq/kg of $^{131}$I | First exceeded | Maximum levels in Bq/kg (sampling date) | Last exceeded | Duration (days) | First exceeded | Maximum levels in Bq/kg (sampling date) | Last exceeded | Duration (days) |
|-------------------|--------------|-----------|-------------------|-----------------------------------------------|------------------------------------------------|----------------|----------------------------------------|--------------|----------------|----------------|----------------------------------------|--------------|----------------|          |
| Dried tea leaves | Tokyo        | n.e.      | 1                 | n.e.                                          |                                                |                |                                        |              | 5.10.2011       | 520 (5.10.2011) | 5.10.2011       | 1            |                |          |
|                   | Ibaraki      | n.e.      | 13                | n.e.                                          |                                                |                |                                        |              | 5.14.2011       | 1030 (5.18.2011) | 6.1.2011        | 19           |                |          |
|                   | Fukushima    | n.e.      | 1                 | n.e.                                          |                                                |                |                                        |              | 5.17.2011       | 930 (5.17.2011) | 5.17.2011       | 1            |                |          |
|                   | Tochigi      | n.e.      | 2                 | n.e.                                          |                                                |                |                                        |              | 5.17.2011       | 890 (5.17.2011) | 5.17.2011       | 1            |                |          |
|                   | Chiba        | n.e.      | 6                 | n.e.                                          |                                                |                |                                        |              | 5.19.2011       | 985 (5.19.2011) | 5.24.2011       | 6            |                |          |
|                   | Gunma        | n.e.      | 1                 | n.e.                                          |                                                |                |                                        |              | 5.24.2011       | 780 (5.24.2011) | 5.24.2011       | 1            |                |          |
|                   | Dried tea leaves | Kanagawa | n.e.      | 11                | n.e.                                          |                                                |                |                                        |              | 5.12.2011       | 3000 (5.12.2011) | 10.28.2011       | 170          |                |          |
|                   | Tochigi      | n.e.      | 2                 | n.e.                                          |                                                |                |                                        |              | 7.5.2011        | 1810 (7.5.2011) | 7.12.2011       | 8            |                |          |
|                   | Gunma        | n.e.      | 2                 | n.e.                                          |                                                |                |                                        |              | 6.27.2011       | 1010 (6.27.2011) | 8.1.2011        | 36           |                |          |
|                   | Chiba        | n.e.      | 8                 | n.e.                                          |                                                |                |                                        |              | 6.29.2011       | 2300 (6.29.2011) | 8.24.2011       | 57           |                |          |
|                   | Saitama      | n.e.      | 9                 | n.e.                                          |                                                |                |                                        |              | 10.17.2011      | 2700 (10.17.2011) | 10.17.2011     | 1            |                |          |
|                   | Processed tea leaves | Chiba | n.e.      | 1                 | n.e.                                          |                                                |                |                                        |              | 5.31.2011       | 2720 (5.31.2011) | 5.31.2011       | 1            |                |          |
|                   | Shizuoka     | n.e.      | 7                 | n.e.                                          |                                                |                |                                        |              | 6.9.2011        | 981 (6.22.2011) | 6.22.2011       | 14           |                |          |
|                   | Tokyo        | n.e.      | 5                 | n.e.                                          |                                                |                |                                        |              | 6.15.2011       | 2700 (6.15.2011) | 10.6.2011       | 114          |                |          |
|                   | Saitama      | n.e.      | 118               | n.e.                                          |                                                |                |                                        |              | 8.10.2011       | 2150 (10.7.2011) | 11.9.2011       | 92           |                |          |
|                   | Rapeseed     | n.e.      | 1                 | n.e.                                          |                                                |                |                                        |              | 7.20.2011       | 720 (7.20.2011)  | 7.20.2011       | 1            |                |          |
|                   | Rice bran    | n.e.      | 1                 | n.e.                                          |                                                |                |                                        |              | 10.7.2011       | 668 (10.7.2011)  | 10.7.2011       | 1            |                |          |
|                   | Nikko maple  | n.e.      | 1                 | n.e.                                          |                                                |                |                                        |              | 11.18.2011      | 710 (11.18.2011) | 11.18.2011     | 1            |                |          |
|                   | Tochu tea    | n.e.      | 1                 | n.e.                                          |                                                |                |                                        |              | 12.9.2011       | 660 (12.9.2011)  | 12.9.2011       | 1            |                |          |

n.e., provisional regulation values were not exceeded.

- Shown is the food category defined for the provisional regulation values (see Table 1).
- Presented is the total number of samples exceeding the provisional regulation values for radioiodine and/or radiocesiums.
- Shown are the dates when samples first or last exceeding the provisional regulation value were taken.
- The number of days from the first day when samples exceeded the provisional regulation value to the last day was counted including the initial day.
- Shown is the number of samples above 100 Bq/kg of $^{131}$I. Shown in parentheses is the number of samples above 300 Bq/kg of $^{131}$I among them.
- Only one sample exceeded the provisional regulation value for radiocesiums.
- Samples from dairy cattle fed in pasture exceeded the provisional regulation value, but not those fed in cow barns.
- Samples were considered to exceed the provisional regulation values by looking back over the past, because the provisional regulation values (except those for radioiodine in seafood) were set on 17 March 2011.
- Sample numbers include different beef samples from the same cattle. Shown in parentheses are the dates when the first data were reported.
- Presented are the dates when cattle were slaughtered.
- MHLW (for water) and NERHQ (for food) did not order restrictions, but each local government voluntarily instructed restrictions and recall for most of these foodstuffs.
- Tea leaves were cultivated outdoors.
- Shown is the radioactivity level in the sample from the same lot shipped to France (see Section 4.7).
- Shown is the English name. Megusuri-no-ki is the Japanese name, and Acer maximowiczianum is the scientific name.
- Shown is the English name. Yama-dori is the Japanese name, and Syrinxus soemmerringii is the scientific name.
- Tea extracted from young leaves of hardy rubber tree Tochu (Eucommia ulmoides), also called du zhong tea.
Table 3. Levels of radioiodine and radionuclides in categories of vegetables and aquatic products (as of 31 March 2012)

| Category a | Subcategory | Item b | Area                | Number of samples (cultivation) c | 131I First exceeded d | Maximum levels in Bq/kg (sampling date) | Last exceeded e | Duration (days) e | 134Cs and 137Cs First exceeded d | Maximum levels in Bq/kg (sampling date) | Last exceeded e | Duration (days) e |
|-----------|-------------|--------|---------------------|-----------------------------------|-----------------------|----------------------------------------|----------------|----------------|-----------------------------------|----------------------------------------|----------------|----------------|
| Vegetables | Fresh       | Horenso (spinach, Spinacia oleracea) | Ibaraki 22 (outdoor) | 3.18.2011 | 54100 (3.18.2011) | 4.6.2011 | 20 | 3.18.2011 | 1931 (3.18.2011) | 4.11.2011 | 25 |
|           |             |        |                     | Ibaraki 7 (indoor) | 3.19.2011 | 11000 (3.19.2011) | 3.30.2011 | 12 | 3.19.2011 | 691 (3.30.2011) | 3.30.2011 | 12 |
|           |             |        |                     | Tochigi 9 (outdoor) | 3.19.2011 | 5700 (3.19.2011) | 3.30.2011 | 12 | 3.19.2011 | 790 (3.19.2011) | 3.30.2011 | 12 |
|           |             |        |                     | Gunma 2 (outdoor) | 3.19.2011 | 2630 (3.19.2011) | 3.19.2011 | 1 | n.e. | 2.11.2011 | 40000 (3.21.2011) | 4.25.2011 | 36 |
|           |             |        |                     | Fukushima 39 | 3.21.2011 | 19000 (3.21.2011) | 4.11.2011 | 22 | 3.21.2011 | 40000 (3.21.2011) | 4.25.2011 | 36 |
|           |             |        |                     | Chiba 2 | 3.24.2011 | 3500 (3.24.2011) | 3.30.2011 | 7 | n.e. | 2.11.2011 | 82000 (3.11.2011) | 3.30.2011 | 13 |
|           |             |        |                     | Chiba 4 | 3.18.2011 | 4300 (3.18.2011) | 3.30.2011 | 13 | n.e. | 2.11.2011 | 82000 (3.11.2011) | 3.30.2011 | 13 |
|           |             |        |                     | Tochigi 2 | 3.24.2011 | 4340 (3.24.2011) | 3.24.2011 | 1 | n.e. | 2.11.2011 | 82000 (3.11.2011) | 3.30.2011 | 13 |
|           |             |        |                     | Gunma 1 (outdoor) | n.e. | 3.19.2011 | 555 (3.19.2011) | 3.19.2011 | 1 |
|           |             |        |                     | Fukushima 5 | 3.21.2011 | 15000 (3.21.2011) | 3.28.2011 | 8 | 3.21.2011 | 82000 (3.21.2011) | 4.11.2011 | 22 |
|           |             |        |                     | Fukushima 5 | 3.21.2011 | 22000 (3.21.2011) | 4.4.2011 | 15 | 3.21.2011 | 28000 (3.21.2011) | 4.18.2011 | 29 |
|           |             |        |                     | Fukushima 21 | 3.21.2011 | 17000 (3.21.2011) | 3.28.2011 | 8 | 3.21.2011 | 13900 (3.21.2011) | 4.11.2011 | 22 |
|           |             |        |                     | Fukushima 2 | 3.21.2011 | 4900 (3.21.2011) | 3.28.2011 | 8 | 3.21.2011 | 24000 (3.21.2011) | 3.28.2011 | 8 |
|           |             |        |                     | Fukushima 6 | 3.21.2011 | 5900 (3.21.2011) | 3.21.2011 | 1 | 3.21.2011 | 3600 (3.28.2011) | 4.18.2011 | 29 |
|           |             |        |                     | Tokyo 1 (outdoor) | n.e. | 3.23.2011 | 890 (3.23.2011) | 3.23.2011 | 1 |
|           |             |        |                     | Fukushima 4 | 3.21.2011 | 5400 (3.21.2011) | 3.28.2011 | 8 | 3.21.2011 | 10800 (3.21.2011) | 4.11.2011 | 22 |
|           |             |        |                     | Fukushima 6 | 3.21.2011 | 8200 (3.21.2011) | 3.28.2011 | 8 | 3.21.2011 | 8900 (3.21.2011) | 4.4.2011 | 15 |
|           |             |        |                     | Fukushima 1 | 3.21.2011 | 3700 (3.21.2011) | 3.21.2011 | 1 | 3.21.2011 | 9000 (3.21.2011) | 3.21.2011 | 1 |
|           |             |        |                     | Fukushima 5 | 3.21.2011 | 5200 (3.21.2011) | 3.21.2011 | 1 | 3.21.2011 | 2600 (3.21.2011) | 4.11.2011 | 22 |
|           |             |        |                     | Fukushima 3 | n.e. | 3.21.2011 | 4000 (4.3.2011) | 5.9.2011 | 50 |

