

Cooperation between the International Atomic Energy Agency (IAEA) and Fukushima Prefecture and activities undertaken by Prefecture authorities following the accident at TEPCO's Fukushima Daiichi Nuclear Power Plant

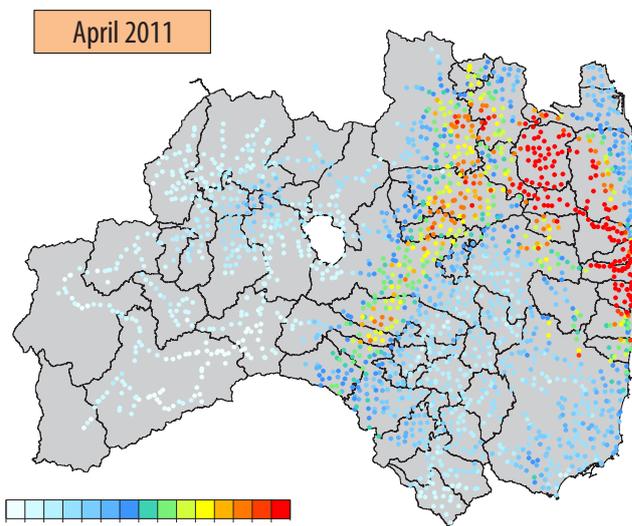


To support ongoing protection of people and the environment from ionizing radiation in Fukushima Prefecture after the accident at TEPCO's Fukushima Daiichi Nuclear Power Plant in March 2011, the IAEA provided assistance under the framework of cooperation with Fukushima Prefecture in three areas – radiation monitoring & mapping, remediation & decontamination and management of radioactive waste. The duration of this initial cooperation was five years (2013-2017). Benefitting from the cooperation with the IAEA, Fukushima Prefecture undertook various activities in these areas.

Radiation Monitoring & Mapping

What was the IAEA's assistance under the cooperation?

- The IAEA provided advice to the Fukushima Prefecture on radiation monitoring and the application of environmental mapping technology, including use of radiation monitoring data from unmanned aerial vehicles.
- The IAEA provided advice to the Prefecture on establishing a long-term radiation monitoring program for forests, reviewing the effectiveness of countermeasures in forests, addressing issues related to the timber industry including the radiation exposure of forest workers, and assessing the radiological impact of forest fires. The IAEA team also provided expert advice in the development of the Satoyama Rehabilitation Model Project.
- The IAEA provided advice to the Prefecture regarding the presence of radiocaesium in wild animals – primarily wild boar and Asian black bear.



What were the activities undertaken by Prefecture authorities?

Online maps with standardized radiation monitoring data were developed by Prefecture authorities. They are accessible via the Fukushima Radioactive Measurement Map website <http://fukushima-radioactivity.jp/>. On this mobile friendly site, readers can find simple, easy-to-understand information. Clickable maps allow users to access data from specific points taken at regular intervals.

According to reports by Prefecture authorities, the systematic monitoring of forest materials shows that most of the radiocaesium is bound in the soil and litter layer. Most of the radiocaesium is retained within the forest and that run-off into agricultural areas is very low.

Studies by Prefecture authorities have confirmed that the level of radiocaesium in the trunk of trees is low and the trunk may be harvested without radiological considerations. Experiments by the authorities also show that the future planting of trees does not need to be restricted. Monitoring by Prefecture authorities at the sites where forest fires have occurred has revealed that there is very little impact on the redistribution of radiocaesium as a result of fires and that wind does not contribute to the increase in radiation levels in surrounding areas.

Prefecture authorities carried out research on the uptake of radiocaesium by wild animals. The results show that the concentration of radiocaesium in the flesh of wild animals varies considerably (from under 10 Bq/kg to 13 000 Bq/kg in fiscal year 2016). A small number of “outliers” (individual animals with very high radiocaesium concentrations in their flesh) are identified every year. Follow up work by Prefecture authorities is under way to determine whether higher radiocaesium concentrations in some animals are due to the consumption of mushrooms or some other factors.

If you would like to know more, see the brochure on monitoring and mapping.

Remediation and Decontamination

What was the IAEA's assistance under the cooperation?

- The IAEA provided advice to Fukushima Prefecture on decontamination for external exposure reduction in the Prefecture.
- The IAEA provided advice to the Prefecture on the investigation of radiocaesium dynamics in rivers and lakes and related countermeasures.

What were the activities undertaken by Prefecture authorities?

In Fukushima Prefecture, houses, public facilities, farmland and roads were decontaminated to reduce the effects of radioactive contamination. According to Prefecture authorities, as of October 2017, almost 100% of the decontamination activities planned for residential buildings had been completed.

Prefecture authorities have confirmed that the radiation doses in the prefecture have been decreasing continuously due to natural processes and decontamination activities. The annual additional exposure of residents as a result of the accident is estimated by Prefecture authorities to be almost below 1 mSv.

The behaviour of radiocaesium in Fukushima Prefecture was analyzed by local experts in view of global experience. The understanding of the behaviour of radiocaesium in the environment provided the basis for planning effective countermeasures by the authorities to ensure the safe use of water from rivers and lakes. Global experience gained during remediation of areas affected by radionuclides provided input for the selection of appropriate and technically feasible decontamination activities by the authorities.

It was confirmed by Prefecture authorities that radiocaesium is strongly bound to suspended particles in water. According to Prefecture data, radiocaesium concentration in rivers has been decreasing continuously since the accident, and is now much lower than the national standard for drinking water (10 Bq/L). The authorities can model effectively the future behaviour of radiocaesium in river water.

For the countermeasures at riversides, authorities verified that decontamination should be performed on the basis of radiocaesium distribution patterns specific to riversides. According to Prefecture findings, the effects of decontamination were maintained even after flooding events.

If you would like to know more, see the brochure on remediation and decontamination.



Management of Radioactive Waste

What was the IAEA's assistance under the cooperation?

- The IAEA provided technical advice to the Prefecture on the safety of the management of radioactive waste from remediation activities in temporary storage sites (TSSs) and on-site storage sites for all normal, altered and extreme situations including fire, heavy rain and earthquakes.
- The IAEA provided technical advice to the Prefecture on the evaluation of the safety of longer storage periods than originally expected as well as future steps in the management of radioactive waste.

What were the activities undertaken by Prefecture authorities?

Prefecture authorities have developed safety assessment for the storage of radioactive waste from remediation activities. It involved identifying all relevant parameters that could affect safety, such as site characteristics, designed safety features of the site, characteristics of the waste and its containers to quantitatively assess the impact of TSSs and on-site storage sites for different periods of time, and different scenarios, in particular, normal operating conditions and accident scenarios. The project also addressed the safety for longer storage periods than originally expected. The development by the authorities of safety assessments for TSSs and on-site storage sites also included the sharing and explanation of the results of assessments to interested stakeholders, including members of the public. According to Prefecture authorities, the results of the safety assessment and the systematic monitoring of the TSSs and on-site storage sites show that any radiological impact on nearby areas is limited and without specific consequences to the public and the environment.

