

# **FINAL SUMMARY REPORT (2013–2022)**

## **Executive Summary**

### **Cooperation between the International Atomic Energy Agency and Fukushima Prefecture**

#### **Radiation Monitoring and Remediation**



## 1. OBJECTIVES AND SCOPE OF THE COOPERATION

The 11 March 2011 earthquake off the Pacific coast of Tohoku and the subsequent tsunami and accident at Tokyo Electric Power Company's Fukushima Daiichi Nuclear Power Plant (hereinafter referred to as 'Fukushima Daiichi accident') resulted in radioactive contamination deposited in various areas of Japan, including Fukushima Prefecture (hereinafter referred to as 'the Prefecture').

In December 2012 the IAEA and the Prefecture signed an agreement titled Practical Arrangements between Fukushima Prefecture and the International Atomic Energy Agency on Cooperation in the Area of Radiation Monitoring and Remediation (hereinafter referred to as 'Practical Arrangements'). The objective of the Practical Arrangements is to define the framework for cooperation between the Prefecture and the IAEA and for the IAEA to provide broad and extensive assistance to the Prefecture in areas related to radiation monitoring and remediation in order to ensure ongoing protection of people and the environment from ionizing radiation resulting from the 2011 Fukushima Daiichi accident. The Practical Arrangements were modified and extended in April/May 2016 and again in December 2017 to consider other areas of work and activities in which cooperation may be pursued.

Cooperation under the Practical Arrangements is designed to complement existing Japanese activities and to provide immediate assistance and support which will be of direct benefit to residents of the Prefecture as well as visitors to the Prefecture.

This document is an Executive Summary of the 'Final Summary Report', which summarizes the status and progress made in the activities conducted under the Practical Arrangements from 2013 through the end of 2022. The Final Summary report' supersedes the Mid Term Summary Report, which covered progress from 2013 through Spring 2020.

Over the period that the Practical Arrangements have been in place, the most important exposure pathway for people is external radiation emitted by radiocaesium ( $^{137}\text{Cs}$  and  $^{134}\text{Cs}$ ), which is present in both the terrestrial and aquatic ecosystems. Radiocaesium levels in the environment, and the associated doses to people will continue to decline without human intervention as a result of radioactive decay of radiocaesium, the removal of radiocaesium by weathering from surfaces and migration of radiocaesium into soil and sediments. In addition, radiocaesium levels in the terrestrial and aquatic ecosystems, and the associated doses to people, have declined due to remediation activities undertaken by the Prefecture. Since the Fukushima Daiichi accident, the Prefecture has performed significant remediation activities and has safely been safely managing the resulting radioactive waste.

The activities that are part of the Practical Arrangements under which IAEA has provided assistance to the Prefecture can be summarized as:

- Research and studies on radiation monitoring in terrestrial and aquatic environments, including application of environmental mapping technology by using unmanned aerial vehicles and long term monitoring of radioactive materials;
- Research and studies on remediation of terrestrial and aquatic environments in the Prefecture;
- Research and studies on the management of radioactive waste from remediation.

Assistance on information dissemination interlinks with, and is in line with, all of the activities that are part of the Practical Arrangements. To strengthen efforts in information dissemination, the IAEA and the Prefecture have organized several activities which were considered examples of best practices in informing the public about the effects of radiation from other countries.

In January 2023, a workshop was held in the Prefecture to present a summary of the activities and the key outcomes of the cooperation during 2013–2022 under the Practical Arrangements. A brief summary of the key outcomes is given in an Annex to this report.

## 2. MONITORING OF RADIOACTIVE MATERIAL IN THE ENVIRONMENT ASSOCIATED COUNTERMEASURES

As a consequence of the Fukushima Daiichi accident, significant amounts of radioactive material were deposited on the territory of the Prefecture, especially in the area to the northwest of the Fukushima Daiichi nuclear power plant. Long term monitoring programmes of radiocaesium in terrestrial and aquatic ecosystems have been established, including the distribution of radiocaesium within these environments and measurement of radiocaesium in wild foods, and associated doses to people have been assessed.

Decisions relating to remediation activities are based on an assessment of current and potential future doses without intervention as well as the decreased doses that can be achieved through remedial actions. It is therefore helpful to make predictions regarding changes over time in air dose rates and doses to people with and without intervention.

