INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Summary of information available in Japan concerning the contamination of foodstuffs by the radionuclides persisting in the environment after the Fukushima accident

13 July 2012

More than a year after the Fukushima Dai-ichi accident occurred on 11 March 2011, IRSN continues to periodically collect and analyse the data published in Japan relating to the contamination of the terrestrial environment, and notably of the foodstuffs produced in the areas affected by the accident.

On the whole, the results of the first half of 2012 show a significant improvement for many categories of foodstuffs (notably vegetables, livestock meat and milk) compared with the spring of 2011, but significant caesium-134 and caesium-137 concentrations are still regularly measured in some types of products: shiitake mushrooms, wild plant shoots (bamboo, Aralia, koshiabura and fiddleheads), game meat (mainly boars), freshwater fish and some marine species caught along the coast near to the damaged plant, etc. These foodstuffs are occasionally found to exceed the sales and consumption standards, and this occurs more frequently since these standards were tightened on 1 April 2012. This has led the Japanese authorities to maintain or even increase the sales and consumption restrictions for the products and territories concerned.

IRSN therefore recommends maintaining a certain degree of caution regarding the consumption of the following foodstuffs:

- *Wild plants and boar meat: these products come from a forest environment, where nothing is done to reduce the contamination;*
- *Shiitake mushrooms: the restrictions are widened daily, and the districts concerned are further and further away from the Fukushima prefecture.*
- *Fish (marine and freshwater), the contamination levels of which regularly and constantly exceed the standards.*

Care should be taken regarding the origin and, where appropriate, the measured contamination levels of these foodstuffs. In general, a varied diet (particularly in terms of its origin) is recommended in order to effectively reduce internal contamination via ingestion.

In view of the long life of the radioactive caesium in the Japanese environment, maintaining regular monitoring of agricultural or wild products is justified if the quality of the foodstuffs consumed in Japan or exported is to be ensured, as the contamination levels will decrease only slowly.

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REMINDER OF THE GENERAL LEVEL OF CONTAMINATION IN THE TERRESTRIAL ENVIRONMENT IN JAPAN FOLLOWING THE FUKUSHIMA ACCIDENT

IRSN report 2012-01 ("*Fukushima, one year later – Initial analyses of the accident and its consequences*"), which was published on 12 March 2012, contains a detailed description of the currently-available data on the environmental contamination in Japan. It states in particular that the terrestrial environment in Japan is durably contaminated by two radionuclides - caesium-134 and caesium-137 - which now constitute almost all of the residual contamination resulting from the nuclear accident. This contamination consists of a superficial deposit that, because of the physicochemical properties of caesium, should remain relatively immobile except in rainwater run-off (transported in the water) and the re-suspension of wind-borne dust; these are only minor and gradual transport processes, however, and they have not significantly changed the overall distribution of radioactive caesium deposits, which are mapped increasingly accurately (see maps in Figure 1) in the successive measurement campaigns that still continue today.

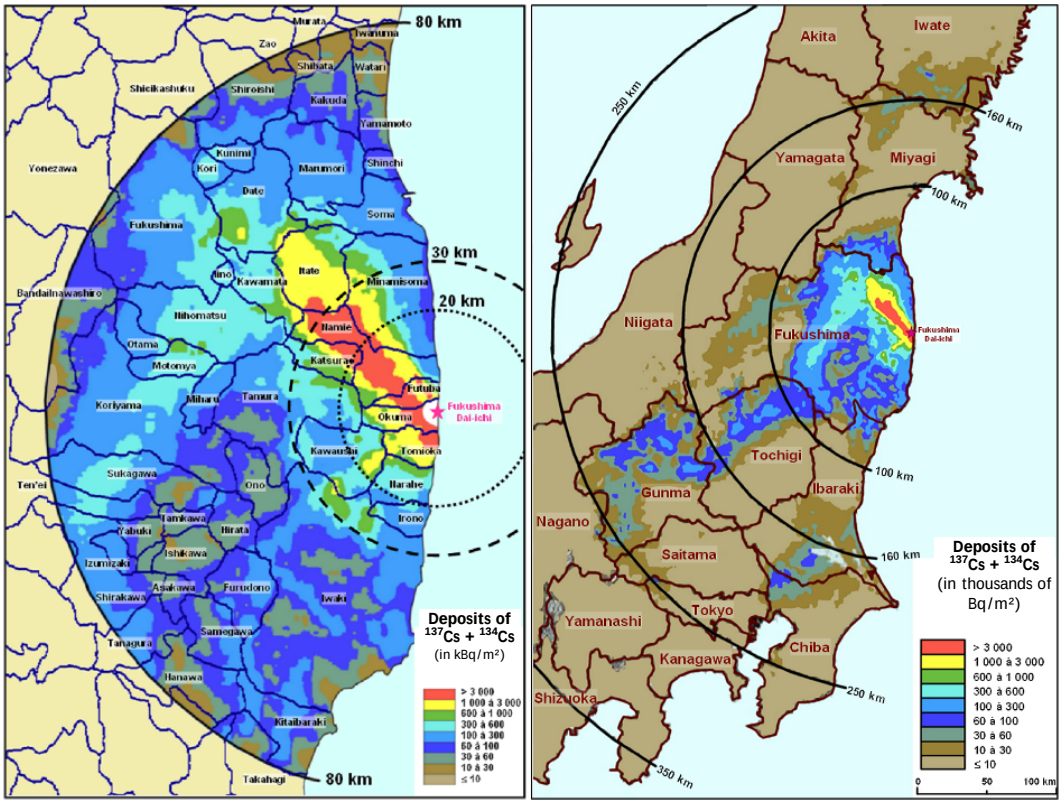

Figure 1 – Maps of caesium-134+137 deposits in Japan (surface activity relating to 5 November 2011). Right: the north-east of Honshū island. Left: a radius of 80 km around the Fukushima Dai-ichi plant (source: "Results of the Fourth Airborne Monitoring Survey by MEXT" published on 16 December 2011)

At the end of June 2012, 97% of the caesium-137 and 65% of the caesium-134 originally deposited at the time of the accident still remains as a result of the respective rates of radioactive decay; approximately 59% of the deposits' remaining radioactivity consists of caesium-137, while the rest consists of caesium-134.

These residual deposits help to maintain the significant external exposure doses of the people living in the contaminated areas. As a result, the people living in areas that received the largest

deposits were evacuated in 2011, from the 20 km-radius "restricted area" around the damaged nuclear power plant (NPP) and from the "deliberate evacuation area" located more than 20 km to the north-west of the Fukushima Dai-ichi NPP (the Katsurao, Iitate and Namie districts, and part of the Kawamata and Minamisoma districts). In April 2012 (see map in Figure 2), the Japanese authorities defined zones within these evacuation areas, to which, in view of the measured contamination levels and the expected levels of external exposure (less than 20 mSv/year), people could initially return in order to perform certain activities for a short period in preparation for the population's return; this concerns part of the Minamisoma, Tamura and Kawauchi districts (green areas on the map in Figure 2). However, no one should be allowed to return to part of these districts (orange areas, where the radioactive caesium deposits exceed 1 million Bq/m^2) in the short term. In the areas with the highest caesium deposit levels (over 3 million Bq/m ^{2}), the population's return seems barely feasible in the long term.