If you would like to know more, see the brochure on radioactive waste from remediation activities.



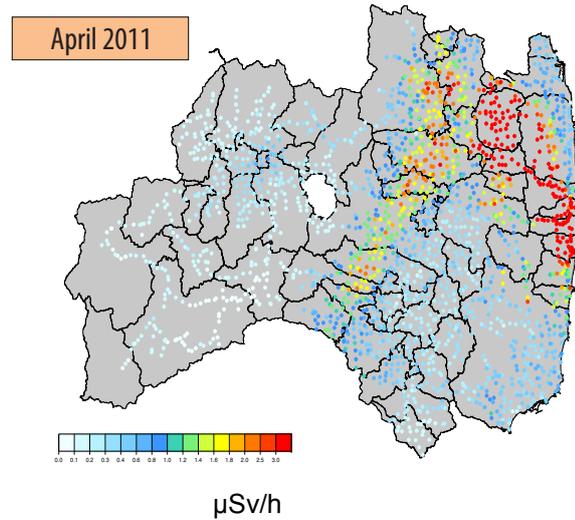
Radiation monitoring and mapping

The IAEA provided advice to Fukushima Prefecture authorities on analysing and interpreting radiation monitoring data and the application of mapping technology to make maps available to the public. You can find simple, easy-to-understand information, also optimized for mobile devices, online. Clickable maps allow users to access data from specific points measured at specific times. These were developed by Prefecture authorities.

Where can you find radiation monitoring data ?

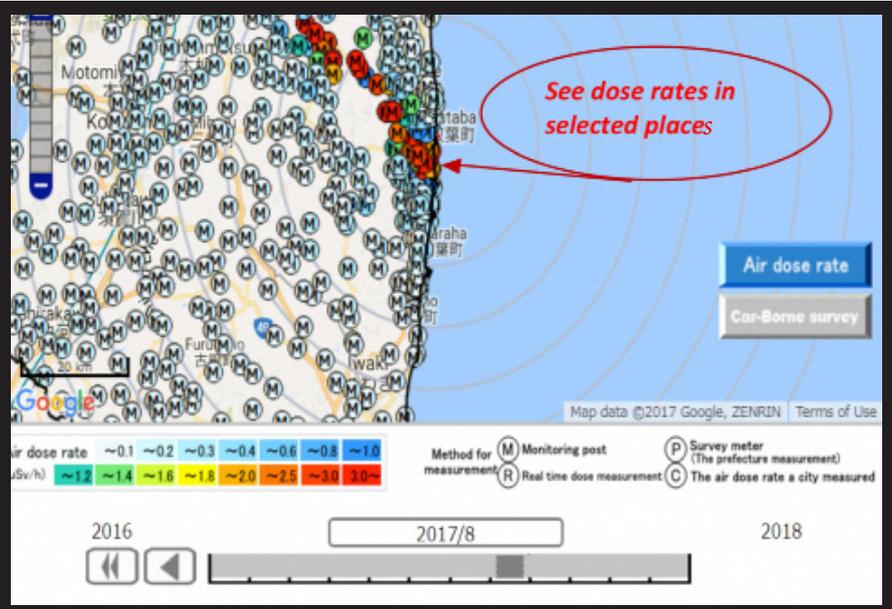
on the Fukushima Radioactive Measurement Map website

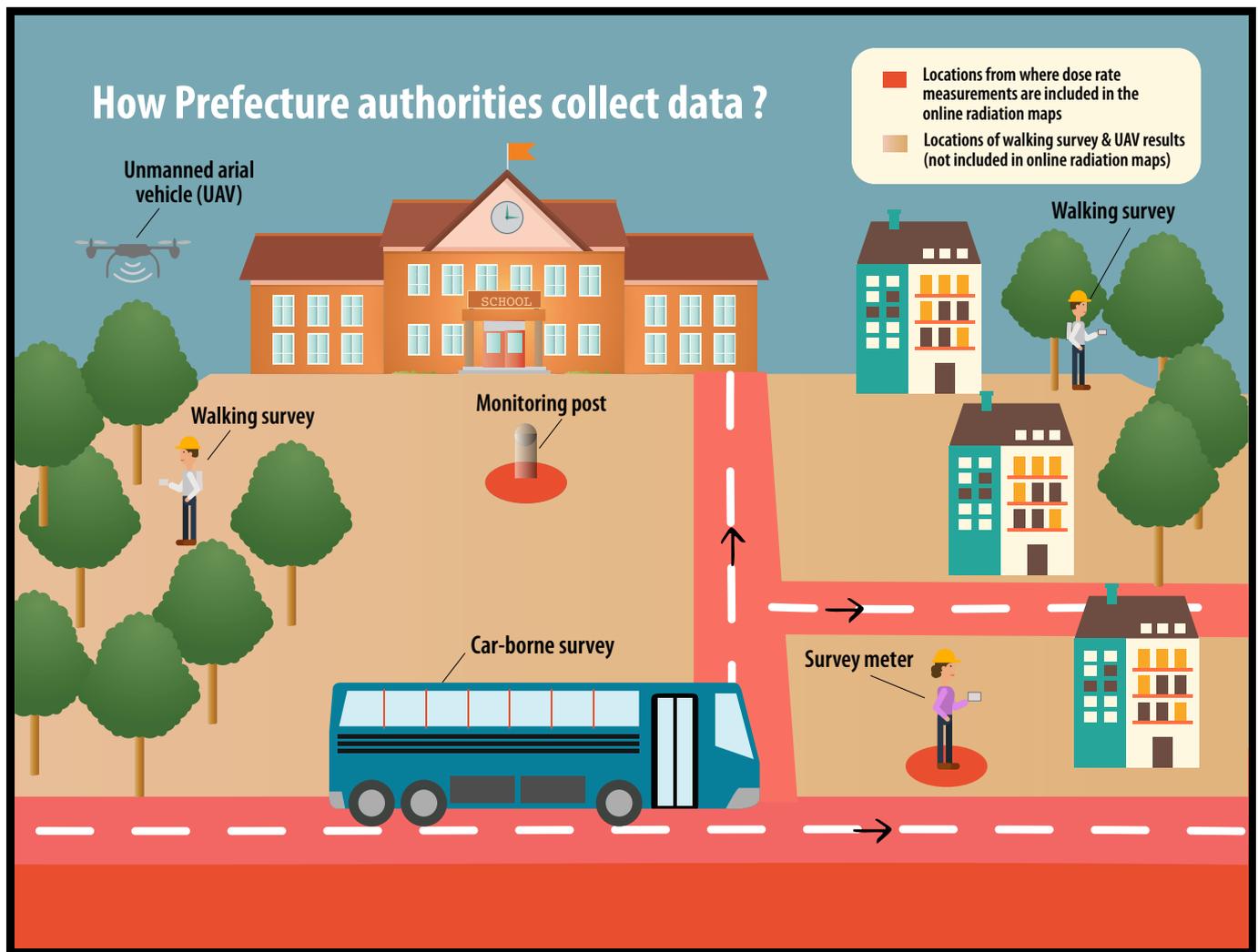
<http://fukushima-radioactivity.jp/>



What can you find here?