Continued
| Category | Subcategory | Item | Area | Number of samples (cultivation) | $^{131}I$ | $^{134}Cs$ and $^{137}Cs$ |
|----------|-------------|------|------|--------------------------------|----------|----------------|
|          |             |      |      | First exceeded | Maximum levels in Bq/kg (sampling date) | Last exceeded | Duration (days) | First exceeded | Maximum levels in Bq/kg (sampling date) | Last exceeded | Duration (days) |
|          |             |      |      | (cultivation)   |                                      |              |               | (cultivation)   |                                      |              |               |
|          |             |      |      | (a)  | (b) | (c)  | (d)  | (e)                    |                  |              | (a)  | (b) | (c)  | (d)  | (e)                |
| Paseri (parsley, *Petroselinum crispum*) | Ibaraki | 7 (indoor) | 3.21.2011 | 12000 (3.21.2011) | 3.30.2011 | 10 | 3.21.2011 | 2100 (3.21.2011) | 5.12.2011 | 53 |
|          | Chiba | 2 | 3.22.2011 | 3100 (3.22.2011) | 3.30.2011 | 9 | n.e. |
|          | Chiba | 1 | 3.22.2011 | 2800 (3.22.2011) | 3.22.2011 | 1 | n.e. |
|          | Chiba | 1 | 3.22.2011 | 2200 (3.22.2011) | 3.22.2011 | 1 | n.e. |
|          | Chiba | 1 | 3.22.2011 | 2100 (3.22.2011) | 3.22.2011 | 1 | n.e. |
|          | Chiba | 1 | 3.22.2011 | 3400 (3.23.2011) | 3.23.2011 | 1 | 3.23.2011 | 560 (3.23.2011) | 3.23.2011 | 1 |
|          | Chiba | 1 | 3.23.2011 | 4900 (3.28.2011) | 3.28.2011 | 1 | 3.28.2011 | 3300 (3.28.2011) | 4.11.2011 | 15 |
|          | Chiba | 2 | 3.24.2011 | 2500 (3.24.2011) | 3.24.2011 | 1 | 3.24.2011 | 670 (3.24.2011) | 4.11.2011 | 19 |
|          | Fukushima | 3 | 3.28.2011 | 11.14.2011 | 1060 (11.14.2011) | 11.14.2011 | 1 |
|          | Fukushima | 2 | 3.28.2011 | 640 (2.1.2012) | 2.1.2012 | 1 |
|          | Chiba | 1 | 4.4.2011 | 9600 (4.4.2011) | 4.11.2011 | 8 |
|          | Chiba | 2 | 4.11.2011 | 1960 (4.11.2011) | 4.18.2011 | 8 |
|          | Fukushima | 55 | 4.27.2011 | 730 (3.26.2012) | 3.26.2012 | 1 |
|          | Fukushima | 3 | 4.28.2011 | 1460 (5.5.2011) | 5.5.2011 | 8 |
|          | Ibaraki | 1 | 3.25.2011 | 3.25.2011 | 1 | n.e. |
|          | Chiba | 2 | 4.4.2011 | 9600 (4.4.2011) | 4.11.2011 | 8 |
|          | Chiba | 2 | 4.11.2011 | 1960 (4.11.2011) | 4.18.2011 | 8 |
|          | Fukushima | 55 | 4.27.2011 | 730 (3.26.2012) | 3.26.2012 | 1 |
|          | Fukushima | 3 | 4.28.2011 | 1460 (5.5.2011) | 5.5.2011 | 8 |
|          | Ibaraki | 1 | 3.25.2011 | 3.25.2011 | 1 | n.e. |
|          | Chiba | 2 | 4.4.2011 | 9600 (4.4.2011) | 4.11.2011 | 8 |
|          | Chiba | 2 | 4.11.2011 | 1960 (4.11.2011) | 4.18.2011 | 8 |
|          | Fukushima | 55 | 4.27.2011 | 730 (3.26.2012) | 3.26.2012 | 1 |
|          | Fukushima | 3 | 4.28.2011 | 1460 (5.5.2011) | 5.5.2011 | 8 |
|          | Ibaraki | 1 | 3.25.2011 | 3.25.2011 | 1 | n.e. |
|          | Chiba | 2 | 4.4.2011 | 9600 (4.4.2011) | 4.11.2011 | 8 |
|          | Chiba | 2 | 4.11.2011 | 1960 (4.11.2011) | 4.18.2011 | 8 |
|          | Fukushima | 55 | 4.27.2011 | 730 (3.26.2012) | 3.26.2012 | 1 |
|          | Fukushima | 3 | 4.28.2011 | 1460 (5.5.2011) | 5.5.2011 | 8 |
|          | Ibaraki | 1 | 3.25.2011 | 3.25.2011 | 1 | n.e. |
|          | Chiba | 2 | 4.4.2011 | 9600 (4.4.2011) | 4.11.2011 | 8 |
|          | Chiba | 2 | 4.11.2011 | 1960 (4.11.2011) | 4.18.2011 | 8 |
|          | Fukushima | 55 | 4.27.2011 | 730 (3.26.2012) | 3.26.2012 | 1 |
|          | Fukushima | 3 | 4.28.2011 | 1460 (5.5.2011) | 5.5.2011 | 8 |
|          | Ibaraki | 1 | 3.25.2011 | 3.25.2011 | 1 | n.e. |
|          | Chiba | 2 | 4.4.2011 | 9600 (4.4.2011) | 4.11.2011 | 8 |
|          | Chiba | 2 | 4.11.2011 | 1960 (4.11.2011) | 4.18.2011 | 8 |
|          | Fukushima | 55 | 4.27.2011 | 730 (3.26.2012) | 3.26.2012 | 1 |
|          | Fukushima | 3 | 4.28.2011 | 1460 (5.5.2011) | 5.5.2011 | 8 |
|          | Ibaraki | 1 | 3.25.2011 | 3.25.2011 | 1 | n.e. |
|          | Chiba | 2 | 4.4.2011 | 9600 (4.4.2011) | 4.11.2011 | 8 |
|          | Chiba | 2 | 4.11.2011 | 1960 (4.11.2011) | 4.18.2011 | 8 |
| Dried vegetables | Dried doku-dami (dried chameleon plant, *Houttuynia cordata*) | 4 | 11.4.2011 | 3400 (11.14.2011) | 12.2.2011 | 30 |
|          | Niga-uri-cha (bitter melon tea, *Momordica charantia*) | 1 | 12.19.2011 | 1020 (12.19.2011) | 12.19.2011 | 1 |
|          | Imogara (dried tato stalk) | 2 | 12.21.2011 | 750 (1.20.2012) | 1.20.2012 | 31 |
| Fresh mushroom | Cultivation Details | Date of Cultivation | Number of Logs (kg) | Sampling Date | Number of Logs (kg) | Number of Logs (kg) | Number of Logs (kg) |
|----------------|---------------------|---------------------|---------------------|---------------|---------------------|---------------------|---------------------|
| Kiriboshi-daikon (dried strips of daikon radish, *Raphanus sativus*) | Fukushima | 3 | n.e. | 1.6.2012 | 3000 (2.12.2012) | 2.12.2012 | 38 |
| Dried leaf of yacon (*Smallanthus sonchifolius*) | Fukushima | 1 | n.e. | 1.13.2012 | 970 (1.13.2012) | 1.13.2012 | 1 |
| Dried oyama-bokuchi (dried pokeweed, *Synurus pangens*) | Fukushima | 1 | n.e. | 1.17.2012 | 570 (1.17.2012) | 1.17.2012 | 1 |
| Shiitake (shii-take mushroom, *Lentinula edodes*) cultivated on bed logs | Fukushima | 40 (outdoor) | 4.1.2011 | 12000 (4.8.2011) | 4.14.2011 | 14 | 4.1.2011 | 13000 (4.18.2011) | 10.13.2011 | 196 |
| Chiha | 6 (outdoor) | n.e. | 7.12.2011 | 1770 (7.12.2011) | 11.11.2011 | 123 |
| Ibaraki | 3 (indoor) | n.e. | 9.26.2011 | 1955 (9.26.2011) | 2.20.2012 | 148 |
| Ibaraki | 6 (outdoor) | n.e. | 10.4.2011 | 1130 (11.7.2011) | 11.7.2011 | 35 |
| Miyagi | 6 (outdoor) | n.e. | 10.11.2011 | 890 (10.11.2011) | 11.15.2011 | 36 |
| Tochigi | 3 (indoor) | n.e. | 12.16.2011 | 1600 (3.1.2012) | 3.12.2012 | 88 |
| Iwate | 1 (outdoor) | n.e. | 2.2.2012 | 600 (2.2.2012) | 2.13.2012 | 12 |
| Shiitake mushroom cultivated on mushroom beds | Fukushima | 1 (indoor) | n.e. | 3.26.2012 | 512 (3.26.2012) | 3.26.2012 | 1 |
| Nameko (nameko mushroom, *Pholiota nameko*) cultivated on bed logs | Fukushima | 2 (outdoor) | n.e. | 10.27.2011 | 850 (10.27.2011) | 10.27.2011 | 1 |
| Tochigi | 3 (outdoor) | n.e. | 8.11.2011 | 4600 (8.11.2011) | 10.28.2011 | 79 |
| Kuri-take (kuritake mushroom, *Hypholoma sublateritium*) cultivated on bed logs | Tochigi | 8 (outdoor) | n.e. | 10.18.2011 | 759 (10.28.2011) | 11.10.2011 | 24 |
| Muki-take (mukitake mushroom, *Panellus serotinus*) cultivated on bed logs | Miyagi | 1 (outdoor) | n.e. | 10.20.2011 | 1908 (11.4.2011) | 11.11.2011 | 23 |
| Chichi-take (chichitake mushroom, *Lactarius volemus*) | Fukushima | 7 | n.e. | 11.13.2011 | 1400 (11.13.2011) | 11.13.2011 | 1 |
| Ibaraki | 1 | n.e. | 8.11.2011 | 28000 (9.1.2011) | 9.13.2011 | 34 |
| Hatsu-take (hatsutake mushroom, *Lactarius hatsudake*) | Fukushima | 8 | n.e. | 9.12.2011 | 8000 (9.12.2011) | 9.12.2011 | 1 |
| Ami-take (amitake mushroom, *Grifola frondosa*) | Fukushima | 2 | n.e. | 9.6.2011 | 19900 (9.15.2011) | 9.15.2011 | 10 |
| Matsu-take (matsutake mushroom, *Tricholoma matsutake*) | Fukushima | 1 | n.e. | 9.15.2011 | 3300 (9.15.2011) | 9.15.2011 | 1 |
| Mai-take (maitake mushroom, *Grifola frondosa*) | Fukushima | 2 | n.e. | 10.5.2011 | 2800 (10.5.2011) | 10.5.2011 | 1 |