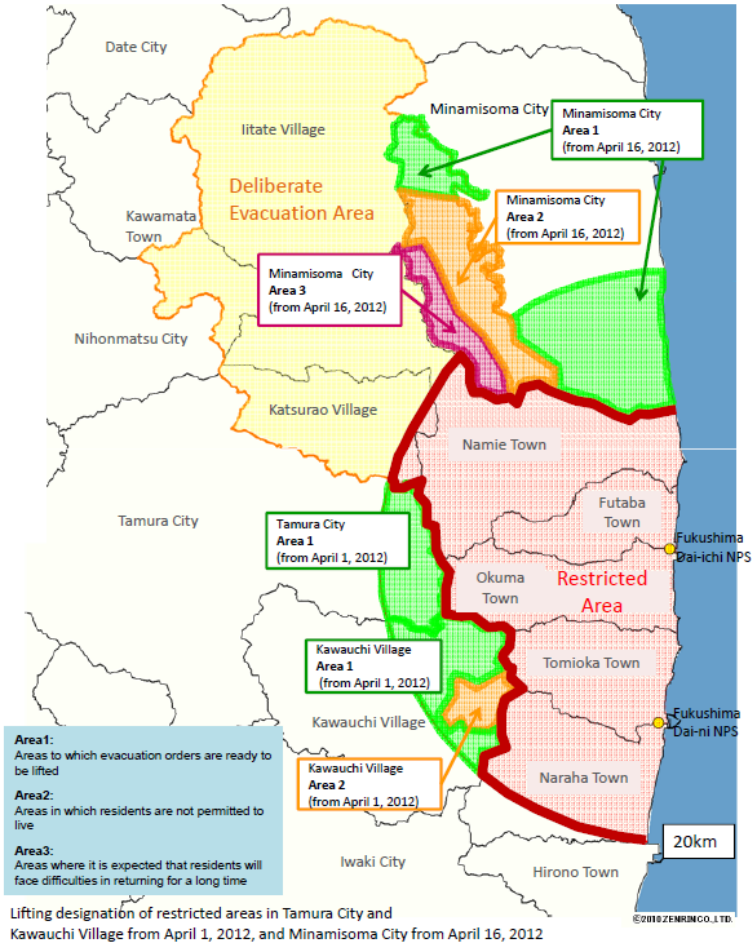

Figure 2 – Restricted area (20 km radius, in red) and deliberate evacuation area (in pale yellow) set up by the Japanese authorities on 1 April 2012 (source: METI, April 2012). The green areas indicate parts of the restricted area set up in 2011 in which preparations are being made for the population's return. The orange areas indicate parts of the Kawauchi and Minamisoma districts to which the population should not be allowed to return in the short term. The pink area represents a part of the Minamisoma district to which the population's return is barely feasible even in the long term due to the very considerable radioactive deposits (the surface activity exceeds 3 million Bq/m^2).

The durable contamination of certain foodstuffs produced in Japan is also caused by the residual radioactive caesium deposits. Whereas the contamination found in plant foodstuffs during the weeks following the accident was due to the direct contamination of the plants' aerial parts

(notably the leaves) through atmospheric deposition, two complementary transfer mechanisms then continued to contaminate various plant products:

- Translocation of the radionuclides initially deposited on the leaves, meaning that the radionuclides (notably caesium) are absorbed by the leaves, transported in the sap and then stored in some structural (wood) or storage tissue (bulbs, fruits, etc.); The plant can then easily remobilise the radionuclides accumulated in this way when new shoots or fruit grow, long after the plant was initially contaminated. The effects of this process tend to fade over the course of time;
- Root transfer of the radionuclides accumulated in the soil. Due to the long life of the caesium-137 in the top layers of the soil, this is the main process resulting in the durable contamination of wild or cultivated plants. The effects of this transfer process vary greatly, however, depending on the physical, chemical and biological properties of the soil and the plant species concerned. This phenomenon may be accentuated by the plant's living conditions, as in the case of rice, where radionuclides can also be transferred directly from the water in which it grows.

The durability of animal foodstuff contamination (meat, milk, eggs, etc.) directly depends on the quality of the animals' feed. Although the quality of livestock's feed can be monitored in order to keep the level of contamination as low as possible, such checks are not possible in the case of wild animals (game).

Lastly, the durability of contamination in foodstuffs coming from aquatic environments (freshwater or marine) depends not only upon the presence of the radionuclides in the water due to regular run-off containing the terrestrial deposits, but also (and mainly) upon the lifestyle and food of the aquatic species concerned.

The results of the measurements taken for various categories of foodstuffs in Japan and published in the first half of 2012 provide an overall assessment of these contamination phenomena involving the residual deposits of radioactive caesium. These results, which were collected and analysed by IRSN, are summarised in the following chapters. They also show which types of products and places of origin always exceed the sales and consumption standards set in Japan.

1. REPORT OF FOODSTUFF CONTAMINATION ACCORDING TO THE RESULTS PUBLISHED IN JAPAN SINCE THE FUKUSHIMA ACCIDENT

1.1. Foodstuff contamination controls and restrictions set up in Japan

After the Fukushima accident occurred in March 2011, restrictions on the sale and consumption of foodstuffs produced in Japan were set up by the Director-General of the Nuclear Emergency Response Headquarters to limit the risk of exposure through the ingestion of contaminated foodstuffs. These restrictions are based both on radioactivity controls performed on the foodstuffs produced in districts affected by radioactive fallout caused by the accident and on compliance with food standards (radionuclide concentrations for different categories of foodstuffs) set at an acceptable level of risk of exposure for the local population, in terms of radiation protection (Table 1). Initially, these standards related to various categories of radionuclides, but with the gradual disappearance of the short-lived radionuclides (notably iodine-131), only radioactive caesium (^{134}Cs and ^{137}Cs) has been detected in Japanese foodstuffs since the summer of 2011.

Early in 2012, the Japanese authorities decided to optimise the existing standards in order to reduce the population's exposure to a level as low as reasonably possible, notably in view of changes in the radioactive contamination in Japan (the disappearance of short-lived radionuclides and the declining levels of detected radioactivity), by applying much more stringent standards with effect from 1 April 2012 (Table 1). These concern only the radioactive caesiums (^{134}Cs+^{137}Cs), which are the only radionuclides attributable to the Fukushima accident that can currently be detected in foodstuffs.

Table 1 – Radioactive caesium concentration standards ($^{134}Cs+^{137}Cs$) in foodstuffs in Japan, defined following the Fukushima accident

Food category	Standards before 01/04/2012 (Bq of $^{134+137}Cs$/kg)
Drinking water	200
Milk	200
Vegetables Cereals Meat, eggs and fish	500

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Food category	Standards after 01/04/2012 (Bq of $^{134+137}Cs$/kg)
Drinking water	10
Milk	50
Other general foodstuffs	100
Infant feeds	50

Detailed rules have been introduced in order to decide when the restrictions (the prohibition of sale or consumption) should be introduced and lifted depending on the doses measured in the foodstuffs:

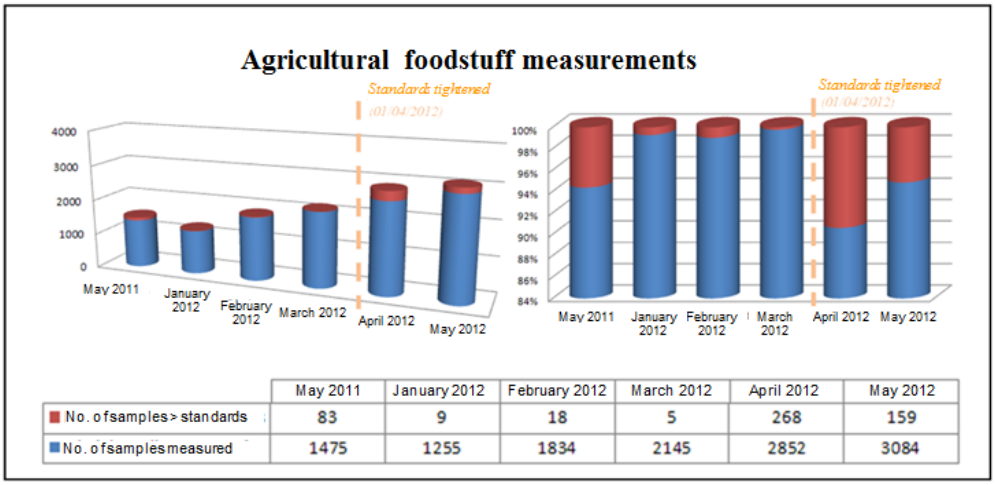
- Restricting the sale of a foodstuff if its caesium concentration ($^{134}Cs+^{137}Cs$) exceeds the standard for the food category concerned;
- Restricting the consumption of a foodstuff if its radioactive caesium concentration is judged too high (the official document by the Japanese authorities does not specify an exact limit);
- Lifting the restriction when the measured doses (in at least three measurements) obtained in the last month for each district are all below the standards.

The MHLW (the Japanese Ministry of Health, Labor and Welfare) has regularly published and updated the list of districts and foodstuffs concerned by these restrictions, as well as the results of the foodstuff monitoring.

The introduction of restrictions in specific districts in application of the rules described above depends on which categories of foodstuffs are actually produced in the districts concerned and, therefore, the harvesting season. As a result, restrictions were introduced in various districts of the Fukushima, Ibaraki, Chiba, Miyagi, Tochigi, Iwate, Gunma and Kanagawa prefectures (solely in the case of tea leaves) at various times during 2011 (and even early in 2012), depending on the types of foodstuffs and the moment when the food standards were seen to have been exceeded. With the more stringent standards introduced on 1 April 2012, new districts have been affected by these restrictions. The restrictions introduced in 2011 or in 2012 are still in force in most districts today. The relatively few districts that have had their restrictions lifted are mainly in the Chiba, Tochigi, Ibaraki and Gunma prefectures, in the case of tea leaves.

According to the available information, it seems that the monitoring conducted by the Japanese authorities is not based on a precisely detailed plan specifying the types of foodstuffs to be checked or the locations in which monitoring is most important. The results should therefore be viewed with a degree of caution when they are compared over the course of time. This is because the measured foodstuffs are not always the same from one month to another, and the samples are not always taken in the same places (the number of sampling points in the districts varies depending on the type of foodstuff and on the previously-obtained measurement results).

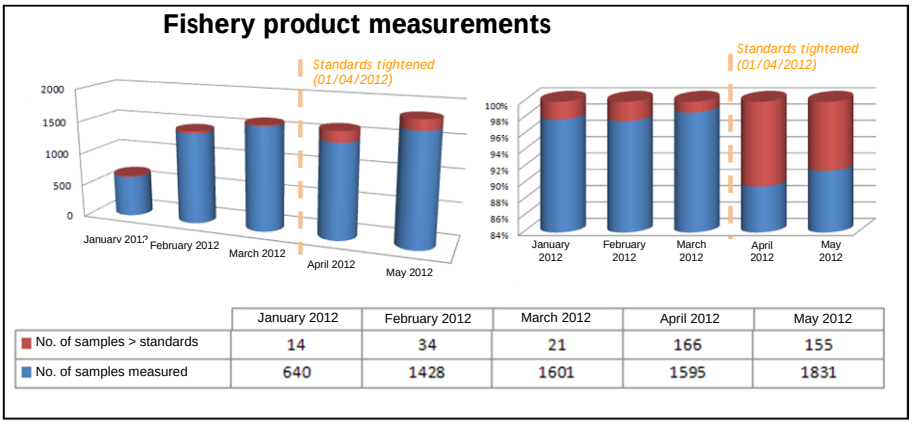
For plant agriculture, the number of analysed samples has increased over the course of time (there were approximately twice as many controls in May 2012 as in May 2011; see Figure 3), reflecting the progressive reinforcement of the control scheme in response to the results already obtained and the more stringent food standards. This has, as expected, resulted in the standards being exceeded more frequently, increasing from a very low level before 1 April 2012 (less than 1% of the controlled foodstuffs) to 9% in April 2012 and 5% in May 2012, i.e. the same level as in May 2011 with the old standards.



	May 2011	January 2012	February 2012	March 2012	April 2012	May 2012
No. of samples > standards	83	9	18	5	268	159
No. of samples measured	1475	1255	1834	2145	2852	3084

Figure 3 – Changes in the number of plant agriculture contamination controls and breaches of food standards in Japan since the beginning of 2012, and comparison with May 2011

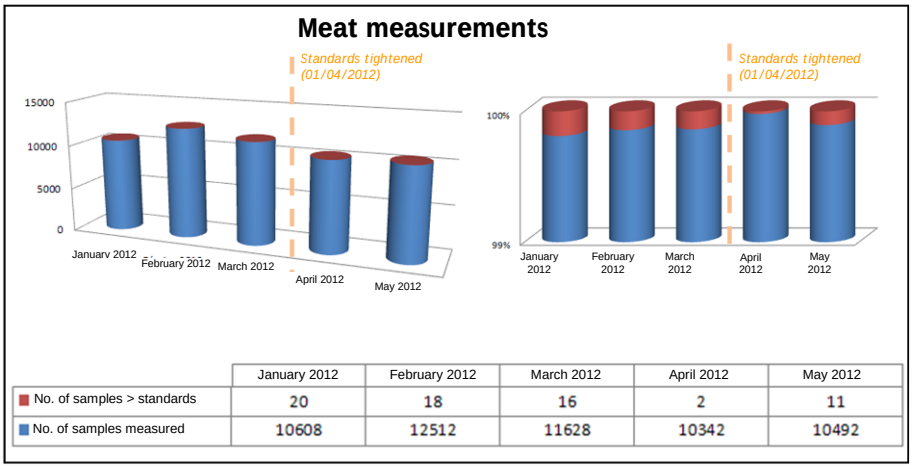
For fishery products (marine and freshwater), the trend is the same as that of plant agriculture (Figure 4). The number of samples taken increases over the course of time as the control scheme is set up. The situation was fairly stable (approximately 4% of the samples exceeded the current standards) until the standards changed on 1 April 2012, when the rate rose to 10%.



	January 2012	February 2012	March 2012	April 2012	May 2012
No. of samples > standards	14	34	21	166	155
No. of samples measured	640	1428	1601	1595	1831

Figure 4 – Changes in the number of fishery product contamination controls and breaches of food standards in Japan since the beginning of 2012, and comparison with May 2011

For meat, the situation is fairly stable and does not seem to be affected by the revised food standards (Figure 5). The food standards are generally exceeded very infrequently, and almost all breaches concern game meat (mainly wild boar).