- the trend of decreasing dose rate,
- the method for measurement.





Prefecture authorities obtain monitoring data the following ways:

- from fixed monitoring stations and survey meters,
- using cars and buses equipped with GPS,
- using unmanned aerial vehicles (UAVs), and
- from walking surveys, with device in the backpack of the surveying staff.

Car-borne surveys are used on roads in residential and rural areas, walking surveys are used in open areas such as parks and forests.

Long-term monitoring of radioactive material in forests

The IAEA provided advice to Prefecture authorities on establishing a long-term radiation monitoring program for forests. Forests play a key role in the economy of Fukushima Prefecture, so it is important to understand the mechanisms of radiocaesium movement within forests and to monitor the radioactivity of wood products. The program includes long-term monitoring by Prefecture authorities of the migration of radiocaesium between the different components of the forest ecosystem, managing the radiation exposure of forest workers and assessing the radiological impact of forest fires.

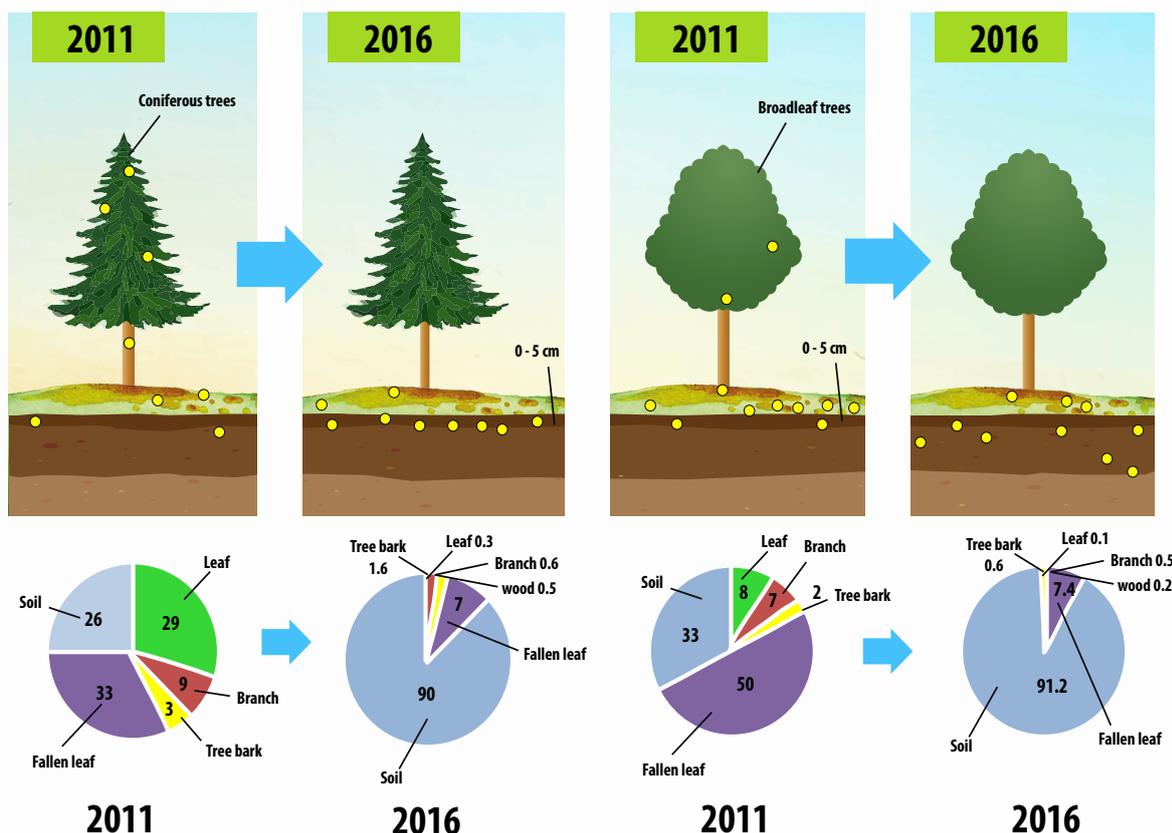
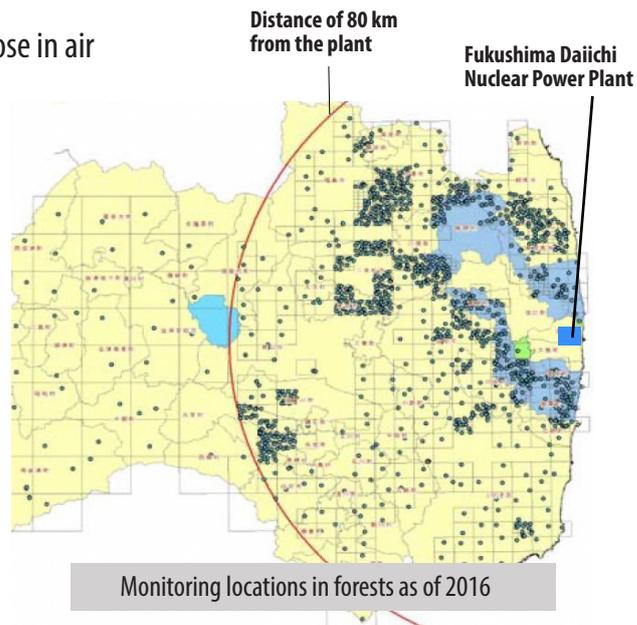
Fukushima Prefecture established an extensive forest monitoring program, expanding from 362 sites in 2011 to 1300 sites in 2017.

Prefecture authorities carried out measurements of radiation dose in air and of radiocaesium levels in soil and forest litter.

Binding radiocaesium

Clay minerals in forest soil bind radiocaesium, so there is low transfer to vegetation, including trees, according to measurements by the Prefecture.