Continued
| Categorya | Subcategory        | Itemb                          | Area      | Number of samples (cultivation)c | 131I First exceededd | Maximum levels in Bq/kg (sampling date) | Last exceededd | Duration (days)e | 134Cs and 137Cs First exceededd | Maximum levels in Bq/kg (sampling date) | Last exceededd | Duration (days)e |
|-----------|--------------------|--------------------------------|-----------|----------------------------------|----------------------|----------------------------------------|---------------|----------------|------------------|----------------------------------|----------------------------------------|---------------|-----------------|
| Hatake-shimeji (fried chicken mushroom, *Lyophyllum decastes*) |       | Fukushima                      | 1         | n.e.                             | 10.12.2011           | 820 (10.12.2011)                          | 10.12.2011   | 1              |
| Chaname-tsumu-take (Chanametsumutake mushroom, *Pholiota lubrica*) |       | Nagano                        | 1         | n.e.                             | 10.24.2011           | 1320 (10.24.2011)                          | 10.24.2011   | 1              |
| Dried mushroom | Dried shiitake mushroom | Shizuoka                    | 3         | n.e.                             | 10.7.2011            | 599 (10.7.2011)                           | 11.24.2011   | 49             |
|                                                             |       | Kanagawa                      | 4         | n.e.                             | 10.19.2011           | 2770 (11.2.2011)                           | 11.7.2011    | 20             |
|                                                             |       | Fukushima                    | 15        | n.e.                             | 11.8.2011            | 4900 (11.18.2011)                           | 11.22.2011   | 15             |
|                                                             |       | Tochigi                       | 19        | n.e.                             | 10.11.2011           | 6940 (11.10.2011)                           | 1.23.2012    | 105            |
|                                                             |       | Gunma                        | 8         | n.e.                             | 11.30.2011           | 2867 (11.30.2011)                           | 11.30.2011   | 1              |
|                                                             |       | Iwate                        | 5         | n.e.                             | 1.30.2012            | 2880 (1.30.2012)                           | 1.30.2012    | 1              |
|                                                             |       | Ibarakig                     | 5         | n.e.                             | 2.2.2012             | 2080 (2.2.2012)                            | 2.2.2012     | 1              |
| Dried kikurage (dried Jew’s ear, *Auricularia auricula*) |       | Fukushima                    | 1         | n.e.                             | 11.17.2011           | 550 (11.17.2011)                           | 11.17.2011   | 1              |
| Fruit and nut | Ume (Japanese apricot, *Prunus mume*) | Fukushima                   | 11        | n.e.                             | 5.26.2011            | 760 (6.9.2011)                            | 6.21.2011    | 27             |
|                                                             |       | Biwa (loquat, *Eriobotrya japonica*) | Fukushima | 1         | n.e.                             | 7.13.2011            | 530 (7.13.2011)                           | 7.13.2011    | 1              |
|                                                             |       | Ichijiku (fig, *Ficus carica*) | Fukushima | 1         | n.e.                             | 7.19.2011            | 520 (7.19.2011)                           | 7.19.2011    | 1              |
|                                                             |       | Yuzu (Citrus junos)          | Fukushima | 7         | n.e.                             | 8.24.2011            | 2400 (8.24.2011)                           | 1.5.2012     | 135            |
|                                                             |       | Kuri (chestnut, *Castanea crenata*) | Fukushima | 2         | n.e.                             | 9.5.2011             | 2040 (9.5.2011)                           | 9.15.2011    | 11             |
|                                                             |       | Zakuro (pomegranate, *Punica granatum*) | Fukushima | 1         | n.e.                             | 10.13.2011           | 560 (10.13.2011)                           | 10.13.2011   | 1              |
|                                                             |       | Kaki (kaki persimmon, * Diospyros kaki*) | Fukushima | 1         | n.e.                             | 11.4.2011            | 670 (11.4.2011)                           | 11.4.2011    | 1              |
|                                                             |       | Kiwifruit (Actinidia delicosa) | Fukushima | 4         | n.e.                             | 11.14.2011           | 1120 (11.14.2011)                          | 12.7.2011    | 25             |
|                                                             |       | Brown seaweed                | Wakame (wakame seaweed, *Undaria pinnatifida*) | Fukushima | 1         | n.e.                             | 5.16.2011            | 1200 (5.16.2011)                           | 5.16.2011    | 1              |
|                                                             |       | Hiji (hiji seaweed, *Sargassum fusiforme*) | Fukushima | 1         | 5.21.2011 | 2200 (5.21.2011) | 5.21.2011 | 1              |
|                                                             |       | Azame (arame seaweed, *Eisenia bicyclus*) | Fukushima | 6         | n.e.                             | 5.21.2011            | 970 (5.21.2011)                           | 8.22.2011    | 94             |
| Aquatic products | Coastal fish products | Konago (juvenile sand lance, *Ammodytes personatus*) | Ibarakig | 6         | 4.1.2011f | 4080 (4.1.2011) | 4.11.2011 | 11             |
|                                                             |       | Fukushima                    | 6         | 4.13.2011          | 12000 (4.13.2011)    | 4.18.2011 | 6              |
|                                                             |       |                             |           |                    | 4.7.2011            | 14400 (4.18.2011)                          | 5.2.2011     | 26             |
| Species (name for the young of anchovy, eel, etc) | Location | Date (Start-End) | Weight (Start-Ending) | Date (Start-End) | Weight (Start-Ending) |
|-------------------------------------------------|----------|------------------|-----------------------|------------------|-----------------------|
| Shirasu (whitebait) | | | | | |
| Ainame (fat greenling, *Hexagrammos otakii*) | | | | | |
| Ezoiso-ainame (Physiculus maximoviczi) | | | | | |
| Ishi-garei (stone flounder, *Kareius bicoloratus*) | | | | | |
| Baba-garei (slime flounder, *Microstomus acne*) | | | | | |
| Mako-garei (marbled flounder, *Pleuronectes yokohamae*) | | | | | |
| Numa-garei (starry flounder, *Platichthys stellatus*) | | | | | |
| Shiro-mebaru (rockfish, *Sebastes cheni*) | | | | | |
| Usa-mebaru (goldeye rockfish, *Sebastes thompsonii*) | | | | | |
| Kutsune-mebaru (fox jacopever, *Sebastes vulpes*) | | | | | |
| Karosoi (black rockfish, *Sebastes schlegeli*) | | | | | |
| Muraoi (spotted rockfish, *Sebastes pachycephalus*) | | | | | |
| Komon-kasube (ocellate spot skate, *Okamejei kenojei*) | | | | | |
| Hirame (bastard halibut, *Paralichthys olivaceus*) | | | | | |
| Suzuki (Japanese seabass, *Lateolabrax japonicus*) | | | | | |
| Saburo (poacher, *Ocella iburui*) | | | | | |
| Kemushikajika (sea raven, *Hemitripterus villosus*) | | | | | |
| Marine invertabrates | | | | | |
| Murasaki-i-gai (blue mussel, *Mytilus galloprovincialis*) | | | | | |
| Hokki-gai (Sakhalin surfclam, *Pseudocardium sachalinense*) | | | | | |
| Uni (short-spined sea urchin, *Strongylocentrotus intermedius*) | | | | | |

| Marine invertabrates | | | | | |
| Murasaki-i-gai (blue mussel, *Mytilus galloprovincialis*) | | | | | |
| Hokki-gai (Sakhalin surfclam, *Pseudocardium sachalinense*) | | | | | |
| Uni (short-spined sea urchin, *Strongylocentrotus intermedius*) | | | | | |
Table 3. Continued

| Categorya | Subcategory | Itemb | Area | Number of samples (cultivation)c | 131I | 134Cs and 137Cs |
|-----------|-------------|-------|------|---------------------------------|------|-----------------|
|           |             |       |      |                                 |      |                 |
|           |             |       |      |                                 |      |                 |
| Kita-murasaki-uni (Northern sea urchin, Strongylocentrotus nudus) | | | | Fukushima | 6 | n.e. | 6.6.2011 | 1660 (12.12.2011) | 12.12.2011 | 190 |
| Mokazu-gani (Japanese mitten crab, Eriocheir japonicus) | | | | Fukushima | 1 | n.e. | 6.19.2011 | 1930 (6.19.2011) | 6.19.2011 | 1 |
| Freshwater fish | Ayu (sweetfish, Plecoglossus altivelis) | | | Fukushima | 21 | n.e. | 5.8.2011 | 4400 (6.20.2011) | 9.12.2011 | 128 |
| | Wakasagi (Japanese pond smelt, Hypomeus nipponensis) | | | Fukushima | 3 | n.e. | 5.10.2011 | 870 (5.10.2011) | 8.9.2011 | 92 |
| | Gunma | 6 | n.e. | 8.22.2011 | 650 (9.9.2011) | 1.6.2012 | 138 |
| | Yamame (landlocked salmon, Oncorhynchus masou) | | | Fukushima | 15 | n.e. | 5.17.2011 | 18700 (3.18.2012) | 3.29.2012 | 318 |
| | Ugui (Japanese dace, Tribolodon hakonensis) | | | Fukushima | 4 | n.e. | 5.20.2011 | 2500 (6.10.2011) | 3.23.2012 | 309 |
| | Gunma | 3 | n.e. | 9.9.2011 | 741 (9.9.2011) | 11.27.2011 | 80 |
| | Iwana (Japanese char, Salvelinus leucomaenis pluvius) | | | Fukushima | 2 | n.e. | 6.9.2011 | 840 (3.29.2012) | 3.29.2012 | 237 |
| | Gunma | 3 | n.e. | 9.15.2011 | 768 (1.29.2012) | 1.29.2012 | 137 |
| | Honmorerko (willow gudgeon, Gnathopogon caerulescens) | | | Fukushima | 1 | n.e. | 7.15.2011 | 1270 (7.15.2011) | 7.15.2011 | 1 |

n.e., provisional regulation values were not exceeded.

a Shown is the food category defined for the provisional regulation values (see Table 1).
b Shown are Japanese names. English and/or scientific names are shown in parentheses when available.
c Presented is the total number of samples exceeding the provisional regulation values for radioiodine and/or radiocesiums. Cultivation conditions are indicated in parentheses when the information is available.
d Shown are the dates when samples first or last exceeded the provisional regulation value.
e The number of days from the first day when samples exceeded the provisional regulation value to the last day was counted including the initial day.
f Samples were considered to exceed the provisional regulation values by looking back over the past, because the provisional regulation values for radioiodine in aquatic products were set on 5 April 2011.
g NERHQ did not order restrictions, but each local government voluntarily instructed restrictions and recall for most of these foodstuffs.
h Fish were reared in hatcheries.
i Dried doku-dami is not generally eaten as it is, rather used for a beverage in its extract like tea.
first few weeks following the accident, was estimated to be about 500 mGy with individual doses ranging from <50 mGy to >5000 mGy, and such internal exposure has been associated with an increase in thyroid cancer incidence [37]. On the other hand, in Fukushima Prefecture, the PRVs for radioiodine were first exceeded in a milk sample taken on 16 March 2011 at a level of 1190 Bq/kg, and its distribution has been restricted since 21 March 2011. A committed equivalent dose to the thyroid in infants, children and adults who were postulated to consume a mean intake of milk containing 1190 Bq/kg of radioiodine (i.e. 0.2, 0.5 and 0.6 l/day) for 6 days (16–21 March 2011) can be estimated to be 26, 11 and 0.86 mSv, respectively. It seems therefore most likely that countermeasures against radioiodine-contaminated milk were taken earlier in the Fukushima accident compared with the case for the Chernobyl accident. Incidentally, since 1 July 2011, postal questionnaires have been used to obtain information on individual behavioral records and on the intake of food and water from all residents of Fukushima Prefecture. The thyroids of residents who were ≤18 years of age as of 11 March 2011 will be checked up with echography throughout their lifetime. The preceding check-up surveys started in October 2011, and will be continued until March 2014. Considering that the thyroid cancer incidence started to be elevated around 4 or 5 years after the Chernobyl accident, follow-up surveys are planned to begin in April 2014 and then be conducted every 2 years (every 5 years in adults of ≥20 years of age).