### 2.1. FORESTS

Once deposited within forests, radiocaesium is retained and recycled within the forest ecosystem — though in gradually decreasing amounts due to natural decay.

Work on monitoring of radiocaesium in forests under the Practical Arrangements focused on providing assistance to the Prefecture in characterizing the distribution of radiocaesium, establishing long term radiation monitoring programmes, reviewing the effectiveness of countermeasures, providing advice on the implementation of the Satoyama Rehabilitation Model Project addressing specific countermeasures for reducing radiation exposures of forest workers, assessing the radiological effects of forest fires and assessing the implications of radiocaesium transfer to forest mushrooms, game animals, freshwater fish, wild birds and vegetables and bamboo shoots. The management of wild foods in the Prefecture was also considered.

### OUTCOMES

An extensive work program has been undertaken to better understand the behaviour of radiocaesium in forests. The key conclusions to date are:

- Radionuclides deposited in the forests of the Prefecture are effectively retained within the ecosystem and the likelihood of transfer of radiocaesium to agricultural land appears to be low.
- Forest maintenance has helped to prevent erosion and soil loss and is also very effective at retaining radiocaesium within the forests.
- A long term monitoring programme in forests has been established to track the rate of reduction of the air dose rate. Compared with August 2011, the air dose rate overall has decreased by about 80% at the end of 2022. These results are broadly in line with the reduction of air dose rate due to radioactive decay of radiocaesium. Figure 1 shows the average of measured air dose rates at 362 monitoring points in forests within the Prefecture and estimated air dose rates based on the radioactive decay of radiocaesium up to the end of 2022.

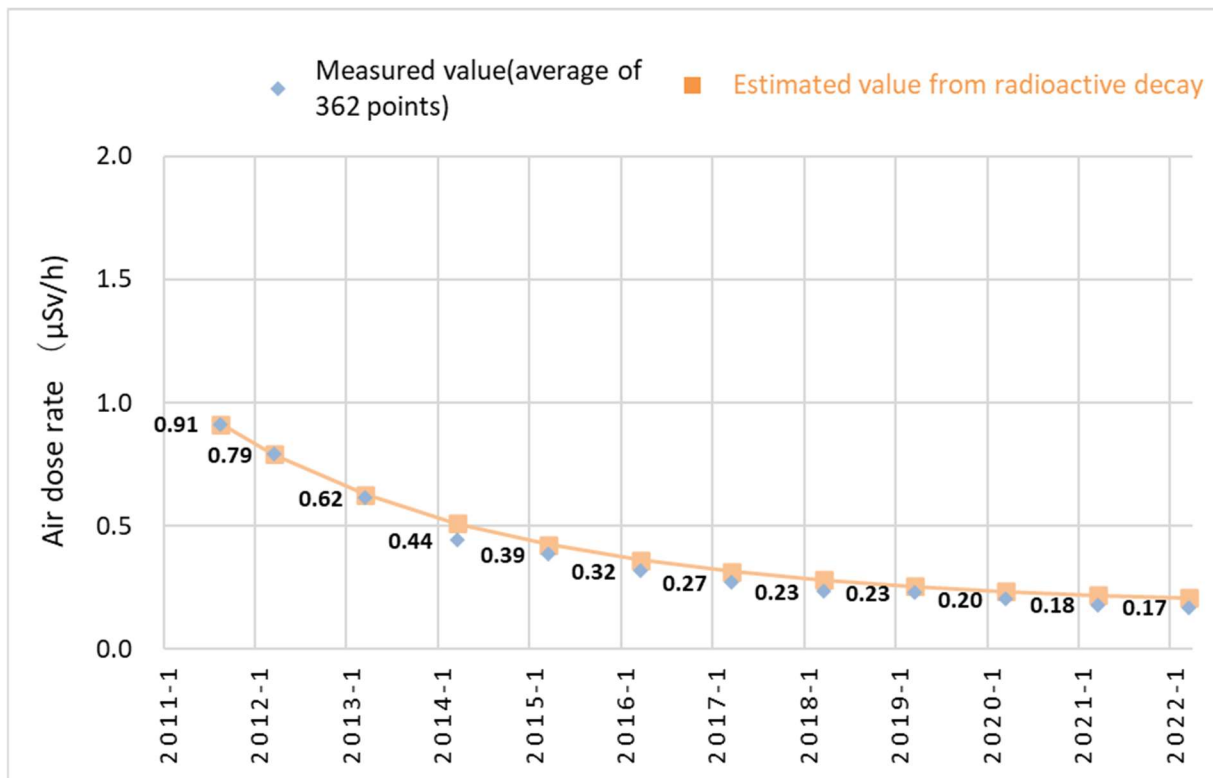


FIG. 1: Measured air dose rates and estimated air dose rates based on radioactive decay of radiocaesium at 362 monitoring points in forests within the Prefecture up to 2022 (Image: Fukushima Prefecture).