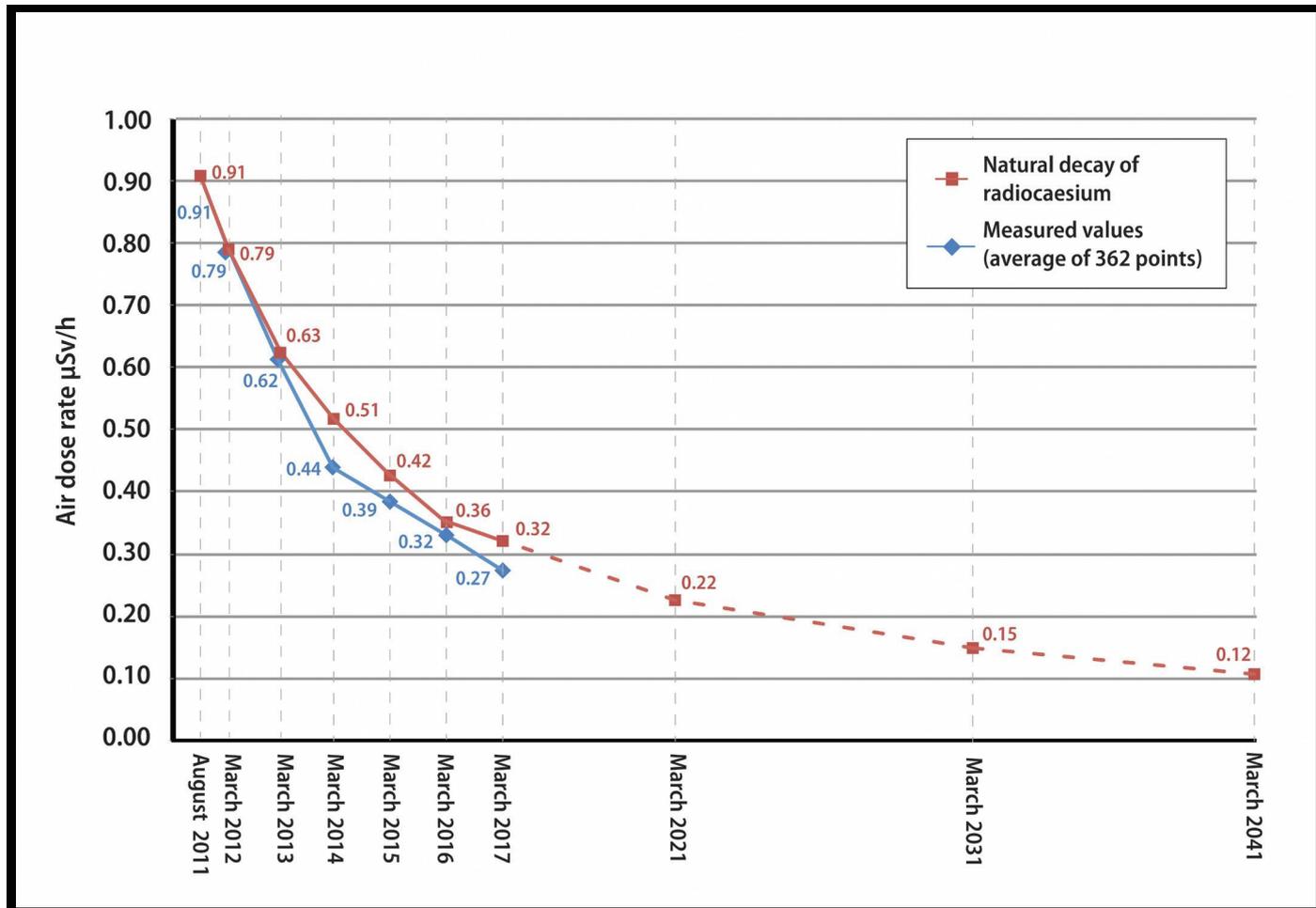
According to Prefecture's data, about 90% of radiocaesium in forests is now in the soil (mostly in the top 5 cm) and a further 7% in the forest litter: this means only 3% in trees



Changes in radiocaesium distribution in the forest ecosystem over time. (Source: Fukushima Prefecture)

According to measurements by the Prefecture, the dose rate in forests has decreased by about **70%** since August 2011.

This is slightly faster than the reduction due to the natural decay of radiocaesium.



Comparison of decreasing measured dose rates and dose rates falling due to natural decay (measured by Fukushima Prefecture authorities at 362 points)

How Prefecture authorities monitored radioactive materials in forests?

Forest samples were collected and radioactive caesium measured by Prefecture authorities. They evaluated the movement of radiocaesium in forest material, surveying Japanese cedar, Japanese cypress and Japanese red pine trees. See the photos below:



Collection of periphery & core



Collection of tree bark



Collection of soil



Collection of new and old leaves



Collection of fallen leaves

Average radiocaesium concentration in Bq/kg

	in 2015	in 2016
Old leaves	1427	908
New leaves	2904	2141
Peripheral wood	32	47
Core wood	38	59

(Source: Fukushima Prefecture authorities)

The national standard for classifying waste material as radioactive waste requiring specific management is **8,000 Bq/kg**. As of 2016, according to Prefecture data, the highest concentration of radiocaesium measured in harvested wood is **5,500 Bq/kg**.

What does this mean for consumers?

Prefecture calculations show that if a residence was built using wood with the maximum radiocaesium concentration, additional annual exposure above the background level would be only about **0.1 mSv**.

Annual exposure due to natural radiation in Japan is 2.1 mSv, according to national statistics.

Advice by Prefecture authorities:

- No need to restrict use of timber, but ongoing monitoring is necessary.
- No need to restrict planting of trees, because the level of radiocaesium will be significantly reduced when trees are harvested in 50-80 years' time.
- It is important to manage the radiation exposure of forest workers.

What about forest fires?