Radioactivity levels in 513 samples of human mother’s breast milk were also monitored. From 16 March 2011 to 14 November 2011, a certain citizen group obtained 382 samples (including samples taken from the same mother on different dates) in Fukushima, Miyagi, Ibaraki, Tochigi, Gunma, Saitama, Chiba, Tokyo or Kanagawa prefectures [38]. Of these, the maximum levels of radioiodine were 36.3 Bq/kg in a sample taken on 29 March 2011 from a mother living in Chiba Prefecture, and 31.8 Bq/kg in a sample taken on 23 March 2011 from a mother living in Ibaraki Prefecture. Then, such levels in the corresponding same mothers’ milk decreased to 14.8 Bq/kg on 4 April 2011 and 8.5 Bq/kg on 30 March 2011, respectively. Radioiodine levels were below 15 Bq/kg in all samples. MHLW reported that the maximum levels of radioiodine and radioceasiums were 8.0 Bq/kg and 2.4 Bq/kg, respectively, among 23 samples obtained in Fukushima, Ibaraki, Chiba, Tokyo or Saitama prefectures on 24 or 25 April 2011 [39]. The National Institute of Public Health (NIPH, Saitama, Japan) reported levels of radioiodine and radioceasiums in 108 samples obtained in Miyagi, Yamagata, Fukushima, Ibaraki, Tochigi, Gunma, Chiba or Kochi prefectures during 18 May 2011 and 3 June 2011 [40]. Of these, seven samples contained a maximum radioceasium level of 13.1 Bq/kg. Radioceasiums in the rest of the 101 samples and radioiodine in all samples were below detectable levels. Incidentally, the above-mentioned citizen group also obtained the disposable paper diapers used by 101 infants living in Fukushima, Iwate, Miyagi, Ibaraki, Chiba, Tochigi, Gunma or Niigata prefectures to monitor levels of radioiodine and radioceasiums in the urine [38]. These urine samples were obtained from 4 September 2011 to 13 March 2012. Among them, the maximum radioceasium level detected was 7.4 Bq/kg, and radioiodine levels were below detectable levels in all samples.

A non-profit organization that was established in Nihon-matsu City of Fukushima Prefecture following the Fukushima accident has conducted monitoring surveys of distributed milk or milk powder since 22 November 2011 [41], and pointed out that some of them contain detectable levels of radioceasiums. In response to this, Meiji Holdings Co., Ltd (a major Japanese milk company) conducted monitoring surveys, and found that several lots of distributed milk powder contained 21.5–30.8 Bq/kg of radioceasiums [42]. On 6 December 2011, Meiji decided to exchange the distributed 400,000 bottles of milk powder products (850 g/bottle) for a new one free of charge [43], even though the radioceasium levels were below the PRV. These products dissolved at 0.15 g/ml in hot water are widely used as a follow-up baby milk to feed infants of 9 months or older.

4.3. Vegetables

Regarding items classified as a subcategory of fresh vegetables in Table 3, the PRV for radioiodine was exceeded for ≤25 days (18 March 2011 to 11 April 2011). The PRV for radioceasiums was exceeded for ≤376 days (18 March 2011 to 26 March 2012) in fresh vegetables (18 March 2011 to 23 June 2011 except hatake-wasabi, ha-wasabi and bamboo shoots, i.e. for ≤98 days), and for ≤101 days (4 November 2011 to 12 February 2012) in dried vegetables. The maximum level detected was 54 100 Bq/kg of radioiodine in spinach sampled on 18 March 2011 in Fukushima Prefecture, and 82 000 Bq/kg of radioceasiums in kikutachi-na on 21 March 2011 in Fukushima Prefecture. All restrictions for fresh vegetables began within 18 days after PRVs were first exceeded, but no restrictions were imposed for dried vegetables. In Fukushima Prefecture, the PRVs have not been exceeded in non-headed leafy vegetables, cabbage and broccoli since 26 April 2011, and in turnip, bamboo shoot and kusa-sotetsu since 24 June 2011, but the restrictions are still ongoing. Restrictions were enforced not only for each foodstuff but also for categorized group items of headed or non-headed leafy vegetables and flower-headed brassicas, so that distribution and consumption of hana-wasabi, mizu-na and vitamin-na were restricted at 2–20 days before the PRVs were exceeded (see footnotes k–n in Table 4). In other prefectures, restrictions were imposed for 19–73 days. Distribution of spinach in
| Category* (subcategory) | Item | Area | Sampling date | Distribution restrictions | Consumption restrictions |
|-------------------------|------|------|---------------|----------------------------|-------------------------|
|                         |      |      |               | Days taken to order | Days taken to lift | Lifted on\(g\) | Duration (days) | Days taken to order | Days taken to lift | Lifted on\(g\) | Duration (days) |
|                         |      |      |               | First exceeded | Last exceeded | Began on\(e\) | Began on\(e\) |          |          |          |          |
| Water and beverages     | Tap water | Fukushima | 3.16.2011 | 3.28.2011 | 6 | 3.21.2011 | 5 | 4.1.2011 | 12 |
|                         |      |      |               | Chiba | 3.22.2011 | 3.25.2011 | (3.21.2011) | 44 | (5.10.2011) | (4-51) |
|                         |      |      |               | Ibaraki | 3.22.2011 | 3.24.2011 | (3.23.2011) | 3 | (3.27.2011) | (2-4) |
|                         |      |      |               | Tokyo | 3.22.2011 | 3.23.2011 | (2) |
|                         |      |      |               | Tochigi* | 3.24.2011 | 3.24.2011 | (2.5) |
| Milk                   | Raw milk | Fukushima | 3.16.2011 | 3.22.2011 | 6 | 3.21.2011 | 19- |
|                        |      |      |               | Ibaraki* | 3.19.2011 | 3.21.2011 | 19 |
| Vegetables (fresh vegetables) | Spinach | Ibaraki* | 3.18.2011 | 4.11.2011 | 4 | 3.21.2011 | 52 | 6.1.2011 | 28-73 |
|                        |      |      |               | Kaki-na | n.e. | n.a. | 3.21.2011 | 4.17.2011 | 28 |
|                        |      |      |               | Parsley | Ibaraki* | 3.21.2011 | 5.12.2011 | 3 | 3.23.2011 | 26 |
|                        |      |      |               | Spinach | Tochigi* | 3.19.2011 | 3.30.2011 | 3 | 3.21.2011 | 26 |
|                        |      |      |               | Kaki-na | Tochigi* | n.e. | n.a. | 3.21.2011 | 4.14.2011 | 26 |
|                        |      |      |               | Spinach | Gunma* | 3.19.2011 | 3.19.2011 | 3 | 3.21.2011 | 19 |
|                        |      |      |               | Kaki-na | Gunma* | 3.19.2011 | 3.19.2011 | 3 | 3.21.2011 | 19 |
|                        |      |      |               | Spinach | Fukushima | 3.21.2011 | 4.25.2011 | 1 | 3.21.2011 | 45- |
|                        |      |      |               | Kaki-na | Fukushima | n.e. | n.a. | 3.23.2011 | 43- |
|                        |      |      |               | Kukitachi-na | Fukushima | 3.21.2011 | 4.11.2011 | 3 | 3.23.2011 | 43- |
|                        |      |      |               | Shinobu-fuyu-na | Fukushima | 3.21.2011 | 4.18.2011 | 3 | 3.21.2011 | 43- |
|                        |      |      |               | Santo-sai | Fukushima | 3.21.2011 | 3.28.2011 | 3 | 3.21.2011 | 43- |
|                        |      |      |               | Komatsu-na | Fukushima | 3.21.2011 | 4.18.2011 | 3 | 3.21.2011 | 43- |
|                        |      |      |               | Kosaitai | Fukushima | 3.21.2011 | 4.11.2011 | 3 | 3.21.2011 | 43- |
|                        |      |      |               | Abura-na | Fukushima | 3.21.2011 | 4.4.2011 | 3 | 3.21.2011 | 43- |
|                        |      |      |               | Chijire-na | Fukushima | 3.21.2011 | 3.21.2011 | 3 | 3.21.2011 | 43- |
|                        |      |      |               | Hana-wasabi | Fukushima | 3.24.2011 | 4.11.2011 | -2 | -2 |
|                        |      |      |               | Mizu-na | Fukushima | 3.28.2011 | 4.11.2011 | -6 | -6 |
|                        |      |      |               | Vitamin-na | Fukushima | 4.4.2011 | 4.11.2011 | -20 | -20 |
|                        |      |      |               | Cabbage | Fukushima | 3.21.2011 | 4.11.2011 | 3 | 3.23.2011 | 36- |
|                        |      |      |               | Broccoli | Fukushima | 3.21.2011 | 4.11.2011 | 3 | 3.23.2011 | 36- |
| Vegetables (fresh mushroom) | Shiitake cultivated outdoor on bed logs | Shiitake cultivated indoor on bed logs | Nameko cultivated outdoor on bed logs | Kuritake cultivated outdoor on bed logs | Chichitake (mycorrhizal fungus) | Hatsutake (mycorrhizal fungus) | Amitake (mycorrhizal fungus) | Matsutake (mycorrhizal fungus) | Maitake (saprophytic fungus) | Hatakeshimeji (saprophytic fungus) |
|-----------------------------|----------------------------------------|----------------------------------------|--------------------------------------|----------------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|
| Turnip                     | Fukushima 3.21.2011 5.9.2011 3 3.23.2011 | 43                                      |                          |                          | 41                            |                          | 13                            |                          |                          | 13                            |
| Bamboo shoot               | Fukushima 4.27.2011 6.23.2011 13 5.9.2011 | 22                                      |                          |                          | 19                            |                          | 17                            |                          |                          | 17                            |
| Kusa-sotetsu               | Fukushima 4.28.2011 5.5.2011 12 5.9.2011 | 13                                      |                          |                          | 24                            |                          | 13                            |                          |                          | 13                            |
| Shungiku                   | Chiba 3.18.2011 3.30.2011 18 4.4.2011 24 | 19                                      |                          |                          | 19                            |                          | 17                            |                          |                          | 17                            |
| Sanchu                     | Chiba 3.22.2011 3.22.2011 14 3.23.2011 32|                          |                          |                          | 24                            |                          | 17                            |                          |                          | 17                            |
| Chingensai                 | Chiba 3.22.2011 3.22.2011 14 3.23.2011 32|                          |                          |                          | 24                            |                          | 17                            |                          |                          | 17                            |
| Cerely                     | Chiba 3.22.2011 3.22.2011 14 3.23.2011 32|                          |                          |                          | 24                            |                          | 17                            |                          |                          | 17                            |
| Parsley                    | Chiba 3.22.2011 3.30.2011 14 3.23.2011 32|                          |                          |                          | 24                            |                          | 17                            |                          |                          | 17                            |
| Spinach                    | Chiba 3.24.2011 3.30.2011 12 3.23.2011 32|                          |                          |                          | 24                            |                          | 17                            |                          |                          | 17                            |