- The presence of clay minerals in the underlying forest soils chemically binds the radiocaesium and limits its transfer to vegetation. The result is that, for the same amount of deposition, the activity concentrations of radiocaesium in plants and animals in the forests in the Prefecture are considerably lower than those observed in European forests following the Chernobyl accident.
- Based on experience with radiation monitoring in areas affected by the Chernobyl accident, radiation monitoring in forests may be necessary for many more years and monitoring procedures for measuring air dose rates and the radioactive content of trees may need to be adjusted to account for changing conditions such as the movement of radiocaesium in the environment and the accumulation of radiocaesium in waterlogged areas where the uptake by vegetation is expected to be higher.
- Since 2012, most of the radiocaesium initially deposited in forests has been transferred from the trees to the soil and litter layers, as shown in Figure 2. The feasibility of removing large amounts of soil in order to reduce the air dose rate is not practical; it is also expensive, produces additional waste material that must be managed and has the potential to reduce the biological and economic productivity of the forest.
- Covering the forest floor with soil or wood chips that has no radiocaesium has proven to be an effective means of reducing air dose rates. A number of questions regarding the long term effectiveness of these measures remain. In the meantime, the Prefecture authorities have already concluded that, because of the associated high costs, the

application of such measures may be justified only over limited areas with high air dose rates, particularly if such areas are close to inhabited areas.



FIG. 2: Change in distribution of radiocaesium in the Prefecture's coniferous forests and deciduous forests from 2011 to 2016 (Adapted from cooperation with the Ministry of Agriculture, Forestry and Fisheries, and the Fukushima Prefectural Forestry Research Centre).

- To date there appears to be no need to restrict the production and use of the timber harvested from forests. However, monitoring of timber needs to continue, especially as logging commences in areas where there are higher concentrations of radiocaesium in the timber.
- Measures have been implemented to restrict the radiation exposure of forest workers; these include the use of harvesting machines and limitations on the number of hours each worker can work in the forest. Overall, a conservative approach has been taken by the Prefecture in order to reduce the radiation doses of these individuals.
- Studies carried out on forest fires in the Prefecture have not identified a significant radiological impact resulting from these events.

- The implementation of the Satoyama Rehabilitation Model Project has been presented and discussed with the IAEA and international experts and a visit to 2 of the sites was arranged in February 2020. It was noted that the attention to detail and the availability of all the information to undertake the remediation was of a high standard.
- There are many similarities between the results of the monitoring programmes for wild foods. The measurements in forest mushrooms, freshwater fish, wild vegetables and wild animals all show high activity concentrations of radiocaesium, many outlier values and a very slow reduction in levels. Activity concentrations in many of these foods exceed the standard limit of 100 Bq/kg for radiocaesium that was established for general foods sold commercially in April 2012. Ongoing attention needs to be given to providing more and better information to those who collect wild foods for their own consumption, so that they can make informed choices on the radiation dose they are prepared to accept, as there are no proven and cost effective measures that can be taken to reduce the concentrations of radiocaesium.
- As time progresses, activity concentrations in wild foods continue to decrease and monitoring programmes will identify more and more activity concentrations that are ‘less than’ or ‘not detectable’ by measurement techniques. These results can be an important communication tool to show that the situation is improving, even if restrictions remain in place. A standard approach to reporting these low measurements of radiocaesium in food needs to be agreed and applied uniformly across all monitoring programmes.
- Because future reductions in air dose rates will be dominated by the radioactive decay of  $^{137}\text{Cs}$ , which has a radioactive half-life of about 30 years, the annual reductions will be low and, as such, the situation can be regarded as being more stable. In such circumstances, it may be justified, from a technical prospective, to reduce the frequency of monitoring without the loss of valuable information.