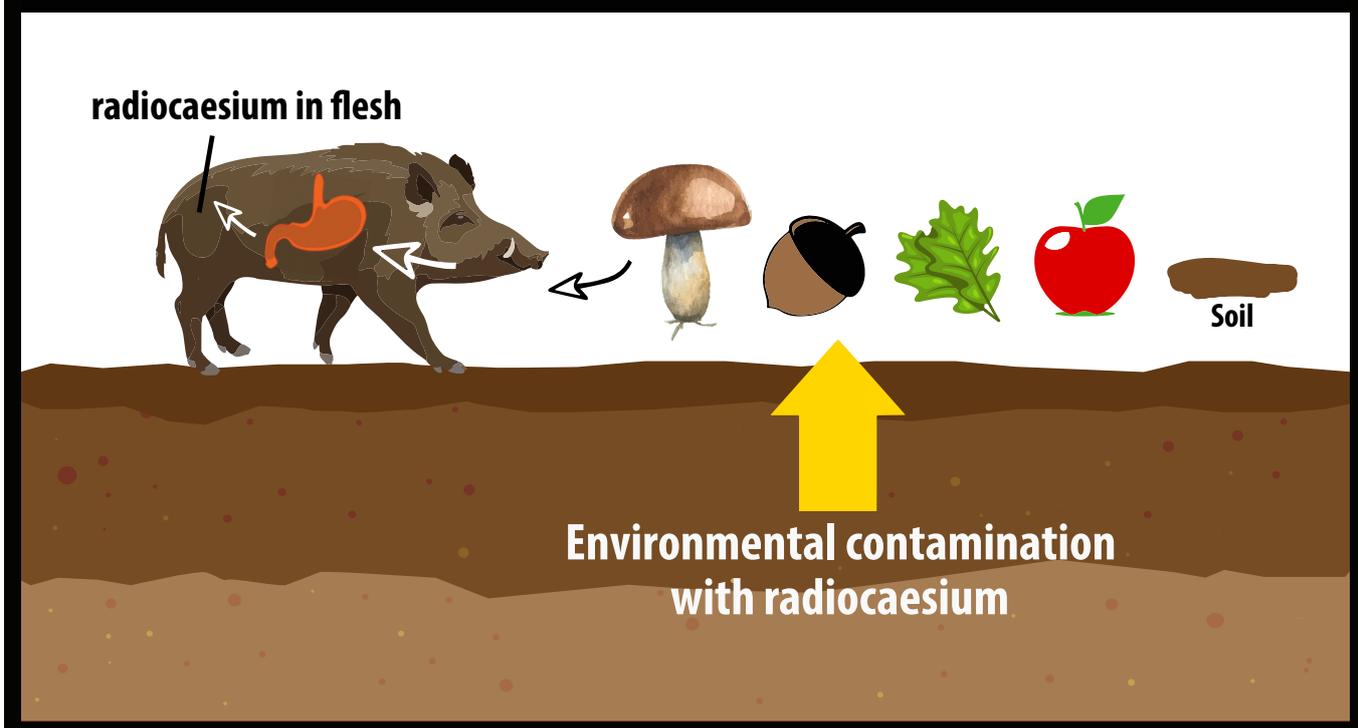
Prefecture authorities have determined that the overall impact is very low:

- Only small amounts of radiocaesium were relocated as a result of fires.
- Only a small increase in air dose rate was observed.
- Radiation impact on the population is negligible.

Monitoring of radiocaesium in wild animals

The IAEA provided advice on the uptake of radiocaesium by wild animals – primarily wild boar and Asian black bear. Prefecture experts are investigating the home range of wild boar and their feeding habits, as well as the seasonal variations in the radiocaesium levels in their flesh.

How did radionuclides transfer to wild animals ?



Radiocaesium concentration in muscles of wild animals



Wild boar

Large differences between individual animals: from under 10 Bq/kg to over 13,000 Bq/kg (fiscal year 2016)

(The limit for radiocaesium in food is 100 Bq/kg.)



Asian black bear

Significantly lower than in boar living in areas with similar radiocaesium levels.

According to data collected by Prefecture authorities, the radiocaesium in animals varies considerably:

- Wild boar captured in areas of greater radiocaesium levels in the environment showed higher radiocaesium concentrations in their body.
- Radiocaesium concentration in wild boar tends to be higher in the autumn and winter than in the summer.
- Research is under way by Prefecture authorities to understand the behaviour and eating habits of animals and how these affect radiocaesium concentrations.

For further information:

Radiation Monitoring Unit, Fukushima Prefecture
<http://www.pref.fukushima.lg.jp/sec/16025d/>

Fukushima Prefecture Radioactive measurement map
<http://fukushima-radioactivity.jp/>

Fukushima Revitalization Station
<http://www.pref.fukushima.lg.jp/site/portal>

Radioactive materials inspection of water and food (Japanese only)
<https://www.pref.fukushima.lg.jp/site/portal/list280.html>

Information of radioactive materials in forest (Japanese only)
<http://www.pref.fukushima.lg.jp/sec/36055a/shinrinhouyasei2.html>

Remediation and Decontamination

Fukushima Prefecture authorities assess that seven years after the accident at TEPCO's Fukushima Daiichi Nuclear Power Plant radiocaesium is the most important radioactive compound remaining in the environment due to its long half-life: its level of radioactivity takes 30 years to drop by half.

The IAEA provided advice to Fukushima Prefecture authorities on decontamination measures in order to quickly reduce radiation doses. Besides radioactive decay, according to Prefecture authorities, levels have declined thanks to:

- decontamination,
- radiocaesium removal from streets and roofs as a result of rain and wind,
- vertical migration of radiocaesium into deeper soil layers.

How are residential areas decontaminated by authorities in Japan?

Decontamination is undertaken based on national and prefectural guidelines.



Topsoil removal in residential gardens



Pavement cleaning with high-pressure water



Deposit removal from house gutters



Deposit removal from roadside ditches



Topsoil removal in schools



Deep plowing of farmland

Outline of decontamination activities:

- In Fukushima Prefecture, decontamination activities were conducted by the national and municipal governments.
- The national government completed its decontamination activities by March 2017.
- The prefectural government identified about 420,000 residential buildings, 12,000 public facilities, 19,000 km of roads and 31,000 ha of farmland in its decontamination plan.
- Forests of about 4,600 ha adjacent to residential buildings were also selected for decontamination by the Prefecture.
- Most of this work was completed by the end of October 2017.
- Decontamination activities generated a large volume of removed soil and other decontaminated waste. This has been managed by authorities at temporary storage sites. It will be delivered to interim storage facilities run by the national government, and disposed of outside Fukushima Prefecture within 30 years after the start of interim storage.

How effective has the decontamination been?