Food safety regulations in the Fukushima accident
Table 4. Continued

| Category* (subcategory)       | Item                  | Area  | Sampling date* | Distribution restrictions | Consumption restrictions |
|------------------------------|-----------------------|-------|----------------|---------------------------|--------------------------|
|                              |                       |       |                | First exceeded | Last exceeded | Days taken to order* | Began on* | Days taken to lift* | Lifted on* | Duration (days)* | Days taken to order* | Began on* | Days taken to lift* | Lifted on* | Duration (days)* |
|------------------------------|-----------------------|-------|----------------|-----------------------|-------------------------|------------------------|------------|-------------------|------------|-----------------|----------------------|------------|-------------------|------------|------------------|
| Vegetables (fruit and nut)   | Ume                   | Fukushima | 5.26.2011 | 6.21.2011 | 8 | 6.2.2011 |                      |            |                   |            |                 |                      |            |                   |            |                 |
|                              | Yuzu                  | Fukushima | 8.24.2011 | 1.5.2012 | 6 | 8.29.2011 |                      |            |                   |            |                 |                      |            |                   |            |                 |
|                              | Kuri                  | Fukushima | 9.5.2011  | 9.15.2011 | 16 | 9.20.2011 |                      |            |                   |            |                 |                      |            |                   |            |                 |
|                              | Kiwi/fruit            | Fukushima | 11.14.2011 | 12.7.2011 | 27 | 12.9.2011 |                      |            |                   |            |                 |                      |            |                   |            |                 |
| Aquatic products (coastal fish) | Konago              | Fukushima | 4.7.2011  | 5.2.2011 | 14 | 4.20.2011 |                      |            |                   |            | 14 | 4.20.2011 |                      |            |                   |            |                 |
| Aquatic products (freshwater fish) | Ayu              | Fukushima | 5.8.2011  | 9.12.2011 | 51 | 6.27.2011 |                      |            |                   |            |                 |                      |            |                   |            |                 |
|                              | Yamame®               | Fukushima | 5.17.2011 | 3.19.2012 | 21 | 6.6.2011 |                      |            |                   |            | 318 | 3.29.2012 |                      |            |                   |            |                 |
|                              | Ugui                  | Fukushima | 5.20.2011 | 3.23.2012 | 29 | 6.17.2011 |                      |            |                   |            |                 |                      |            |                   |            |                 |
| Meat                         | Beef®                | Fukushima | 3.20.2011 | 12.18.2011 | 112 | 7.19.2011 |                      |            |                   |            | (8.25.2011¹) |                      |            |                   |            |                 |
|                              |                      | Tochigi  | 4.15.2011 | 7.19.2011 | 110 | 8.2.2011 |                      |            |                   |            | (8.25.2011¹) |                      |            |                   |            |                 |
|                              |                      | Miyagi   | 5.6.2011  | 9.29.2011 | 84 | 7.28.2011 |                      |            |                   |            | (8.19.2011¹) |                      |            |                   |            |                 |
|                              |                      | Iwate    | 5.21.2011 | 3.21.2012 | 73 | 8.1.2011 |                      |            |                   |            | (8.25.2011¹) |                      |            |                   |            |                 |
|                              |                      | Wild boar meat | 9.5.2011 | 3.4.2012 | 66 | 11.9.2011 |                      |            |                   |            | 66 | 11.9.2011 |                      |            |                   |            |                 |
|                              |                      | Tochigi  | 7.16.2011 | 1.27.2012 | 141 | 12.2.2011 |                      |            |                   |            | (12.5.2011**) |                      |            |                   |            |                 |
|                              |                      | Ibaraki  | 9.7.2011  | 2.8.2012 | 88 | 12.2.2011 |                      |            |                   |            | (12.21.2011**) |                      |            |                   |            |                 |
|                              | Venison               | Tochigi  | 7.3.2011  | 12.4.2011 | 154 | 12.2.2011 |                      |            |                   |            |                 |                      |            |                   |            |                 |
|                              | Wild moon bear meat  | Fukushima | 8.15.2011 | 12.25.2011 | 111 | 12.2.2011 |                      |            |                   |            |                 |                      |            |                   |            |                 |
| Cereals                      | Brown rice harvested in 2011 | Fukushima | 11.14.2011 | 2.3.2012 | 4 | 11.17.2011 |                      |            |                   |            |                 |                      |            |                   |            |                 |
| Other foodstuffs             | Tea leaves®           | Kanagawa | 5.9.2011  | 10.28.2011 | 25 | 6.2.2011 |                      |            |                   |            | 82– |                      |            |                   |            |                 |
|                              |                      | Ibaraki* | 5.14.2011 | 6.1.2011 | 20 | 6.2.2011 |                      |            |                   |            | 139– |                      |            |                   |            |                 |
|                              |                      | Tochigi  | 5.17.2011 | 7.12.2011 | 17 | 6.2.2011 |                      |            |                   |            |                 |                      |            |                   |            |                 |
n.e., provisional regulation values were not exceeded. n.a., not applicable. When distribution and/or consumption of several foodstuff items were simultaneously restricted in the prefecture, the dates are shaded light or deep grey.

* Shown is the food category defined for the provisional regulation values (see Table 1).

1 Area here refers to a whole prefectural area or its certain municipalities. Above-listed foodstuffs were produced in own prefecture.

2 Presented are the dates when samples first or last exceeded the provisional regulation values for radioiodine and/or radiocezsiums. See Tables 2 and 3 for details.

3 Shown are the days from the date when the sample first exceeded the provisional regulation value to the date when the first restriction began.

4 Shown are the days from the date when the sample last exceeded the provisional regulation value to the date when the last restriction was lifted.

5 The number of days was counted including the initial day.

6 Restrictions on consumption by all age groups except infants were enforced only in Iitate Village.

7 Shown in parentheses are restrictions on consumption only by infants.

8 Spinach cultivated outdoor and indoor was not separately restricted.

9 All non-headed leafy vegetables (except spinach and kaki-na) were restricted.

10 All headed leafy vegetables were restricted.

11 All flower-headed brassicas were restricted.

12 All non-headed leafy vegetables were restricted.

13 Restrictions on all wild mushrooms belonging to mycorrhizal fungi were instructed on 6 September 2011. Then, restrictions on all wild mushrooms were instructed on 15 or 21 September 2011 (each instruction was given to different municipalities).

14 Except hatchery-reared fish.

15 The order to restrict the distribution of beef cattle over 12 months of age reared in the own prefecture to slaughterhouse and other prefectures.

16 Shown are the dates when restrictions were partially withdrawn. By such partial withdrawal, beef cattle regulated in each prefectural government can be distributed.

17 Raw tea leaf, dried tea leaf and processed tea leaf were not separately restricted.

18 Restrictions were withdrawn by 1 April 2011, except in Iitate Village.

19 Provisional regulation values were not exceeded during the restricted period.

20 Among seven samples that exceeded the provisional regulation values (see Table 3), six samples were taken by 30 March 2011, but one sample was taken on 12 May 2011.

21 Shown are the dates when restrictions were partially withdrawn. By such partial withdrawal, wild boar meat regulated in each prefectural government can be distributed.
Gunma Prefecture and six vegetable items in Chiba Prefecture were restricted for 19 days, but no samples exceeded the PRVs during the restricted period. In Ibaraki Prefecture, restrictions on the distribution of parsley were lifted on 17 April 2011, but one sample taken on 12 May 2011 exceeded the PRV. Kaki-na was restricted in Fukushima, Ibaraki and Tochigi prefectures, though the PRVs were not exceeded.

Fresh mushrooms exceeded the PRV for radioiodine for ≤14 days (1–14 April 2011) and that for radiocesiums for ≤361 days (1 April 2011 to 26 March 2012). Dried mushrooms exceeded the PRV for radioiodine for ≤119 days (7 October 2011 to 2 February 2012), but not that for radioiodine. The maximum level detected was 12 000 Bq/kg of radioiodine in outdoor log-cultivated shiitake sampled on 8 April 2011 in Fukushima Prefecture, and 28 000 Bq/kg of radioiodine in chichitake on 1 September 2011 in Fukushima Prefecture. Restrictions were instructed within 27 days after the PRVs were first exceeded. In Fukushima Prefecture, restrictions were not imposed for each kind of mushroom but also for categorized group items of all wild mushrooms, and distribution and consumption of amitake, matsutake, maitake and hatakeshimeji were restricted at 1–37 days before the PRVs were exceeded (see footnote o in Table 4). In six prefectures, 59 samples of dried shiitake exceeded the PRV for radioiodine, but restrictions were not imposed.

Fruit and nut exceeded the PRV for radioiodine for ≤225 days (26 May 2011 to 5 January 2012) only in Fukushima Prefecture, and did not exceed that for radioiodine. The maximum radioiodine level detected was 2400 Bq/kg in yuzu sampled on 24 August 2011. Restrictions began within 27 days after the PRVs were first exceeded. These restrictions are still ongoing, although the PRV has not been exceeded in ume since 22 June 2011, and kuri since 15 September 2011.

Seaweeds exceeded the PRV for radioiodine for ≤99 days (16 May 2011 to 22 August 2011) only in Fukushima Prefecture. The PRV for radioiodine was exceeded only in one hijiki sample taken on 21 May 2011. These seaweeds grown in reefy shallows were sampled at the depth of 1–2 m. The maximum level detected was 2200 Bq/kg of radioiodine in hijiki sampled on 21 May 2011, and 1200 Bq/kg of radioiodines in wakame on 16 May 2011. Despite no restrictions imposed, seaweeds were not distributed due to suspension of fishing (the same holds true for most seawater fish and marine invertebrates).