	January 2012	February 2012	March 2012	April 2012	May 2012
No. of samples > standards	20	18	16	2	11
No. of samples measured	10608	12512	11628	10342	10492

Figure 5 – Changes in the number of meat contamination controls and breaches of food standards in Japan since the beginning of 2012, and comparison with May 2011

The following paragraphs show the changes in the contamination of the main categories of controlled foodstuffs in Japan. The values shown are based on the analytical results published up to the end of June 2012 for 185,756 foodstuff samples, of which 28,477 are for the Fukushima prefecture alone. During the months following the accident, these results regularly revealed significant specific activity in caesium-134, caesium-137 and iodine-131. Iodine-131 has not been detected in foodstuffs since summer 2011 because of its short radioactive life (8 days), which has resulted in it disappearing from the environment. Subsequently, only radioactive caesium specific activity (expressed in Becquerels of $^{134}Cs+^{137}Cs$ per kilogramme of fresh product – Bq/kg) is used to track the residual effect of fallout from the Fukushima accident upon food in Japan.

1.2. Terrestrial plant products

As plant production is often seasonal, the results available for the first half of 2012 relate only to products actually harvested during this period. They relate to both cultivated and wild products.

- **Mushrooms**

Between March 2011 and March 2012, the sales standards in force during this period have been exceeded many times in the case of shiitake mushrooms (Figure 6). The shiitake mushroom, which is also called the "black mushroom", "scented mushroom", "lentin" or "oak lentin", takes its Japanese name from *shii*, a type of tree (similar to the oak) on which it grows in its natural habitat, and *take*, which means "mushroom growing on". The shiitake is the second most widely-cultivated fungus in the world. It can easily be found on grocery store shelves, often in its dried form. In Japan, it is grown in greenhouses or outdoors, on wooden logs ("log-grown") or on a bed of compost in a mushroom house ("mushroom bed-grown").

More rarely, other species of mushrooms have exceeded the standards during this period: *Grifola frondosa* (maitake), *Lactarius volemus* (tawny milkcap), *Suillus bovinus* (Jersey cow) and *Pholiota nameko*.

Between April and June 2012, the only mushrooms that exceeded the new sales standards have been shiitake: of more than 800 analysed samples, 196 fresh and 79 dried shiiitake mushrooms exceeded the standard.

Figure 6 – Shiitake mushroom grown on a trunk

The graph in Figure 7 shows the 2036 results of radioactive caesium activity measurements ($^{134}Cs+^{137}Cs$) in undried shiitake mushrooms obtained between April 2011 and May 2012, distinguishing between the analysed mushrooms' prefectures of origin. The 812 values below the detection limits are conventionally recorded as 1 Bq/kg. This graph shows that the measured levels of contamination vary considerably (by a factor of 1000:1), which can be explained by the analysed samples' place of origin and their growing conditions; in addition, no significant difference can be seen between the results for samples from the Fukushima prefecture and those from other monitored prefectures. This graph also shows that the contamination levels have not changed over the course of the period.

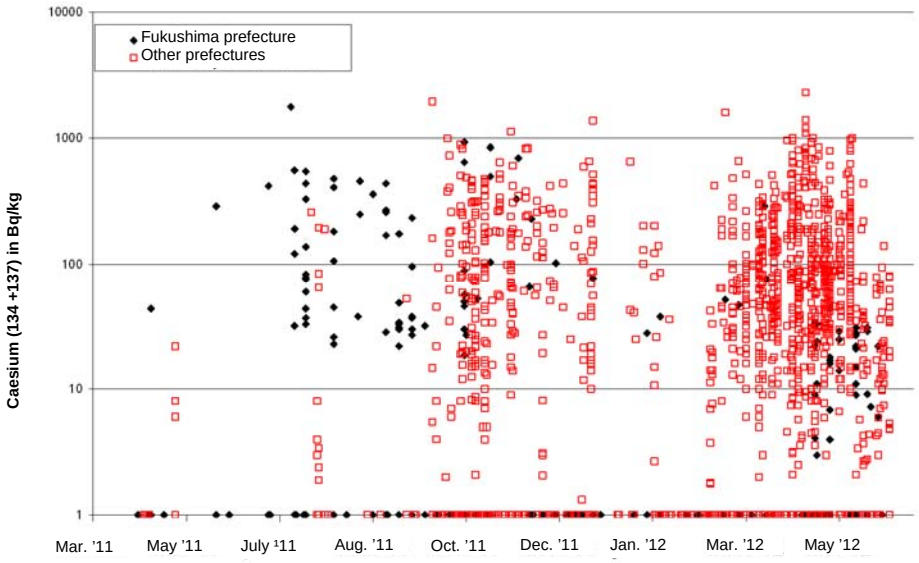


Figure 7 - Specific activity in caesium-134+137 in undried shiitake mushrooms measured between April 2011 and May 2012 (source: MHLW). By convention, measurements that are "undetectable" are given a value of 1 Bq/kg

Most of the 549 analysed samples applying to shiitake grown indoors (mushroom bed-grown or log-grown) have revealed radioactive caesium activity levels below the measuring instruments' detection limits. Of these 549 results, only four exceed 500 Bq/kg: three log-grown shiitake samples (with a maximum value of 1,770 Bq/kg) and a mushroom bed-grown shiitake sample (850 Bq/kg), all of which are from the Fukushima prefecture.

Of the 535 analytical results for shiitake mushrooms grown outdoors (usually on logs), the caesium activity exceeds 170 Bq/kg in half of the cases and 40 results exceed 500 Bq/kg, most of which involve samples taken from the Iwate prefecture. The maximum value is 2,300 Bq/kg for a log-grown shiitake sample from the Iwate prefecture.

In the other published measurement results, it is not specified whether the shiitake was grown indoors or outdoors.

Of course, as the drying process concentrates the caesium, the dried shiitake mushrooms' specific activity can reach even higher values, with a maximum value of 6940 Bq/kg measured in a sample from the Tochigi prefecture in November 2011.

All of these results suggest that the contamination of these mushrooms (and more specifically, of the carpophorus, the edible part) is mainly the result of the translocation of mycelium contamination (the mycelium, the perennial part of the mushroom, has a life of several years). This mycelium contamination may either have been directly caused by the radioactive fallout in March 2011 or be due to contamination of the substrate on which the mycelium grows (if the log has been exposed to the radioactive plume, for example). We can expect the mushroom contamination to last for years or even decades with little change in the caesium activity.

The map in Figure 8 shows the districts affected by the shiitake mushroom sales restrictions, indicating (in green) those to which the old standards applied and those (in red) to which the new, more stringent food standards apply since their introduction in Japan.

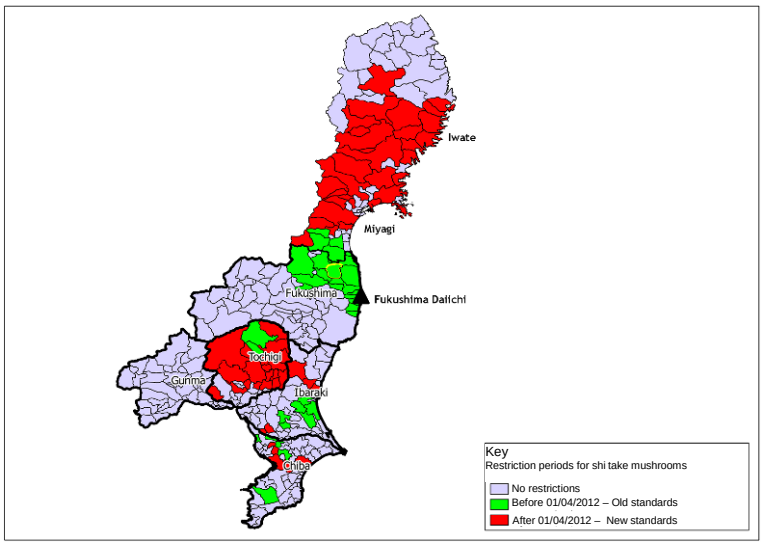


Figure 8 – Map of Japanese districts affected by the shiitake mushroom sales restrictions as at 22 June 2012