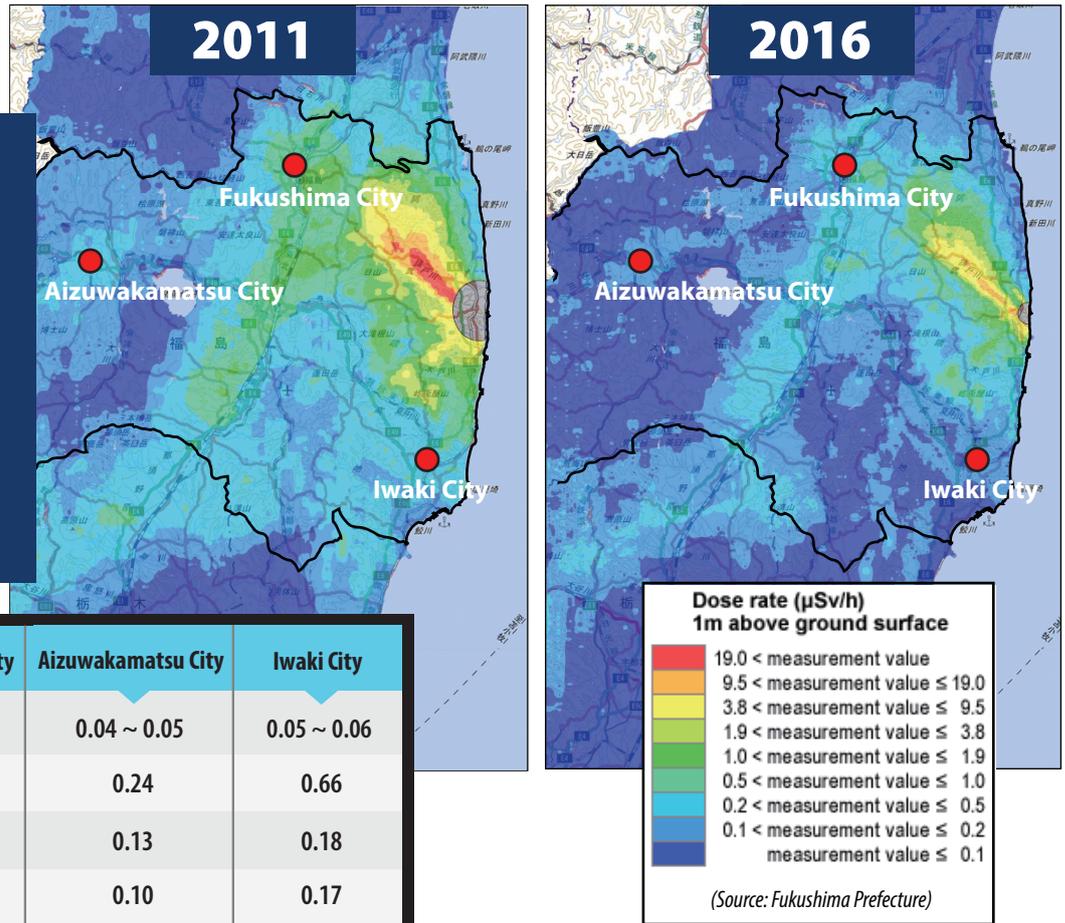
The effectiveness of decontamination depends on the surface and the method applied. According to Prefecture's data, air dose rates have in general been reduced by approximately 20-50%. Similar results have been obtained in locations outside Japan which were also affected by the deposition of radiocaesium.

Category	Number of measurements	Air dose reduction rate by decontamination %
Houses	82 757	36
Public facilities	32 311	45
Roads (km)	33 451	31
Farmland (ha)	20 147	29
Forests (ha)	12 697	21
Roads (km) / Farmland (ha) / Forests (ha)		

Data was published by the Ministry of the Environment concerning air dose rates before and after decontamination by the national government and prefectural government, from March 2012 to October 2013.

Current status of environmental recovery in Fukushima

Comparison of air dose rates in 2011 & 2016



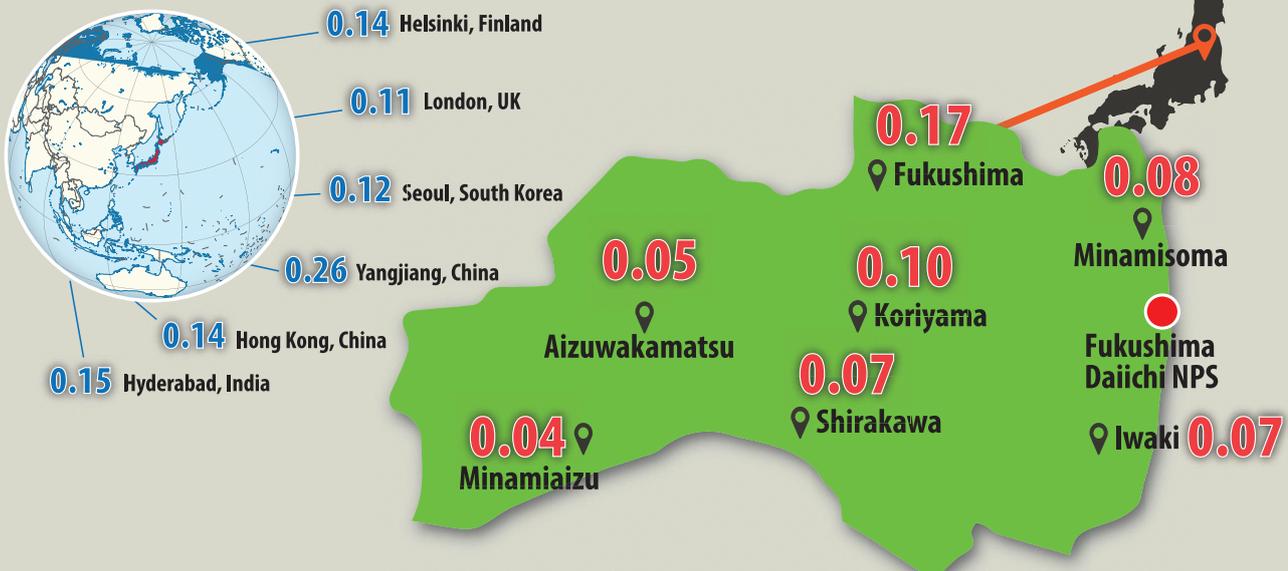
All data in μSv per hour	Fukushima City	Aizuwakamatsu City	Iwaki City
Before March, 2011	0.04	0.04 ~ 0.05	0.05 ~ 0.06
April, 2011	2.74	0.24	0.66
September, 2011	1.04	0.13	0.18
March, 2012	0.63	0.10	0.17
March, 2013	0.46	0.07	0.09
March, 2015	0.23	0.06	0.07
March, 2017	0.17	0.05	0.07

Source: Fukushima Prefecture Disaster Response Headquarters (provisional values)

The air dose rates in major cities of Fukushima Prefecture have decreased to similar levels as measured elsewhere in the world.

Comparison of air dose rates between selected cities in the world and Fukushima Prefecture

reference/source: UNSCEAR, Fukushima Prefecture As of March 1 - 2017



All data in μSv/h

Radiocaesium dynamics in rivers and lakes and the countermeasures applied

The IAEA provided advice on the investigation of radiocaesium dynamics in rivers and lakes and relevant countermeasures based on global experience.

Radiocaesium dynamics in rivers and lakes

Global knowledge, as communicated by the IAEA

- Radiocaesium is strongly bound to clay minerals in soil and moves very slowly in the environment.
- Dissolved radiocaesium in water is easily taken into the bodies of fish and other aquatic organisms.
- However, its concentration is very low because it is strongly bonded to sediments and suspended particles in water.
- Radiocaesium bound to suspended particles is deposited and/or transported to downstream areas during flood events.

The Prefecture's evaluation of the situation in Fukushima

- Radiocaesium concentration in suspended particles has been decreasing.
- Dissolved radiocaesium concentration in rivers is significantly below the national standard for drinking water (10 Bq/L).