4.4. Aquatic products
Coastal fish, but not migratory seawater fish, exceeded the PRV for radioiodine for ≤18 days (1–18 April 2011) and that for radiocesiums for ≤351 days (4 April 2011 to 19 March 2012). The maximum level detected was 12 000 Bq/kg of radioiodine in konago sampled on 13 April 2011 in Fukushima Prefecture, and 14 400 Bq/kg of radiocesium in konago on 18 April 2011 in Fukushima Prefecture. Of these, only konago was restricted in Fukushima Prefecture. This restriction is still ongoing although the PRVs have not been exceeded since 3 May 2011. For coastal fish whose bones and all are habitually consumed by Japanese citizens, the Fisheries Agency (FA), one of the affiliated agencies of MAFF, monitored levels of $^{89}\text{Sr}$ and/or $^{90}\text{Sr}$ in nine samples taken from 6 April 2011 to 1 July 2011, all of which were below detectable levels [44, 45]. Only in Fukushima Prefecture, marine invertebrates exceeded the PRV for radioiodine for ≤211 days (16 May 2011 to 12 December 2011), but not that for radiocesiums. A maximum level detected was 1930 Bq/kg of radiocesiums in mokuzugani on 19 June 2011. Restrictions were not imposed for marine invertebrates. Bivalvia murasaki-i-gai and hokki-gai inhabit the coastal shallows. Konago and shirasu inhabit the surface layer of the sea, and suzuki inhabits the middle layer. Ainame, ezoiso-ainame, ishi-garei, baba-garei, maiko-garei, numa-garei, komon-kasube, hirame, shiro-mebaru, usu-mebaru, kitsune-mebaru, kurosoi, murasoi, saburo and kemushikajika inhabit the lower layer or are benthic on shallow sea floors (~100 m in depth). Coastal fish that inhabit the deeper sea showed a trend to become contaminated at a later time. Radioiodines are incorporated into the body of seawater fish such that as radioiodine concentrations in seawater increase, those in the fish body increase and become concentrated 5–100-fold compared with the surrounding seawater. If radioiodine concentrations in seawater decrease, radioiodines are gradually excreted from the fish body (e.g. it takes about 50 days to excrete half of the radioiodines). Freshwater fish are known to incorporate more ions including radioiodines and excrete incorporated ions more slowly than seawater fish do, because of differences between freshwater and seawater (e.g. in terms of the osmotic pressure, diffusiveness of ions and exchange rate of water).

Freshwater fish exceeded the PRV for radioiodine for ≤327 days (8 May 2011 to 29 March 2012), but not that for radioiodine. The maximum radioiodine level detected was 18 700 Bq/kg in yamame on 18 March 2012 in Fukushima Prefecture. Restrictions on distribution of ayu, yamame and ugui were imposed only in Fukushima Prefecture that began within 51 days after the PRV was first exceeded. Of these, restrictions on consumption of yamame were imposed at 318 days after the PRV was first exceeded.

4.5. Meat
4.5.1. Setting of provisional tolerance values
On 19 March 2011, MAFF provided three directives to prevent or minimize exposure of farm animals to radioactive materials [46]. (i) For feeding, use dried pasture grass that was harvested prior to the Fukushima accident and stored indoors (or stored outdoors and packaged so as
to block exposure to the air, where packing materials should be wiped prior to use for feeding). (ii) Prevent drinking water for farm animals from being contaminated with the radioactive fallout particles (e.g. by covering the water storage tank). (iii) Do not graze farm animals in the field for the meantime.

On 14 April 2011, MAFF set provisional tolerance values (PTVs) to minimize contamination of milk and beef by regulating contaminated livestock feed for cattle [47]. Values set were 300 Bq/kg of radiocesiums in roughage for beef cattle and dairy cattle, 5000 Bq/kg of radiocesiums for other cattle and 70 Bq/kg of radioiodine for dairy cattle. Values for radioiodine in cattle excluding dairy cattle were not set, because PRVs for radioiodine in meats have not been set. Alternatively, it was advised that roughage harvested from areas where restrictions on distribution of crops (i.e. vegetables) because of excess radioiodines have not been enforced should be fed to cattle excluding dairy cattle. Thus far, 1014 samples of the pasture grass taken in 14 prefectures were monitored from 21 April 2011 to 2 December 2011 [48]. Of these, the maximum level detected was 170 Bq/kg of radioiodine, and 9200 Bq/kg of radiocesiums in the sample taken in Fukushima Prefecture on 27 April 2011.

On 1 August 2011, MAFF further set PTVs for radiocesiums in feed for cattle, horse, swine, poultry and other farm animals [49]. Values set were basically 300 Bq/kg (water content of 80% in roughage, and product weight in other feed), but exceptionally 3000 Bq/kg (water content of 80%) in feed for breeding cattle (except dairy cattle and fattening cattle) that will not be slaughtered for the moment. Simultaneously, the PTV for radiocesiums was also set in fertilizers (including manure and compost), soil amendments and ridging (400 Bq/kg in product weight) and that in feed to rear fish in hatcheries (100 Bq/kg in product weight). It was directed that products exceeding the PTVs should not be used and should be handled according to the policy for radiocesium-contaminated sludge as explained in Section 4.1. Regarding animal feed, 933 samples of forage crops (corn, fermented rice-plant roughage and rice straw) planted in 17 prefectures after 11 March 2011 were monitored as of 31 March 2012, but none of them exceeded the PTVs [50]. Among 23 samples of straw of wheat or barley planted before 11 March 2011 and harvested later in four prefectures, one sample taken on 6 September 2011 in Fukushima Prefecture contained 2200 Bq/kg of radiocesiums exceeding the PTVs [50]. As of 31 March 2012, 6287 samples of fertilizers taken from 4 August 2011 to 30 March 2012 have been monitored in 20 prefectures [51]. Cattle dung exceeded the PTVs in 13 prefectures, and its use was voluntarily restricted. The PTVs were also exceeded in rice-straw manure in Fukushima Prefecture, and in horse dung and poultry manure in Tokyo Prefecture. The maximum radiocesium level detected was 26 000 Bq/kg in cattle dung sampled in Fukushima Prefecture on 15 November 2011.

4.5.2. Beef

Sampling of beef started on 15 March 2011 and 20 March 2011 in Fukushima and Ibaraki prefectures, respectively. In one sample from the cattle slaughtered on 15 March 2011 in Fukushima Prefecture, 510 Bq/kg of radiocesiums were detected on 31 March 2011, and the beef was stored to prevent its distribution. On 1 April 2011, another two samples from the same cattle were reexamined, revealing that radiocesiums were below detectable levels. None of the other samples taken by 7 July 2011 exceeded the PRVs.

It was on 8 July 2011 that 2300 Bq/kg of radiocesiums were detected in the sample from the cattle that was reared in Fukushima Prefecture and slaughtered on the same day. Beef exceeding the PRV for radiocesiums was then reported in the cattle reared in other prefectures. Radioactivity levels were analyzed in all previous lots whose stock was available. Monitoring results reported on 2 September 2011 showed that beef from the cattle slaughtered as far back as 30 March 2011 exceeded the PRV for radiocesiums. Such contamination of beef resulted from the rice straw being fed to cattle. Rice straw had been left horizontally in the rice field since rice crops were harvested in 2010, and thereby contaminated with the radioactive fallout particles more severely than pasture grass that grew longitudinally. MAFF had provided the directives and set PTVs to avoid the use of contaminated feed (Section 4.5.1), but the farmers had not been well notified regarding the rice straw. As a result, the farmers fed their cattle on the rice straw highly contaminated with radiocesiums (reportedly ~690 000 Bq/kg). Distribution restrictions were instructed in Fukushima Prefecture on 19 July 2011, and later in Miyagi, Iwate and Tochigi prefectures. Distributed beef was recalled, but most of the cattle slaughtered by June 2011 had already been consumed [52]. It should also be noted that radioactivity levels could not be monitored in many lots owing to a sellout without additional stock.

On 23 August 2011, MAFF issued a notice for the policy on the handling of bedding materials for farm animals, where the PTV set for radiocesiums was basically 400 Bq/kg in product weight [53]. In September 2011, the notice was issued for the policy on handling of bran or mash of wheat and barley (two-rowed barley, six-rowed barley and rye) as well as bran, chaff and straw of rice, all of which are by-products of crops harvested in 2011 and may be potentially used as feed [54–56]. On 6 October 2011, the notice was issued for the policy on the handling of husks or hulls of rice harvested in 2011 [57]. MAFF thus notified the farmers again not to use contaminated feed including rice straw. However, beef exceeding the PRV for radiocesiums was still detected in the cattle that were reared in Fukushima and Iwate prefectures on 18

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December 2011 and 21 March 2012, respectively. Such contamination might have arisen from contaminated feed other than rice straw.

Beef exceeded the PRV for radiocesiums for ≤359 days (30 March 2011 to 21 March 2012), but not that for radioiodine. The maximum radiocesium level detected was 3400 Bq/kg in the sample from the cattle that was reared in Fukushima Prefecture and slaughtered on 30 June 2011. All distribution restrictions began within 112 days after the PRV was first exceeded, and are still ongoing, though partially lifted on 19 or 25 August 2011.

4.5.3. Wild animal meat
Meat from wild deer, boars, bears, rabbits and birds exceeded the PRV for radiocesiums in Ibaraki, Tochigi, Iwate, Yamagata or Fukushima prefectures for ≤253 days (3 July 2011 to 11 March 2012), but not that for radioiodine. The maximum radiocesium level detected was 14 600 Bq/kg in wild boar meat sampled on 5 September 2011 in Fukushima Prefecture. All restrictions began within 154 days after the PRV was first exceeded. Restrictions on the distribution of wild boar meat were partially removed, as was the case for beef (Sections 3.2.5 and 4.5.2).

4.6. Cereals
Besides restrictions on rice cultivation, pre-harvest and post-harvest monitoring surveys were conducted to minimize production of radioactively contaminated rice (Section 3.2.7). Nonetheless, in Fukushima Prefecture, brown rice samples exceeded the PRV for radiocesiums for ≤82 days (14 November 2011 to 3 February 2012), but not that for radioiodine. Distribution restrictions began within 4 days after the PRV was firstly exceeded. The maximum radiocesium level detected was 1540 Bq/kg in brown rice sampled on 22 December 2011. As yet, the PRVs have not been exceeded in polished rice samples: the maximum radiocesium level detected was 500 Bq/kg in a sample taken on 24 November 2011.

The PRV for radiocesiums was also exceeded in one wheat sample taken on 19 July 2011.

4.7. Other foodstuffs
Tea leaves exceeded the PRV for radiocesiums for ≤185 days (9 May 2011 to 9 November 2011), but not that for radioiodine. The maximum radiocesium level detected was 3000 Bq/kg in dried tea leaves sampled on 12 May 2011 in Kanagawa Prefecture. All distribution restrictions began within 38 days after the PRVs were first exceeded. In Ibaraki Prefecture, it took 20 days to restrict the distribution, but no samples exceeded the PRV during the restricted period. Restrictions are still ongoing, although the PRV has not been exceeded in Ibaraki, Tochigi, Gunma and Chiba prefectures since 1 June 2011, 12 July 2011, 1 August 2011 and 24 August 2011, respectively. Restrictions were not imposed in Saitama Prefecture, though the PRV had been exceeded in 127 samples taken during 10 August 2011 and 9 November 2011.