- **Other terrestrial plant foodstuffs**

In addition to the mushrooms, various other cultivated or wild plant foodstuffs have been regularly monitored in Japan during their harvest periods. Some of them have revealed radioactive caesium concentrations that exceed the new food standards introduced on 1 April 2012. They are:

- **Young tree or bush shoots eaten in spring:** Caesium concentrations in excess of the new standards were measured in 57 koshiabura samples and 19 *Aralia* shoot samples taken in April and May 2012. The shoots of the koshiabura tree are usually consumed in the form of doughnuts (tempura). The young *Aralia* shoots are consumed in Russia and Asia, and they are also used in the manufacture of cosmetic beauty products. Figure 9 shows the changes in caesium activity ($^{134}Cs+^{137}Cs$) in these foodstuffs between March 2011 and May 2012; these results concern 151 *Aralia* shoot samples, 51 of which were grown in greenhouses and 44 were "wild" (no information was provided on the 56 other samples), and 81 koshiabura samples, 25 of which were "wild" (no information was provided on the others). The samples were highly seasonal, and most were taken in spring 2011 and spring 2012. The 69 "wild" samples (44 *Aralia* shoots and 25 koshiabura shoots) were all taken in April and May 2012; they were probably gathered in forests.

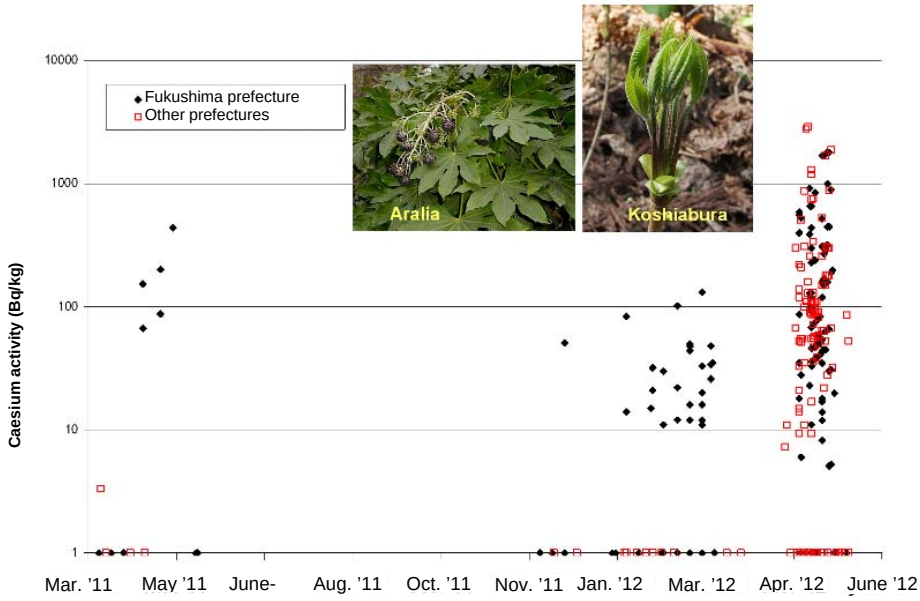


Figure 9 - Specific activity in caesium ($^{134}Cs+^{137}Cs$) in edible young tree shoots (koshiabura and Aralia) between March 2011 and May 2012 (source: MHLW). By convention, measurements that are "undetectable" are given a value of 1 Bq/kg

These foodstuffs are still considerably contaminated, with the same contamination levels as in 2011. The highest specific activities (2,800 Bq/kg and 2,900 Bq/kg) were found in two "wild" koshiabura samples taken at the end of April/beginning of May 2012 in the Tochigi prefecture. The winter 2011/2012 samples were, on the other hand, grown in greenhouses and revealed lower specific activities. The highest specific activity found in a greenhouse-grown sample was 130 Bq/kg in an *Aralia* shoot sample from Kawamata (Fukushima prefecture) taken at the end of February 2012. Apart from the seasonality, there does not seem to be any noticeable trend over the course of time. The young shoots are contaminated through translocation from the perennial part of the tree. The caesium concentration levels can be expected to remain high for the next few years. The maps in Figure 10 show the districts affected by the Aralia and koshiabura shoot sales restrictions, taking into account the new food standards in force in Japan.

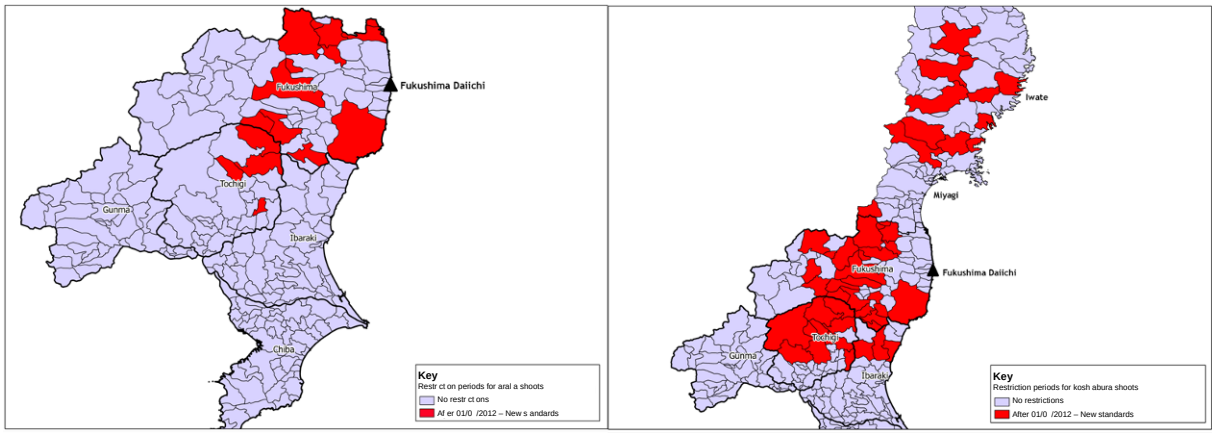


Figure 10 - Maps of Japanese districts concerned by Aralia (left) and koshiabura (right) shoot sales restrictions as at 22 June 2012

- **Bamboo shoots:** Between April and May 2012, caesium concentrations exceeding the new standards were measured in 47 bamboo shoot samples. Figure 11 shows the changes in caesium activity ($^{134}Cs+^{137}Cs$) in the bamboo shoots from March 2011 to May 2012. This situation is similar to that of the tree shoots, with the spring 2012 concentration levels slightly lower than those in 2011 (the standards were exceeded three times less in May 2012 than in May 2011). The durability of the contamination is due to a phenomenon of translocation from the perennial part of the plant, and we can expect this to occur again during the next few years.