Countermeasures in rivers and lakes by Prefecture authorities based on global practice

- Decontamination of riversides and irrigation ponds in the residential areas.
- Prevention of radiocaesium outflow from irrigation ponds by using sediment removal and silt fences.
- Restriction of fishing and fish consumption.



Irrigation control with silt fence



Sediment removal from irrigation

Demonstration of decontamination at riversides

A decontamination test was performed by Prefecture authorities at a riverside, used as a route to school and for outdoor education. The impact of floods on air dose rates after decontamination, investigated following consultation with the IAEA, led to the analysis by Prefecture authorities of the distribution pattern of radiocaesium.

The site

- The river is located about 55 km to the northwest from TEPCO's Fukushima Daiichi Nuclear Power Plant. This river is adjacent to an elementary school.
- The average air dose rate before the demonstration was 0.70 $\mu\text{Sv/h}$ (as of Aug. 2014, Prefecture data).
- At riversides, radiocaesium is often distributed deeper due to sediment deposition. Thus, understanding the distribution pattern is important for decontamination activities.

Decontamination methods:

- weeding,
- removal of soil and sediment in floodplain,
- vegetation and soil removal from banks



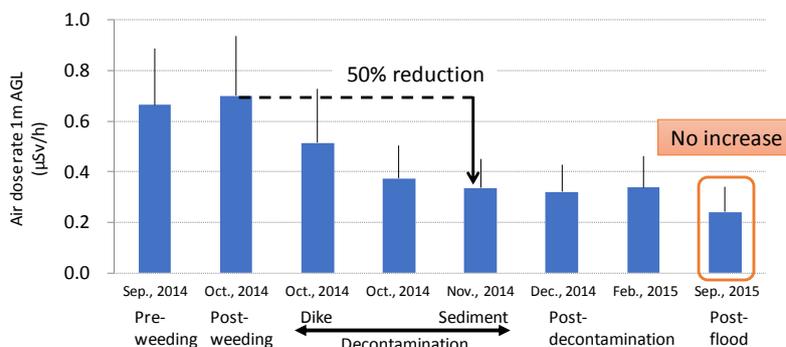
Removal of soil and sediment in floodplain



Views of river area before and after demonstration

Air dose rate was reduced by 50%.

Did flooding have an influence on the effectiveness of countermeasures implemented in rivers?



Air dose rates at one meter above ground before, during, and after the decontamination at the river (Source: Fukushima Prefecture authorities)

Subsequent to decontamination, a large-scale flood event occurred, and a lot of sediments were deposited and eroded. However, according to Prefecture measurements, the air dose rate did not increase. A similar result was observed in parks along other rivers.

Management of radioactive waste from remediation activities



Since the accident at TEPCO's Fukushima Daiichi Nuclear Power Plant, Fukushima Prefecture authorities have performed a significant amount of work on remediation and the management of the resulting radioactive waste. The IAEA has supported this work with expert advice, based on best practices from around the world.

Goals of radioactive waste management

- reduce radiological activity,
- reduce volume of waste, and
- place waste in interim storage, and ultimately disposal.

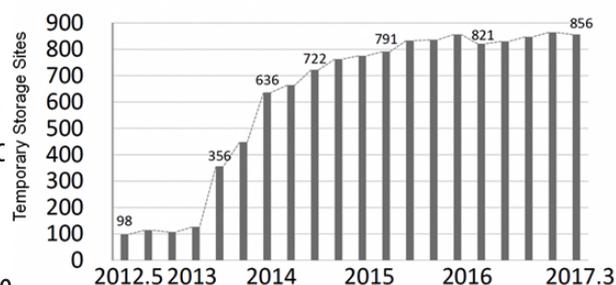
The pyramid of radioactive waste management



Management of radioactive waste generated from remediation activity in Fukushima Prefecture

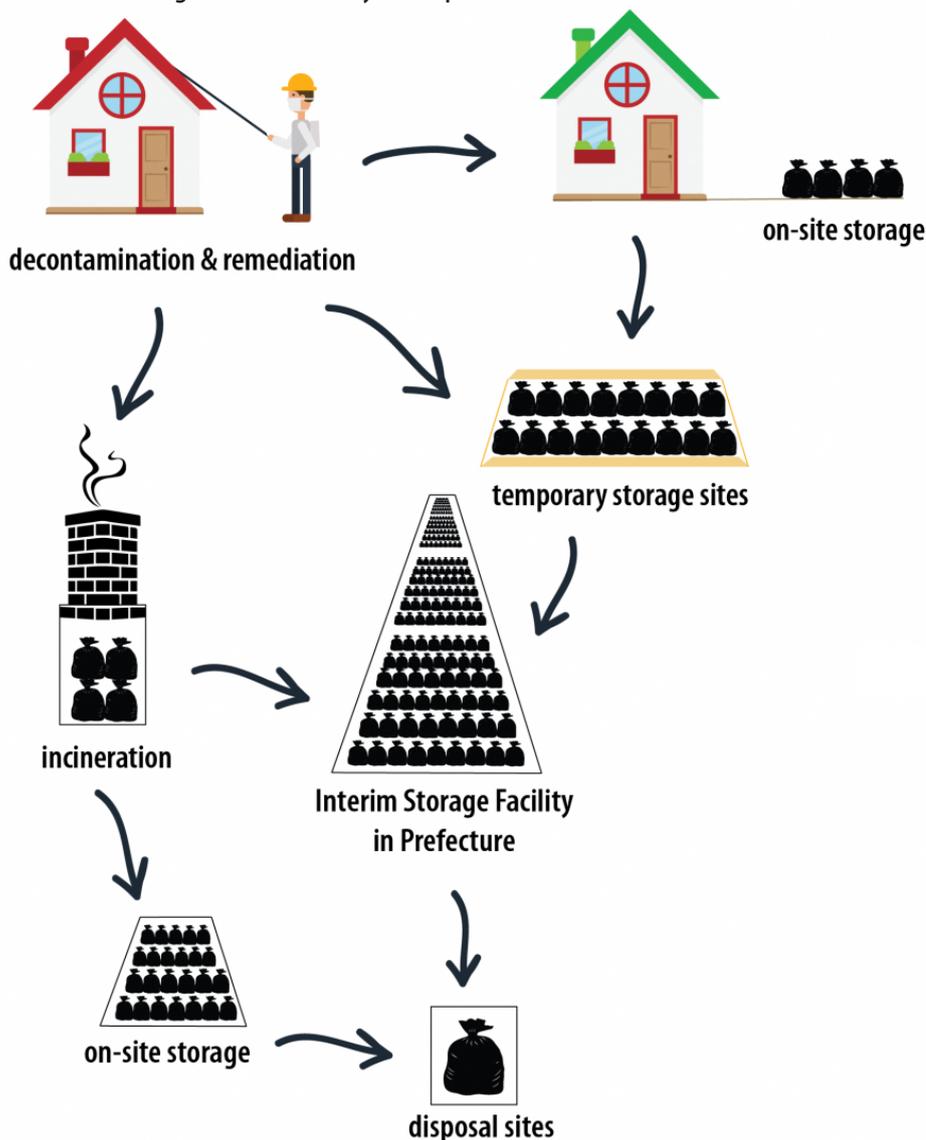
In order to quickly decrease the exposure of the public to radiation, Fukushima Prefecture authorities undertook decontamination and remediation activities in the immediate aftermath of the accident. According to Prefecture records, this activity has generated 6 million m³ of radioactive waste, as of September, 2017. To protect the public and the environment, the authorities set up temporary storage sites throughout the Prefecture to safely keep the waste until the Interim Storage Facility is available, and while its radioactivity is reduced due mainly to natural decay.