On 8 April 2011, 27 Member States of the European Union (EU) agreed to lower the ‘maximum permitted levels’ of radioiodine and radiocesiums for human food and animal feed originating in or consigned from 12 Japanese prefectures [58], whereas EU had not revised the levels in the past 24 years [59]. On 17 June 2011, the General Directorate for Competition Policy, Consumer Affairs and Fraud Control of France (DGCCRF) reported that at the Charles de Gaulle Airport (Roissy), Paris, 1038 Bq/kg of radiocesiums exceeding the EU’s maximum permitted level of 500 Bq/kg (the same as the PRV) were detected in dried tea leaves that were shipped as a lot of 162 kg from Shizuoka Prefecture. On 22 June 2011, 981 Bq/kg of radiocesiums were detected in the same lot of tea leaves, so Shizuoka Prefecture voluntarily restricted the distribution and recalled the distributed products. Another six samples also exceeded the PRV in Shizuoka Prefecture, but NERHQ did not instruct restrictions.

One sample of rice bran taken in Miyagi Prefecture on 7 October 2011 exceeded the PRV for radiocesiums. This suggests that its raw materials (i.e. brown rice) should have exceeded the PRV, but the monitoring result of that brown rice was not reported. Rice bran is not generally consumed as is, but is used to extract oil or to pickle vegetables as salted paste, so it was categorized in other foodstuffs rather than cereals. The PRV for radiocesiums was also exceeded in one sample of rapeseed, Nikko maple and Tochu tea. Restrictions of these foodstuffs were not instructed.

4.8. Medicinal plants
In Japan, every November or later is a peak season to harvest medicinal plants that are used to produce crude drugs (herbal medicine, or kampo). Prior to this season, the Japan Kampo Medicines Manufacturers Association under the umbrella of the Federation of Pharmaceutical Manufacturers Association of Japan (FPMAJ) has voluntarily conducted surveys of medicinal plants in 17 prefectures (i.e. the currently assigned target local governments for food monitoring surveys described in Section 3.2) since March 2011, and reported the monitoring results on 14 October 2011 [60]. Among 109 samples of 35 different plants sampled from 24 March 2011 to 6 September 2011, radiocesiums were detected in 23 samples of 9 plants. Of these, 8 samples of 3 plants were contaminated with levels above 500 Bq/kg of radiocesiums, and the maximum level recorded was 1910 Bq/kg in a magnolia flower sampled on 24 June 2011. It was also documented that these contaminated plants have not been used to produce drugs.

In keeping with the regulation that drugs produced from radioactively contaminated plants cannot be sold according to Article 56, Item 7 of the Pharmaceutical Affairs Law,
MHLW provided two directives to all Japanese local governments in terms of handling of medicinal plants and crude drugs on 24 October 2011 [60]. (i) As a measure of precaution, pharmaceutical manufacturers should conduct voluntary inspections, and recall drugs produced from plants harvested in March 2011 or later in 17 prefectures, as well as sending notification to MHLW. (ii) For the time being, only plants containing radiocesiums below detectable levels should be used to produce drugs, and monitoring surveys of plants should be conducted in each city, town and village where drugs are manufactured.

On 13 December 2011, MHLW issued the guideline for surveys of radioactivity levels in medicinal plants to produce crude drugs [61]. (i) Specify the place where medicinal plants were produced, and conduct surveys in each city, town or village by using NaI(Tl) scintillation detectors or germanium semiconductor detectors. (ii) Monitor levels of 131I, 134Cs and 137Cs in each lot of medicinal plants with germanium semiconductor detectors of which lower detectable limits should be no more than 20 Bq/kg. If radioactive concentrations are at non-detectable levels, medicinal plants can be shipped to manufacturers or used by manufacturers to produce crude drugs. (iii) Manufacturers should conduct surveys of radioactivity levels in intermediate products or final products. If non-detectable, intermediate products can be shipped to other manufacturers, or the final products can be shipped for sale.

On 16 January 2012, FPMAJ reported the monitoring results for another 60 samples of medicinal plants taken from 7 April 2011 to 31 October 2011 [62]. Of these, radiocesiums were detected in two samples of two plants with a maximum level of 19 Bq/kg, and was non-detectable in the rest of the samples. It was also documented that FPMAJ plans to conduct monitoring surveys twice a year considering the harvest season.

Collectively, among all food and water items, PRVs were initially exceeded in tap water, raw milk and leafy vegetables, and subsequently in other foodstuffs such as mushrooms, aquatic products, beef and tea leaves. Coastal fish that inhabit the deeper sea showed a tendency to become contaminated at a later time. PRVs were exceeded for over 100 days in fresh shiitake mushrooms, dried shiitake mushrooms, venison, wild boar meat, wild moon bear meat, yuzu, tea leaves, kita-murasaki-uni, some coastal fish (ishi-garei, kurosoi, hirame and suzuki) and freshwater fish (ayu and wakasagi), over 200 days in coastal fish (ainame, ezoiso-ainame, baba-garei, mako-garei, shiro-mebaru, usu-mebaru, komon-kasube and hirame) and iwana, and over 300 days in beef and freshwater fish (yamame and ugui). All restrictions were instructed within 318 days (within 154 days except yamame, and within 82 days except meat and yamame) of PRVs first being exceeded in each item. Prior to the instruction of each restriction, NERHQ asked MHLW for advice about the necessity of restrictions. Contaminated beef began to be detected after it had been distributed and consumed for several months. This may be because the monitoring surveys were done only for a limited number of samples, but also because farmers were not well notified of the preceding directives to avoid the use of contaminated feed for farm animals and thereby fed contaminated rice straw to their cattle until July 2011. Such experience illustrates the importance of communications between the risk management authorities and individuals concerned (farmers in this case). Most foodstuffs contaminated above PRVs in Fukushima Prefecture were restricted except seafood (seaweed, coastal fish and marine invertebrates). Contaminated seafood items were not restricted except konago in Fukushima Prefecture, but were not distributed because fishing was restricted. Once enforced, many restrictions were not removed for a long period of time after PRVs were last exceeded. Such long-term restrictions on distribution and consumption may affect the sustainable development and rehabilitation of the affected areas, so the optimization principle should be appropriately implemented [63]. Taken together, the beginning of restrictions in March 2011 was concurrent with the massive social dislocations that were manifested as the selling out of bottled water, milk, instant noodles and various non-perishables. Such dislocations resulted at least in part from a lack of effective communication strategies.

In the Fukushima accident, it took 6 and 7 days to start sampling food and water for monitoring surveys and to set PRVs, respectively, after the establishment of NERHQ. The first restrictions were then instructed on 21 March 2011 (5 days after the setting of PRVs, ≥6 days after PRVs were first exceeded, and 11 days after the establishment of NERHQ). A series of monitoring data illustrated that PRVs for radiiodine were exceeded in tap water and food sampled from 16 March 2011 to 21 May 2011 (i.e. for 67 days), though it remains unclear whether food and water had been contaminated at levels of concern on 15 March 2011 or earlier. PRVs for radiocesiums were exceeded in food sampled from 18 March 2011 to date, and may continue to exceed them for several years. On the one hand, 137Cs (which has a physical half-life of 30.0 years) and 90Sr (29.1 years) will be a more predominant contaminant than 134Cs (2.06 years) and 89Sr (50.5 days) at a later time owing to the difference in physical half-lives, and this would especially be the case for terrestrial food. On the other, as radioactive concentrations in freshwater of lakes or rivers and those in seawater decrease, incorporated radioce- siums will be excreted from fish bodies according to biological half-lives (about 50 days in seawater fish, and a longer time in freshwater fish). In contrast, radiostrontiums will be accumulated in fish bones, and therefore will be a significant contaminant especially to fish whose bones and all are habitually eaten by Japanese citizens.
5. FORTHCOMING NEW REGULATION VALUES

PRVs have been effective since 17 March 2011, except those for radioiodine in aquatic products that have been effective since 5 April 2011. However, new food safety regulatory limits shall come into effect before long.

On 20 March 2011, MHLW requested FSCJ to evaluate health risks associated with consumption of contaminated food and water. FSCJ started deliberations on 21 April 2011, and finished drawing up a draft report on 26 July 2011 [64]. The draft concluded that a lifetime cumulative effective dose of about ≥100 mSv posed by internal radiation exposure via consumption of contaminated food and water has detrimental effects on human health. This conclusion was drawn mainly from the following three papers. (i) A cohort study of cancer incidence among residents of the high natural background radiation area in Kerala, India indicates that exposure to a cumulative dose of >500 mGy does not increase cancer risks [65]. (ii) A cohort study of mortality among atomic bomb survivors in Hiroshima and Nagasaki indicates that the excess solid cancer risks linearly increase in the dose range of 0–125 mSv, which was statistically significant, but were not significantly related to the dose at 0–100 mSv [66]. (iii) A cohort study of cancer mortality among atomic bomb survivors in Hiroshima and Nagasaki indicates that compared with the control (0 Gy) group, the excess relative leukemia risks significantly increase at an organ-absorbed dose of ≥0.2 Gy, but not at <0.2 Gy [67]. The draft also pointed out the possibility that infants and children are more radiosensitive than adults especially for thyroid cancer and leukemia. Taken together, it was documented in the draft that the risk management authority (i.e. MHLW) should determine how to assign the life-span effective dose of 100 mSv to each year. The draft was open for public consultation from 29 July 2011 to 27 August 2011, during which time comments were submitted from 3089 individuals or organizations. On 27 October 2011, FSCJ submitted the final report to MHLW [68] along with partial disclosure of public comments [69], but an above-described conclusion was unchanged.