## 2.2. TERRESTRIAL AND AQUATIC ENVIRONMENTS

Work on monitoring and remediation of radiocaesium in terrestrial and aquatic environments of under the Practical Arrangements has focused on providing assistance to the Prefecture on the following topics:

- Behaviour of radiocaesium in terrestrial and aquatic ecosystems, (see Section 2.1 for forest environments), in the areas of the Prefecture affected by the accident;
- Effectiveness of remediation and decontamination measures in aquatic systems;
- Analysis of monitoring results to identify temporal trends in radiocaesium concentrations in environmental media (soil, water, sediments), radioactive particles and of air dose rate;
- Review of experience gained from remediation activities in order to provide input for the selection of appropriate and technically feasible remedial actions;
- Application of models to simulate radiocaesium flux in aquatic systems;
- Effectiveness of decontamination measures implemented in residential areas;
- Impacts of extreme weather events, such as typhoons, on radiocaesium dynamics in freshwater environments.



The behaviour of radiocaesium in ecosystems has been studied worldwide for the last several decades. In general, international experience has shown that in the terrestrial environment, radiocaesium is strongly bound by mineral soil components, which results in slow movement in soil and a low uptake by plants. In freshwater ecosystems, radiocaesium is in general strongly bound to suspended sediments, which deposit on the bottom of bodies of water and which causes a rapid decline of dissolved radiocaesium levels in the water column. Sorption of radiocaesium to suspended sediments, therefore, plays a key role in its environmental behaviour.

In addition to the final summary report, an annex to that report has been prepared, in collaboration with the Prefecture scientists, that summarizes the main findings of the project covering ‘Terrestrial and Aquatic Environments’. The purpose of this report is: to provide a comprehensive and concise summary of the findings; to highlight the key results of the work conducted in the Prefecture; and to provide a comparison of the results obtained with the experience gained in the investigation and management of environmental contamination outside Japan.

## OUTCOMES

- Since 2011, intensive remediation and decontamination work has been carried out by the Prefecture in homes, public facilities, roads, agricultural land and forests close to inhabited areas. Depending on the type of area, the Prefecture observed that air dose rates were reduced by 20–50%, similar to results achieved by remediation in areas affected by the Chernobyl accident. In addition, the Prefecture has initiated projects on the remediation and decontamination of freshwater bodies to demonstrate the effectiveness of such countermeasures.
- In the freshwater bodies of the Prefecture, dissolved radiocaesium levels in water fell to levels close to or below the detection limit of 0.05 Bq/L by 2018, a level that is well below the water quality objective for safe drinking water in Japan (10 Bq/L). This can be explained by the strong sorption of caesium by sediments in riverbeds, in which much higher radiocaesium levels are observed. There has been a clear corresponding decline in the concentration of radiocaesium in suspended sediments (Figure 3).
- The reduction of the radiocaesium levels in surface water catchments is mainly caused by radioactive decay. Runoff of radiocaesium causes further small reductions, for example up to a few percent from the catchments of the Abukuma and the Kuchibuto tributaries.
- Measurements of radiocaesium in reservoirs reveal that the amount of suspended radiocaesium in the outflow is much less than in the inflow. This indicates that reservoirs act as a ‘sediment trap’ for radiocaesium.
- The physicochemical conditions in surface waters can also affect the transport and dynamics of particles which bind radiocaesium. Such conditions might explain the generally stronger radiocaesium sorption onto soils and sediments that was measured under the conditions in the Prefecture than in the vicinity of the Chernobyl Power Plant following the 1986 accident.
- The continuation of routine monitoring of radiocaesium in river catchments of the Prefecture is important to assess its temporal and spatial changes. This includes monitoring within a river drainage basin, where water collects, as well as the tributaries that carry radiocaesium from upstream areas of the basin into the larger rivers downstream. In conducting such monitoring to assess radiocaesium dynamics through

time and space, it is recognised that it is important to apply standardized sample collection and storage procedures, and where relevant, standardized expression of monitoring results, to facilitate intercomparison between aquatic systems, which allows the results to be compared with the international literature.