Number of TSSs in municipalities



(Source: Fukushima Prefecture authorities)

Waste in temporary storage sites will eventually be safely retrieved and transported to the Interim Storage Facility within the Prefecture, and ultimately to a disposal facility outside the prefecture. Some of the radioactive waste does not follow this process but is incinerated, which decreases its volume. The radioactive waste product of the incineration will also be moved to storage and ultimately to disposal.

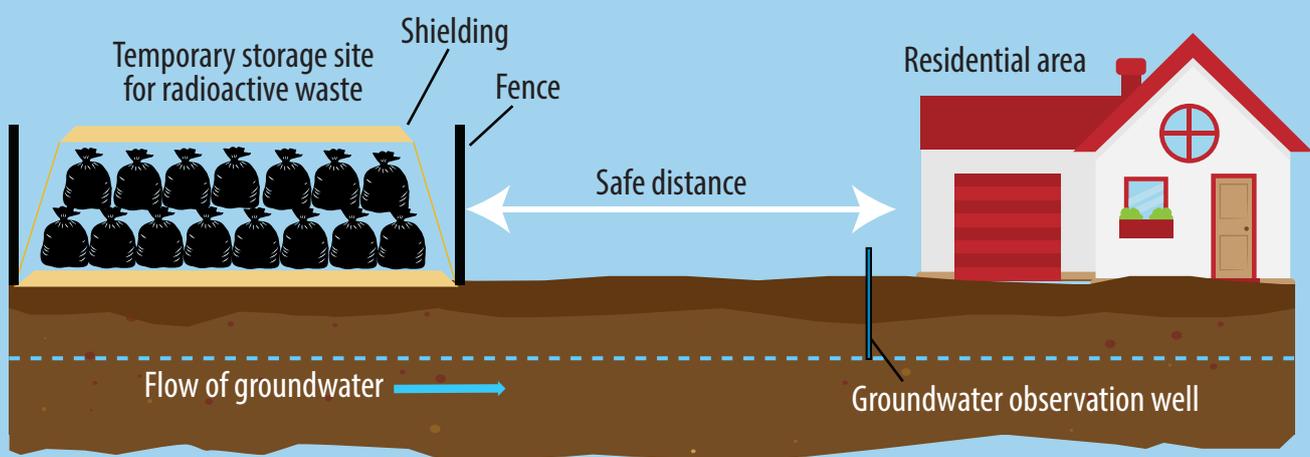


Temporary Storage Sites (TSSs)

Prefecture authorities have developed, based on advice from the IAEA, a guidance document on the establishment and operation of TSSs, taking stock of the experience gained with the development and operation of TSSs in the immediate aftermath of the accident. The guidance document identifies the main issues affecting TSSs, good practices implemented and a comparison of the different strategies for the development of TSSs in different municipalities.

Prefecture authorities have set up and managed TSSs based on laws and relevant government guidelines. To ensure the safe and sustainable handling of this radioactive waste, Prefecture authorities manage it in line with IAEA Safety Standards, developed based on experience gathered in radioactive waste management worldwide. The IAEA's assistance to Fukushima Prefecture included the development of technical guidelines for temporary storage sites and related advice on the safety of these sites.

The IAEA's support included the evaluation of the safety of TSSs and on-site storage for normal situation, as well as under special and extreme situations including fire, heavy rain and earthquake.



Typical layout for a TSS.

Safety of storage sites

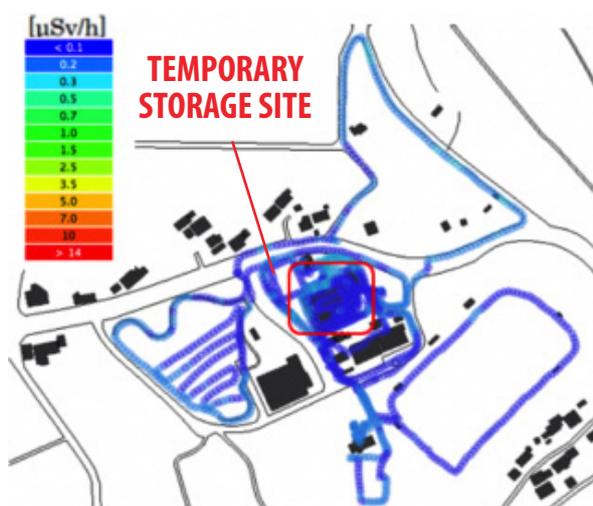
TSSs were established by the Prefecture with the intention that waste would be stored in these facilities for three years before being transferred to the Interim Storage Facility. The Prefecture had to subsequently assess the consequences on safety of longer storage periods, with respect to the ageing of materials, evolution of site conditions and weather conditions.

The IAEA advised Fukushima Prefecture authorities on the development and implementation of the safety assessment of storage sites and provided necessary tools for these assessments. Fukushima Prefecture authorities have conducted the safety assessments of TSSs and on-site storage locations considering different parameters, including the amount of waste, the concentration of radioactive caesium, the shielding situation and the distance from storage sites to buildings. They have developed the assessment for normal situations, as well as for potential accidental situations such as fire, heavy rain and earthquake.

In the future, Prefecture authorities will secure the safety of storage sites in consideration of the following:

- ageing, strength, degradation of materials used in TSSs,
- retrievability of bags from TSSs for transport to interim storage facility, and
- transport of bags from TSSs and on-site storage to the interim storage facility.

Data by the Prefecture show that any radiological impact on nearby areas is limited and without specific consequences to the public and the environment.



Radiation monitoring near a temporary storage site in the Nakadori region as an example of using walking survey.

Prefecture authorities monitor radiation regularly in the vicinity of temporary storage sites.

These measurements indicate that the dose rate near temporary storage sites is equal to or less than the dose in nearby areas, showing that proximity to the temporary storage sites does not increase dose rates.