MHLW mentioned on 28 October 2011 that new regulation values will be set not to exceed a committed effective dose of 1 mSv/year and that these come into effect on 1 April 2012. On 24 November 2011, MHLW further described the preliminary approaches to calculating the new regulation values [70–72]. First of all, the index values (i.e. the predecessor of PRVs) were set not to exceed IL in any age groups of infants (0–1 year of age), children (1–6 years) and adults (≥17 years) using the mean intake of food and water without distinction between males and females. For the new regulation values, age groups of infants (≤1 years), children (1–6 years), juveniles (7–12 years), adolescents (13–18 years) and adults (≥19 years) will be considered. Males and females of ≥13 years will be evaluated separately on account of differences in the mean intake of food and water. Second, the index values were expressed as radioactive concentrations of indicator radionuclides by postulating the relative radioactive concentration of coexisting radionuclides at 0.5 days after shutdown of the pressurized water reactor where fuel having an initial concentration of 3% is burned at 30 GWD/ton, and given to radionuclide groups of radioiodines, radiocesiums, uranium and plutonium, and other transuranic α emitters. The IL considered was a committed effective dose to the thyroid of 50 mSv/year for radioiodine, and a committed effective dose of 5 mSv/year for other radionuclide groups. In this regard, the new regulation values will be expressed as radioactive concentrations of radiocesiums (134Cs and 137Cs), and food and water contaminated with another six radionuclides (90Sr, 238Pu, 239Pu, 240Pu, 241Pu and 106Ru) will be regulated by using a contribution factor of radiocesiums at the time point of 1–2 years after 11 March 2011 (86% for ≤6 years of age, 84% for 7–18 years and 88% for ≥19 years). For this, only radionuclides with a physical half-life of ≥1 years were considered, and the new values will not be given to radioiodines (because they have short half-lives and have not exceeded PRVs since 22 May 2011) and uranium (because of limited discharges and no difference to levels of naturally existing uranium isotopes within the site of the Fukushima NPP1). Last, regarding categories of food and water, five categories were considered to calculate the index values for radiocesiums (see Table 1), but four categories will be considered for the new values: (i) water and beverages (drinking water, water used for cooking, tea, coffee, etc.); (ii) infant food (e.g. powdered milk); (iii) cow’s milk (mean daily intake of 146.9 g for 1–6 years of age, 279.7 g for 7–12 years, 179.1 g for 13–18 years and 83.2 g for ≥19 years); and (iv) other food. Infant food was set as an independent category, taking into account the possibility of higher radiosensitivity of infants and children raised in the above-described report by FSCJ [68]. Collectively, the new values will be expressed as radioactive concentrations of 134Cs and 137Cs considering the contribution of 90Sr, 238Pu, 239Pu, 240Pu, 241Pu and 106Ru, set not to exceed a committed effective dose of 1 mSv/year, and given to water and beverages, infant food, cow’s milk and other food. On 22 December 2011, a sub-committee for measures against radioactive materials in Pharmaceutical Affairs and Food Sanitation Council of MHLW approved of the newly proposed regulation values. On 27 December, a proposal for the new regulation values was submitted to the Radiation Council of Japan (a consultative body founded in MEXT) for deliberations and approval [73] according to Article 6 of the Act on Technical Standards for Prevention of Radiation Hazard. MHLW mentioned that whereas a certain transition period from
PRVs to the new regulation values will take place depending on foodstuff items to minimize the disruption of the market, the new regulation values will be promulgated in early March 2012, and come into effect on 1 April 2012. The proposed values expressed as a total radioactive concentration of $^{134}\text{Cs}$ and $^{137}\text{Cs}$ were 10 Bq/kg for drinking water and tea, 50 Bq/kg for cow’s milk and infant food, and 100 Bq/kg for other food, and were 1/4th to 1/20th of PRVs (for comparison, see Table 5) [73]. MHLW made the proposed new regulation values public for consultation from 6 January 2012 to 4 February 2012, during which time comments were submitted from 1,877 individuals or organizations. Of these, 1,449 and 55 comments requested regulation values that are lower and higher than proposed, respectively. The Radiation Council of Japan had held six meetings for deliberations since 27 December 2011, and on 16 February 2012 approved the proposed regulation values with an opinion that the proposed new values do not improve the efficacy of radiation protection. This was because the deterministically estimated median annual dose posed by an annual intake of food and water contaminated with radioactivites at the median levels of PRVs and the proposed regulation values was 0.051 and 0.043 mSv/year, respectively (i.e. estimated reduction of only 0.008 mSv/year) [73]. Such reductions of regulatory limits in Japan may lead to reductions of limits in Europe or other countries as well. MHLW promulgated the new regulation values on 15 March 2012 [74]. Considering the operation of new regulation values on 1 April 2012, NERHQ issued the fourth version of the notice for policy on surveys and restrictions of food on 12 March 2012 [75], whereas the third version was issued on 4 August 2011 [26] (for details, see Section 3.2). In the fourth version, the target local governments were categorized into two groups. The first group consists of Fukushima, Miyagi, Ibaraki, Tochigi, Gunma and Chiba prefectures, where various foodstuff items have been restricted. The second group is composed of Aomori, Iwate, Akita, Yamagata, Saitama, Kanagawa, Niigata, Yamanashi, Nagano, Tokyo, and Shizuoka prefectures, where single foodstuff items have been restricted or their neighboring local governments. The target food categories assigned were vegetables, fruit and nuts, milk, tea, aquatic products, wheat, rice and beef.

On 30 November 2011, MEXT issued the notice to board of local schools in 17 prefectures (i.e. the currently assigned target local governments for food monitoring surveys described in Section 3.2) that only foodstuffs of 40 Bq/kg or below can be used for school meals in primary/elementary schools and lower secondary/junior high schools. Considering not only that the currently effective PRVs for radioactivites are 200 Bq/kg or 500 Bq/kg (Table 1), but also that the level of a committed effective dose posed by ingestion of radioactivites will be reduced from 5 mSv/year to 1 mSv/year in the new regulation values, a value of 40 Bq/kg was conservatively chosen as being one-fifth of 200 Bq/kg without distinction between the categories of food and water. This was the first time regulatory guideline levels were set for school meals.

On 1 August 2011, MAFF set PTVs for radioactivites in feed for farm animals and fish in hatchery, fertilizers, soil amendments and ridging [49], as described in Section 4.5.1. Considering that MHLW was planning to change regulatory limits for radioactivites from 200 Bq/kg in milk and 500 Bq/kg in meat (PRVs) to 50 Bq/kg in cow’s milk and 100 Bq/kg in adult food that includes meat but excludes milk, water and tea (new regulation values), MAFF reduced PTVs for radioactivites in cattle feed from 300 Bq/kg (or exceptionally 3000 Bq/kg) to 100 Bq/kg (water content of 80% in roughage, and product weight in other feed), albeit with no changes in other PTVs [76]. A transition period of 1 or 2 months took place for this revision, so that, if unavoidable, feed for daily cattle and other cattle contaminated below the previous PTVs could be used by 15 and 31 March 2012, respectively. On 23 March 2012, MAFF reduced PTVs for radioactivites in cattle feed from 300 Bq/kg to 100 Bq/kg, swine from 300 Bq/kg to 80 Bq/kg, poultry from 300 Bq/kg to 160 Bq/kg and feed to rear fish in hatcheries from 100 Bq/kg to 40 Bq/kg [77].

On 28 February 2012, MAFF issued a notice for the policy on planting and cultivation of rice for the year 2012 [78], which contained the following three directives. First,

| Category | Provisional regulation value (Bq/kg) | New regulation value (Bq/kg) |
|----------|-------------------------------------|-----------------------------|
| Water and beverages | 200 | 10 |
| Milk | 200 | 50 |
| Food | 500$^a$ | 100$^d$ |
| Infant food | not defined | 50 |

$^a$Values were set on 17 March 2011 and effective until 31 March 2012. Values were defined as a total radioactive concentration of $^{134}\text{Cs}$ and $^{137}\text{Cs}$ not to exceed a committed effective dose of 5 mSv/year, considering the contributions of $^{89}\text{Sr}$ and $^{90}\text{Sr}$. The logic behind the definition of the values has been described previously [20].

$^b$Food for the provisional regulation values indicates all food that includes infant food but excludes milk, water, and beverages (details described in footnote to Table 1).

$^c$Values were promulgated on 15 March 2012 and become effective on 1 April 2012. Values were defined as a total radioactive concentration of $^{134}\text{Cs}$ and $^{137}\text{Cs}$ not to exceed a committed effective dose of 1 mSv/year, considering the contributions of $^{89}\text{Sr}$, $^{238}\text{Pu}$, $^{239}\text{Pu}$, $^{240}\text{Pu}$, $^{241}\text{Pu}$ and $^{106}\text{Ru}$.

$^d$Food for the new regulation values indicates all food that excludes infant food, milk, water and beverages.

Table 5. Provisional regulation values vs. new regulation values for radioactivites

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rice cultivation should be restricted in the stay-away evacuation zone, planned evacuation zone and areas where brown rice harvested in 2011 exceeded 500 Bq/kg of radioce- sesiums (PRV in cereals). Second, in areas where brown rice harvested in 2011 contained 100 Bq/kg (new regulation value) to 500 Bq/kg of radioce- sesiums, rice cultivation is basically restricted, but can be permitted if a series of mea- sures (e.g. suppression of resorption of radioce- sesiums prior to planting, monitoring surveys in each lot of harvested rice) are taken not to distribute rice exceeding the new regulation value. Last, rice cultivation is not restricted in other areas.

6. CONCLUSIONS

Here we have described the policy for the execution of monitoring surveys and restrictions, and outlined the food safety regulations implemented in the first year following the Fukushima accident, based on the information available as of 31 March 2012.

To regulate contaminated human food and water, MHLW set PRVs on 17 March 2011, and most of these values were adopted from the index values preset by NSC. PRVs for radioiodine in aquatic products were additionally set on 5 April 2011. PRVs for radioiodine had been exceeded for 67 days, and countermeasures against radioiodine-contaminated milk were taken earlier than for the Chernobyl accident. PRVs for radioce- sesiums have been exceeded in various foodstuffs for over a year, and will be exceeded for additional years. NERHQ imposed and removed restrictions on distribution and consumption of food, along with advice from NSC. MHLW instructed and lifted restrictions on consumption of tap water. All restrictions were imposed within 318 days of each item becoming contaminated with levels above the PRVs. A partial removal of restrictions was conducted for beef and wild boar meat. Brown rice but not polished rice exceeded the PRV for radioce- sesiums regardless of three-stage strategies (i.e. cultivation restrictions, pre-harvest survey and post- harvest survey). The experience of distribution and con- sumption of contaminated beef and the experience of social dislocations manifested as the selling out of bottled water, milk, etc. indicated the importance of strategies for effective communications between the risk management authorities and individuals concerned. The PRVs were effective until 31 March 2011, and the new regulation values go into effect on 1 April 2012. These new values will be expressed as radioactive concentrations of $^{134}$Cs and $^{137}$Cs considering the contribution of $^{90}$Sr, $^{238}$Pu, $^{239}$Pu, $^{240}$Pu, $^{241}$Pu and $^{106}$Ru, set not to exceed a committed effective dose of 1 mSv/year, and given to water and tea, infant food, cow’s milk and other food.

To minimize the production of contaminated food, MAFF set a series of PTVs in animal feed, fish feed, fertilizers, soil amendments and ridging in April 2011 or later. The PTVs were exceeded in fertilizers (cattle dung and rice-straw manure), and its use and distribution were voluntarily restricted. Forage crops planted and harvested after 11 March 2011 did not exceed PTVs.

This paper focused on the safety regulations for contami- nated food and water, but the future retrospective reviewing of overall countermeasures would be important in verifying the justification of the enforced restrictions on account of radiological and social impacts. Then, the overall lessons learned from the experience of the enforced restrictions should help improve the nuclear or radiological emergency preparedness all over the world.

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