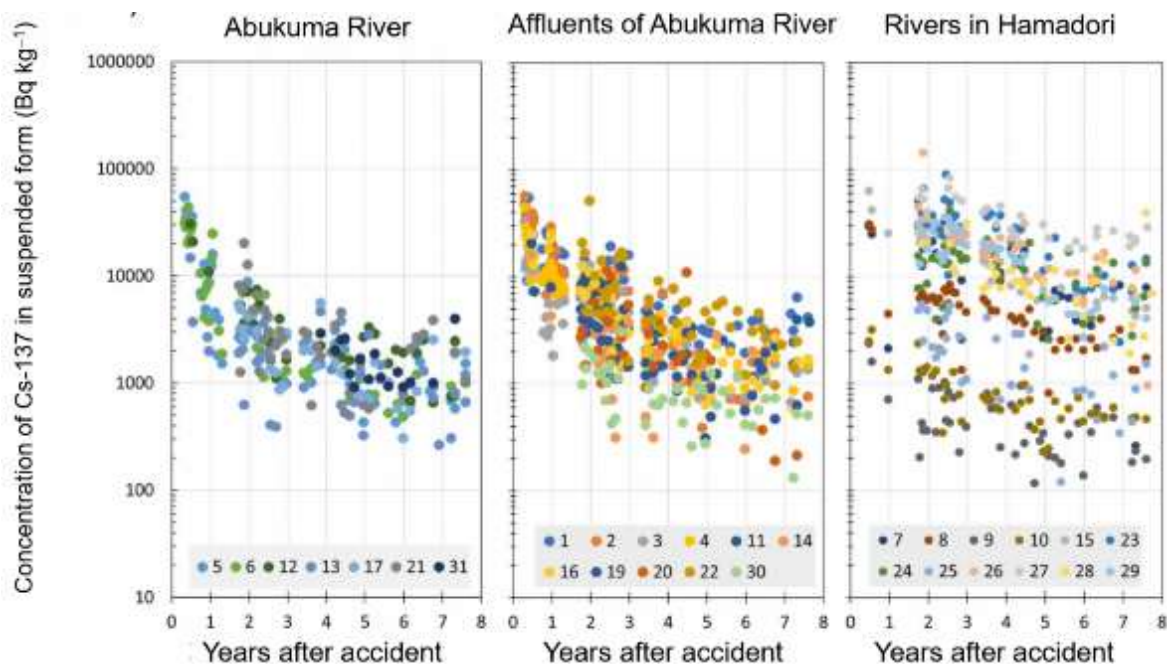


FIG. 3: Decline of  $^{137}\text{Cs}$  in suspended matter of rivers in the Prefecture, 2011–2019 (Image: Fukushima Prefecture).

- The density of plankton in freshwater bodies studied in the Prefecture was very low and the total radiocaesium activities for both phytoplankton and zooplankton comprised only a small fraction of a percent of the radiocaesium present in the water bodies studied.
- To facilitate the interpretation of monitoring results, models were applied by the Prefecture to simulate the transport of radiocaesium from the catchment area through the river system to the Pacific Ocean. International experiences from using different types of model for predicting radiocaesium dynamics in aquatic ecosystems have been shared with the Prefecture experts. These types of model are also very useful in selecting appropriate remedial options and assessing the effectiveness of remediation measures being applied in rivers and can also enable the assessment of the effect of recontamination of rivers.
- Monitoring data collected following Typhoon No 19 in 2019 indicate that air dose rates on riverbanks impacted by the typhoon have not increased, remaining similar or showing some reduction, compared to pre-typhoon values (see Figure 4).

### 2.3. APPLICATION OF ENVIRONMENTAL MAPPING TECHNOLOGY USING UNMANNED AERIAL VEHICLES

The Prefecture identified a need to conduct radiation monitoring in areas that are not accessible by other characterization methods, such as carborne surveys, or where high radiation levels might exist. Consequently, the Prefecture developed a methodology for the use of Unmanned

Aerial Vehicles (UAVs) in areas that are inaccessible on foot or where high radiation levels might exist. Significant assistance was provided to the Prefecture in the two consecutive cooperative projects “Rapid Environmental Mapping with UAV and “Rapid Environmental Mapping with UAV Phase II: Operational Support”, both administered by the IAEA Department of Nuclear Sciences and Applications.