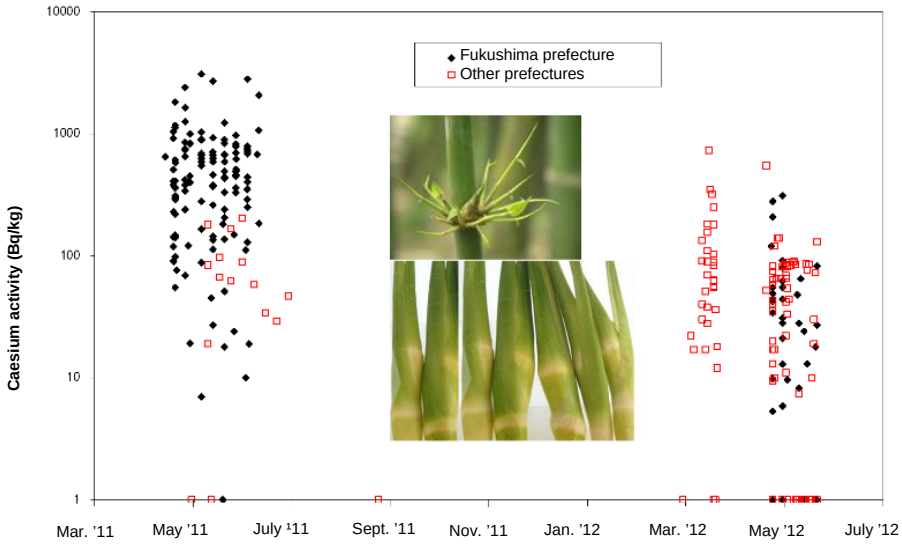


Figure 11 – Specific activity in caesium ($^{134}Cs+^{137}Cs$) in bamboo shoots between March 2011 and May 2012 (source: MHLW). By convention, measurements that are "undetectable" are given a value of 1 Bq/kg

The map in Figure 12 shows the districts affected by bamboo shoot sales restrictions. The more stringent food standards have had a considerable effect on the number of districts newly affected by restrictions.

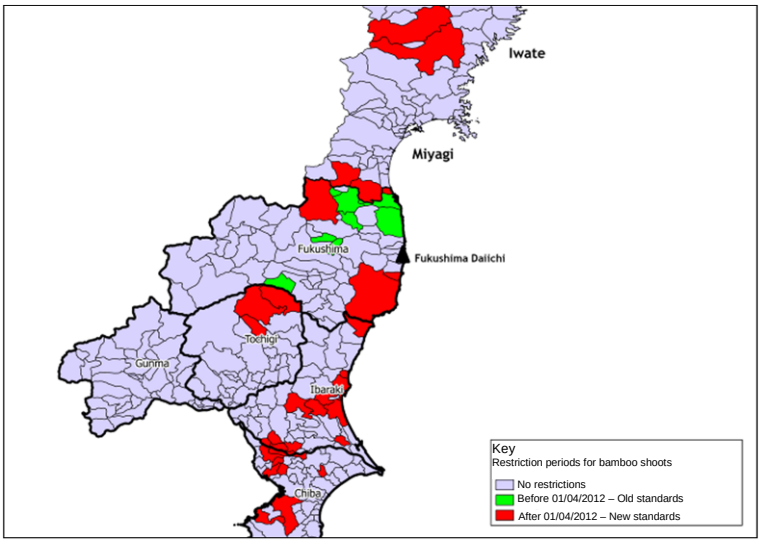


Figure 12 – Map of Japanese districts affected by bamboo shoot sales restrictions as at 22 June 2012 (in red: districts affected since the introduction of the new food standards)

- **Fiddleheads (Figure 13)**: between April and May 2012, 44 samples of fern varieties with edible fiddleheads (ostrich ferns, royal ferns and bracken) were measured with caesium concentrations

exceeding the new standards (between 110 and 1100 Bq/kg). The contamination process (translocation) and trends are similar to those of tree shoots and bamboo shoots;

Figure 13 - Edible fiddleheads

- **Tea,** which has been analysed very many times and yet it has only exceeded the detection limits (let alone the sales standards) in a minority of cases. In the month of May 2012 alone (the period of the "first flush", or first harvest), 536 tea samples were analysed and only 11 exceeded 10 Bq/kg, with none ever exceeding 25 Bq/kg, in the Tochigi, Ibaraki and Chiba prefectures. However, some sales restrictions introduced in 2011 still remain, mainly in the Ibaraki prefecture. Since 1 April 2012, the tea-leaf sales restriction has been lifted in only 13 districts in the Ibaraki, Tochigi, Gunma and Chiba prefectures;

- **Yacón tea leaf powder** from the Miyagi prefecture, of which 4 samples taken in 2012 (from a total of 12 measured samples) have revealed radioactive caesium specific activity levels ranging from 15,000 Bq/kg to 20,000 Bq/kg. Despite its name, yacón tea cannot be compared with an infusion tea: it is a powder extracted from a tuber, the Peruvian ground apple (or yacón), grown for its sweetening properties (Figure 14). It is a perennial member of the Asteraceae family, similar to the sunflower and Jerusalem artichoke. Yacón provides two products: yacón syrup and yacón tea. The very high caesium concentrations measured in 2012 are probably due to the powder transformation process.

Figure 14 – Yacón: aerial part (left) and edible tubers (right)

The caesium concentrations of the other plant foodstuffs monitored in Japan more rarely exceed the new food standards: petasites (or butterbur scape, a wild herbaceous plant) and a few other edible wild plants (ashitaba, uwabamisou, etc.) (approximately a dozen cases); emu, or Japanese apricot (two cases); spinach (one case); wasabi (one case); and Japanese parsley (one case).

1.3. Meat and milk

Numerous controls have been performed on the meat produced in Japan, which mainly consists of beef, since the Fukushima accident (see Figure 5).

- **Livestock meat and cow's milk**

Each month, many beef samples are measured (approximately 98% of the total number of meat measurements) but none, or virtually none, are found to exceed the food standards (one sample from the Iwate prefecture in January and another in March 2012). In May 2012, only 20 of the more than 10,000 analytical results exceeded the detection limits, with a maximum of 92 Bq/kg (from the Miyagi prefecture).

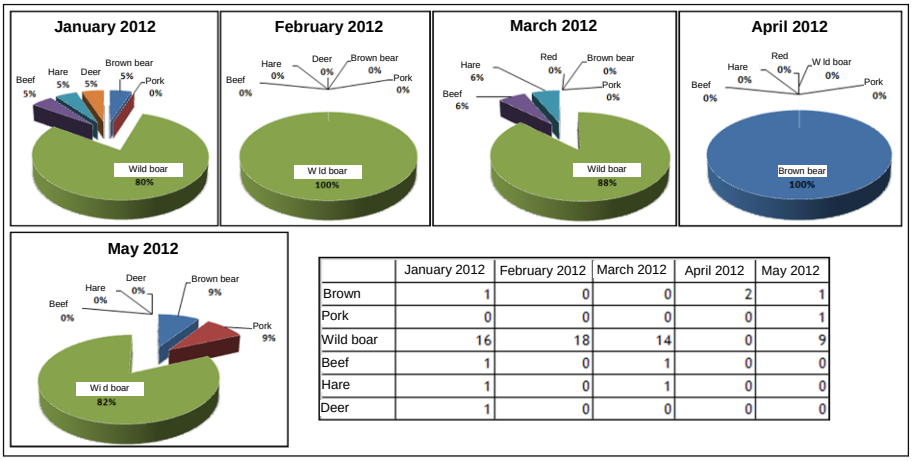
The results are similar for pork, with less intense monitoring. For the month of May 2012 alone, only 6 of the 77 caesium specific activity samples analysed ($^{134}Cs+^{137}Cs$) exceeded the detection limits, with a maximum of 110 Bq/kg (from the Fukushima prefecture).

Cow's milk is also constantly monitored, with most results below the measuring instruments' detection limits, as well as all forms of infant milk.