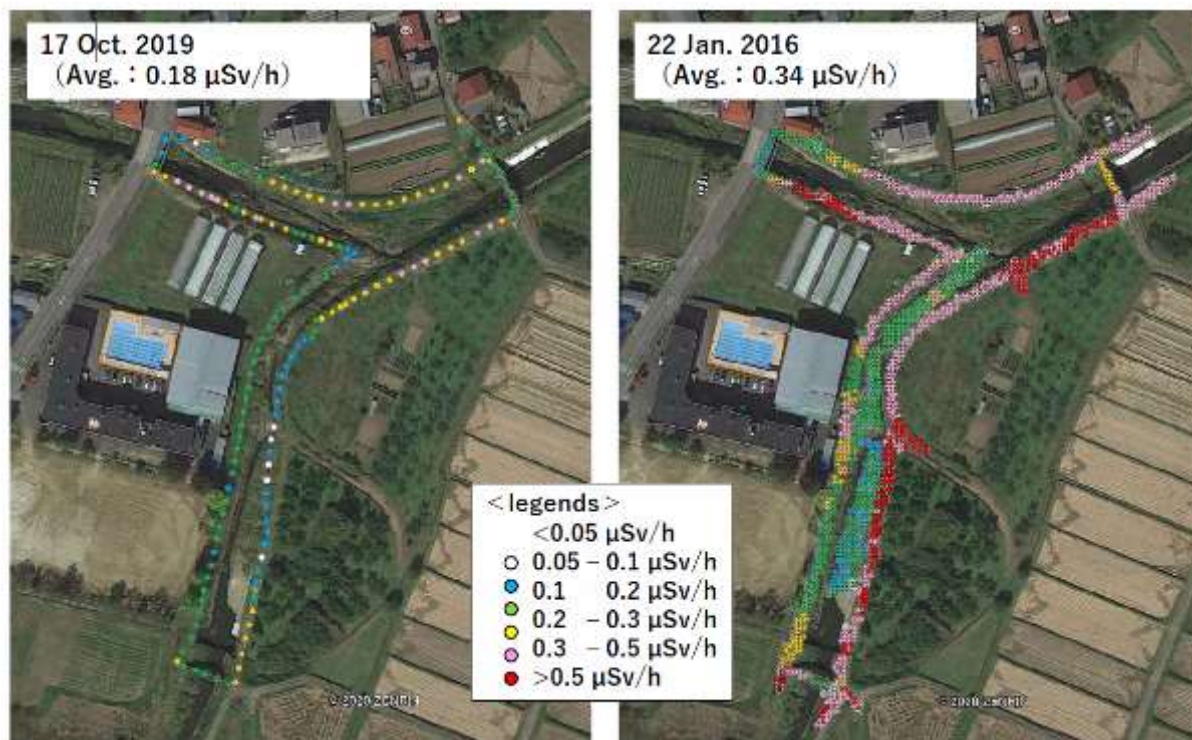


FIG. 4: Maps of air dose rates at 1 m height above the ground before and after Typhoon No. 91 (Image: Fukushima Prefecture).

## OUTCOMES

- Assistance was provided to the Prefecture on the development of a methodology for the use of instrumented UAVs by the IAEA Department of Nuclear Sciences and Applications through two consecutive cooperative projects. This included the provision of a complete UAV based instrumentation system capable of making radiation measurements together with the post-measurement analysis and interpretation methodology. These projects also included training of the Prefecture staff in the use of UAV, its instrumentation and related software for data taking and analysis.
- The first part (validation) of the project consisted of in situ calibration of equipment and validation of measurement procedures. Both experimental data from reference NaI surveys, combined with Monte Carlo modelling, were used to establish altitude dependence of the UAV based measurements, define correction factors between UAV and NaI results and perform extensive sensitivity analysis. In most of the cases UAV based data were also compared to equivalent backpack surveys, obtained using CsI spectrometers.
- In the second part (application), trial measurements were carried out. Figure 5 illustrates the radiological mapping carried out at one of the temporary storage sites located in the

Prefecture, where a combination of backpack (loaded with CsI spectrometer) and UAV based measurements were performed. The established methodology has a great potential to be expanded and applied in radiological mapping relevant to contaminated sites as a result of nuclear accidents, mining activities as well as part of decommissioning and remediation projects.