These good results, both for meat and for milk, seem to confirm that the quality of the livestock feed is properly controlled; this is made easier by the rearing technique most widely used in Japan (stalling). In view of the durable environmental contamination, the maintaining of regular monitoring is justified in order to detect any adverse events. If cattle regularly consume moderately-contaminated feed (approximately 100 Bq/kg), the meat's caesium concentration can gradually increase and exceed the sales standards, as occurred in July 2011 in the case of some herds (Kawamata-Machi).

- **Game**

Unlike livestock, it is not possible to check the quality of wild game's food. As a result, it is in this type of meat that the highest radioactive caesium concentrations are most regularly found. This is particularly true of wild boar meat, in which the contamination regularly exceeds the food standards. This is due to the fact that the wild boars live in forests, which are seriously contaminated as a result of discharges into the atmosphere and have not been decontaminated. Very occasionally, the current standards are exceeded by brown bear, deer or even hare meat samples (see Figure 15).



	January 2012	February 2012	March 2012	April 2012	May 2012
Brown	1	0	0	2	1
Pork	0	0	0	0	1
Wild boar	16	18	14	0	9
Beef	1	0	1	0	0
Hare	1	0	1	0	0
Deer	1	0	0	0	0

Figure 15 – Distribution of breaches of sales standards by meat type, since the beginning of 2012

Figure 16 shows the changes in caesium activity ($^{134}Cs+^{137}Cs$) in wild boar meat from March 2011 to May 2012. Despite a slight downward trend over the course of time, the values remain consistently

higher than the detection limits and often exceed the sales limits. This situation can be expected to last for as long as the forests' specific activity remains high.

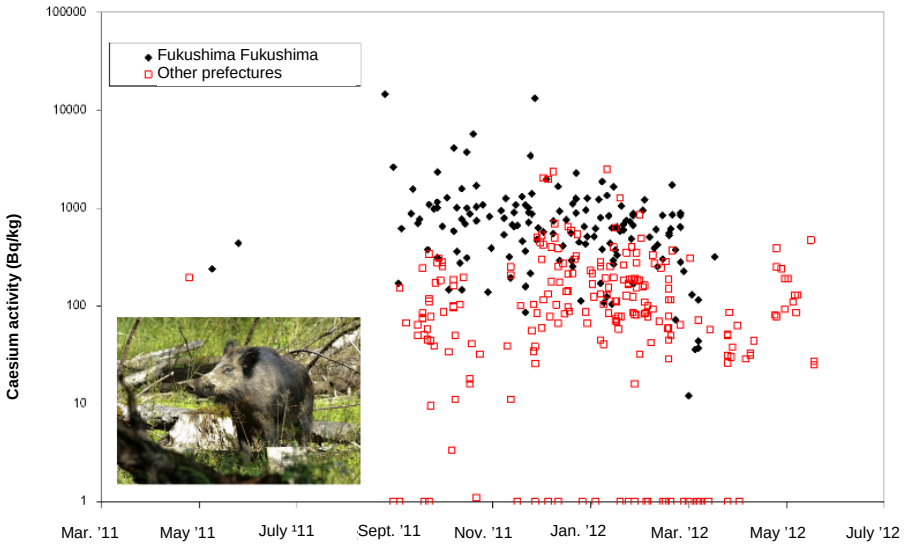


Figure 16 – Specific activity of caesium (^{134}Cs+^{137}Cs) in wild boar meat between March 2011 and May 2012 (source: MHLW). By convention, measurements that are "undetectable" are given a value of 1 Bq/kg

1.4. Marine or freshwater foodstuffs

The marine or freshwater foodstuffs sampled in the areas affected by the accident still have fairly high levels of caesium contamination, justifying the maintaining of production monitoring and restrictions. A more detailed description of the situation regarding marine organisms is contained in IRSN memo entitled *"Updated summary of knowledge concerning the impact on the marine environment of radioactive discharge from the damaged nuclear site of Fukushima Dai-ichi"*. This summary only contains the main elements concerning marine or freshwater organisms intended for human consumption.

- **Marine products**

In the last few months and before the 1 April 2012, the date on which the new food standards were introduced, the only marine organisms whose caesium concentration exceeded the standard in force at the time (500 Bq/kg wet) were fish, all of which were from the Fukushima prefecture. After this standard was reduced to 100 Bq/kg wet, it was sometimes exceeded not only by various species of fish, but occasionally also by clams and sea urchins. This has led the Japanese authorities to extend the fish and marine product sales and consumption restrictions to other areas (Figure 17): in addition to the ports in the Fukushima prefecture, which were already affected by the restrictions before 1 April 2012, the restrictions have been extended to the ports in the Miyagi and Ibaraki prefectures. These restrictions apply to the landing of the fish specified by the authorities (this list is periodically updated by the MLHW) in the prefectures' ports, regardless of where they were caught.

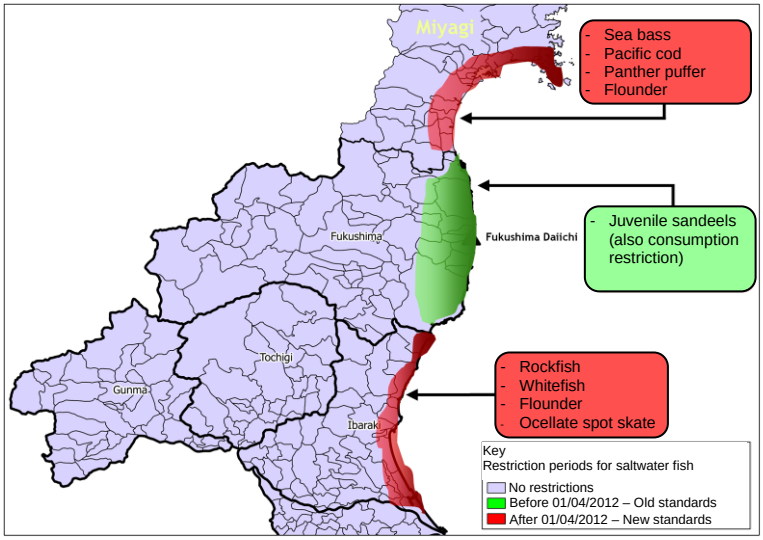


Figure 17 – Map of areas in which the landing of saltwater fish is restricted as at 22 June 2012

The graph in Figure 18 shows the measured caesium concentration levels in different marine species between March 2011 and March 2012.