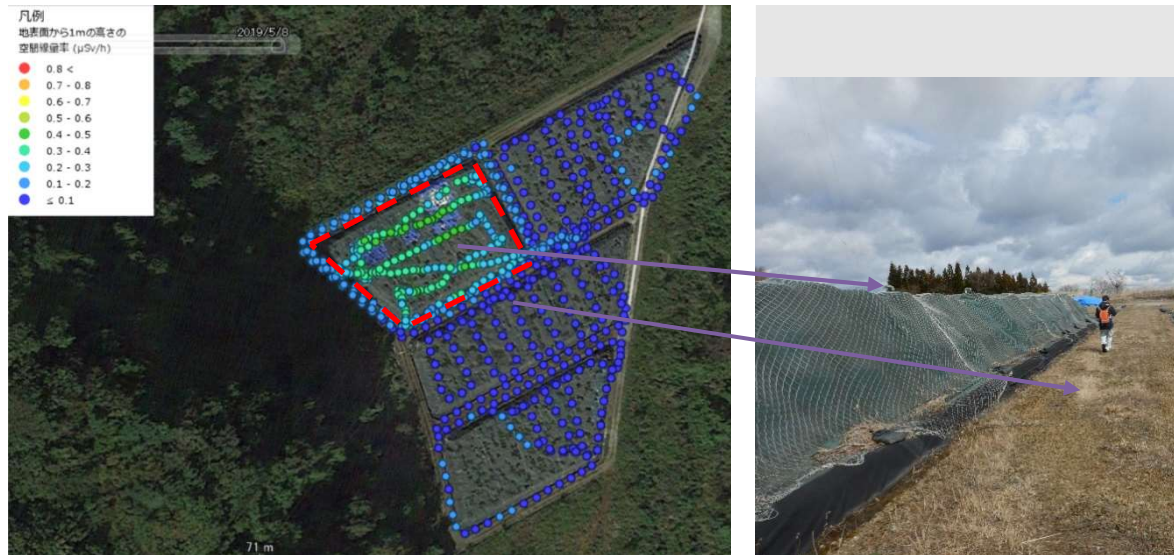


FIG. 5: Combination of UAV (marked within red rectangle) and backpack based radiological mapping, carried out at one of the temporary storage sites of the Fukushima Prefecture. Image: Fukushima Prefecture.

### 3. MANAGEMENT OF WASTE FROM REMEDIATION ACTIVITIES

Since the Fukushima Daiichi accident, the Prefecture has performed a significant amount of remediation activities and has been safely managing the resulting radioactive waste. According to the plan formulated by the Japanese MOE (Ministry of the Environment), contaminated soil and waste generated from remediation in the Prefecture are to be collected and stored at, or near, the sites undergoing remediation at temporary storage sites (TSS). Afterwards, the waste will be placed in an ISF (Interim Storage Facility) near the site of the Fukushima Daiichi Nuclear Power Plant under the responsibility of the Japanese government. After interim storage of the waste in the ISF for up to 30 years, the waste will be disposed of outside the Prefecture.

Three main types of TSS have been established in municipalities in the Prefecture — above ground storage, semi-underground storage, and underground storage (Figure 6).

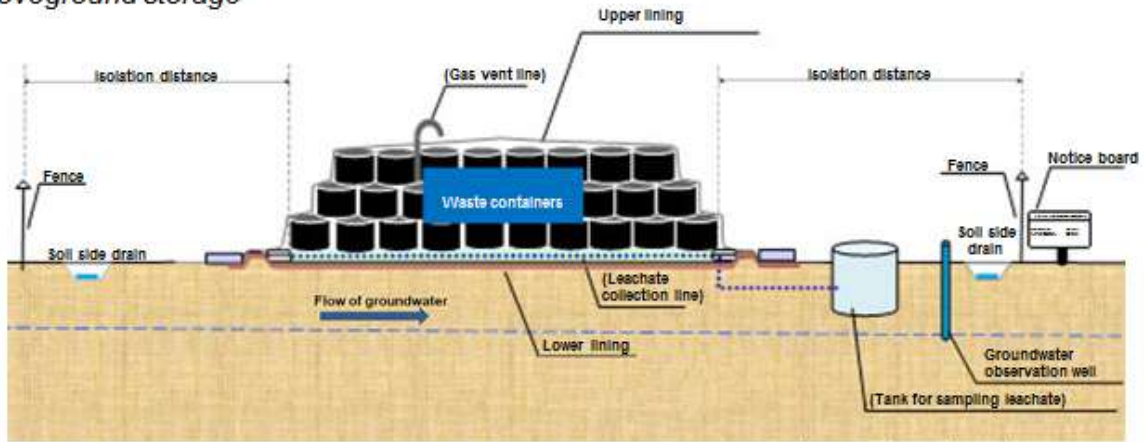
Radioactive waste from remediation activities requires timely, safe and sustainable management, in line with the applicable IAEA, National and Local Safety Standards. When activities under the Practical Arrangements commenced in 2013, the Prefecture was faced with a shortage of TSS in which to store waste from remediation activities and also needed to demonstrate the safety of the TSS. The TSS were established with the intention that waste would be stored in these facilities for only three years before being transferred to the ISF. However, it has become necessary to store waste in TSS for longer, pending transfer to the ISF.