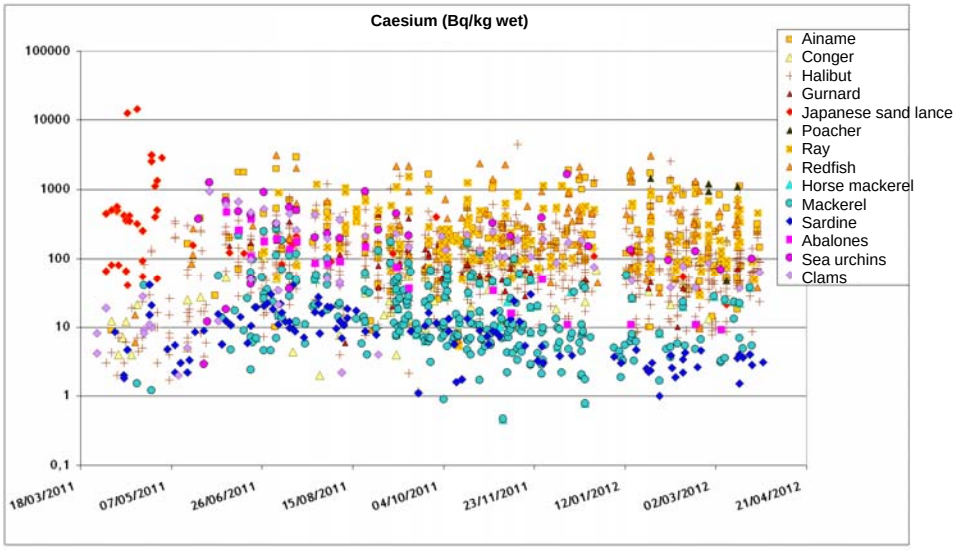


Figure 18 – Changes over time of $^{137}Cs+^{134}Cs$ (Bq/kg wet) concentrations in some marine products, between March 2011 and March 2012

The following comments can be made regarding these results:

- The caesium concentration varies greatly (by a factor of 1000:1), due to the wide range of places in which the various species were caught and their lifestyle (mobility, feed, etc.);
- Sedimentary fish (represented by orange symbols in Figure 18), such as ainames, halibuts, gurnards, rays and rockfish, tend to have higher concentration levels than pelagic species (represented by bluish symbols in Figure 18) such as mackerel, sardines and horse mackerel;
- It should be noted that the sea urchin, abalone and clam samples taken from the Fukushima prefecture can also reach high levels (represented by pink symbols in Figure 18);

- For most species, it is difficult to see any change in contamination over the course of time (upward or downward), given the wide range of results obtained. However, a downward trend in the contamination levels can be seen in the molluscs (such as mussels, oysters, clams and abalones) or grazing organisms (sea urchins), due to a reduction in the ambient contamination of the sea water and the lack of any new major discharges.

The results show the long-lasting high levels of contamination in various marine species caught along the coast of the Fukushima prefecture; these regularly exceed the sales and consumption standards, particularly since the standards were tightened on 1 April 2012. This situation justifies the continued monitoring of marine species caught in the north-eastern coastal waters of Japan.

- **Freshwater products**

Five fish species of which samples were caught in lakes or rivers have higher contamination levels that regularly exceed the food standards in the Fukushima prefecture and are regularly monitored (Figure 19). They are: dace (*Tribolodon hakonensis*), white-spotted char (*Salvelinus leucomaenis*), ayu (*Plecoglossus altivelis*), masu salmon (*Oncorhyncus masou*) and Japanese smelt (*Hypomesus nipponensis*). Apart from the dace, all of the other species are amphihaline (meaning that they migrate from fresh to salt waters and vice versa). However, it should be noted that some populations of these species may remain attached to fresh waters throughout their life-cycle.

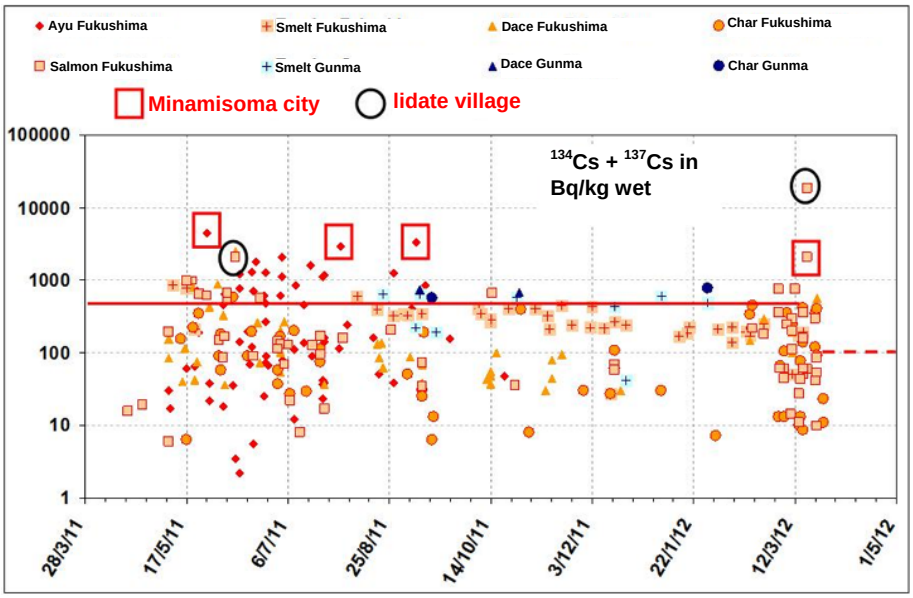


Figure 19 – Caesium concentration levels ($^{134}Cs+^{137}Cs$) in five species of fish caught in rivers or lakes in the Fukushima prefecture The red lines represent the maximum permitted levels for food consumption (solid line up to 1 April 2012: 500 Bq/kg wet; dotted line from 1 April 2012: 100 Bq/kg wet)

The results vary considerably, however what clearly stands out is the fact that the most affected samples were all collected from rivers or lakes in the Fukushima prefecture (shown in red) except for a few specimens fished from lakes in the Gunma prefecture (shown in blue). The highest levels were found in fish caught near to the city of Minamisoma in the Fukushima prefecture. A contamination level of a masu salmon sample caught in Iidate on 18 March 2012 was extremely high, reaching 18700 Bq/kg wet.

These changes should generally be directly related to the high contamination levels in these environments.

It should be noted that one species of salmon, the chum salmon (*Oncorhyncus keta*), was also monitored regularly in the Hokkaido and Fukushima prefectures. The levels found are almost always below the detection limits. This can be directly related to how this species lives; only adult specimens are found in rivers, and they do not eat during that phase of their lives, which tends to highlight the importance of the trophic route as the main source of contamination in the fish.

A number of other species have been subjected to more or less regular monitoring, such as various types of molluscs, crabs, crawfish, shrimps, carp and other species of salmon. Since January 2012, the levels detected in these samples are usually less than 200 Bq/kg wet ($^{137}Cs+^{134}Cs$), although these levels may occasionally be exceeded.

2. CONCLUSION

The results of the monitoring by the Japanese authorities generally show that the livestock and plant production contamination level is considerably lower than in the spring of 2011. In addition, the monitoring has been increased and some producers have even set up more stringent measures than those of the Japanese authorities. All of these measures help to increase Japan's food safety. Some foodstuffs, however, still reveal high radioactive caesium levels in the first half of 2012: shiitake mushrooms, some plant products such as bamboo shoots or even wild plants, game, certain freshwater fish (salmon and carp) from the Fukushima prefecture or adjoining prefectures, or some marine products caught along the coast near to the damaged nuclear power plant. Fortunately, in most cases these are foodstuffs said to be of "lesser importance" as they play a small part in the standard diet in Japan (with the exception of fish).

This situation has resulted in the Japanese foodstuff sales and consumption standards being exceeded more frequently since they were made more stringent on 1 April 2012.

IRSN therefore recommends a certain degree of caution regarding the consumption of the following foodstuffs:

- Wild plants and boar meat: these products come from a forest environment, where nothing is done to reduce the contamination;
- Shiitake mushrooms: the restrictions are widened daily, and the districts concerned are further and further away from the Fukushima prefecture.
- Fish (marine and freshwater), the contamination levels of which regularly and constantly exceed the standards.

Care should be taken regarding the origin and, where appropriate, the measured contamination levels of these foodstuffs. In general, a varied diet (particularly in terms of its origin) is recommended in order to effectively reduce internal contamination via ingestion.