The activities concerning the management of waste from remediation activities under the Practical Arrangements consequently focused initially on providing assistance to the Prefecture in finalizing technical guidelines for the establishment of TSS and assisting the Prefecture to assess and demonstrate the safety of the TSS. The provision of assistance shifted gradually to focus more on the safety of the longer term operation of the TSS, on strategies for the retrieval of waste from the TSS, and on the remediation of former TSS. A key aspect of the assistance provided by IAEA has been to facilitate the sharing of expertise and experiences of relevant radioactive waste management practices from outside Japan.

#### OUTCOMES

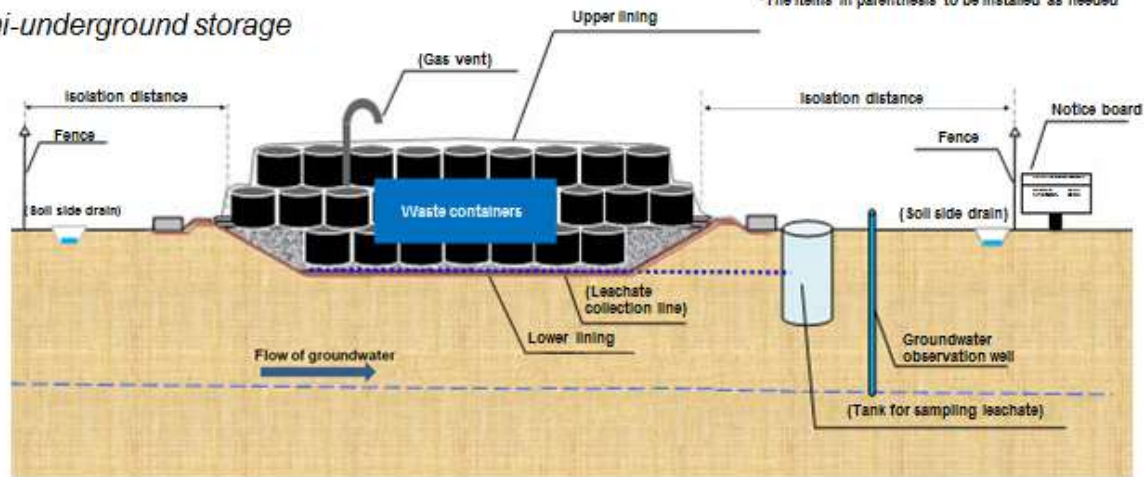
- Safety assessment was carried out by the Prefecture using the IAEA methodology for assessing the safety of predisposal radioactive waste management facilities incorporated within the IAEA's SAFRAN software. During the use of the software, a part of the SAFRAN database was tailored to fit the specific conditions of the TSS in the Prefecture.
- The safety assessment for the TSS in the Prefecture was developed in a gradual and iterative way through the application of SAFRAN initially to a model site, then to a site in the Prefecture and eventually to nine selected TSS. The safety assessment was an important step in establishing a safe approach for the storage of the large amount of radioactive waste accumulated from remediation activities.
- During the development of the safety assessment for TSS, several technical issues were identified and their impact on safety evaluated (e.g. localised water accumulation in the temporary storage facilities, flooding, fires, degradation of waste bags, transport of the waste bags and collapse of waste stacks). On the basis of specific evaluations, technical measures to remediate and prevent the problems were identified and their effectiveness estimated.

*Aboveground storage*



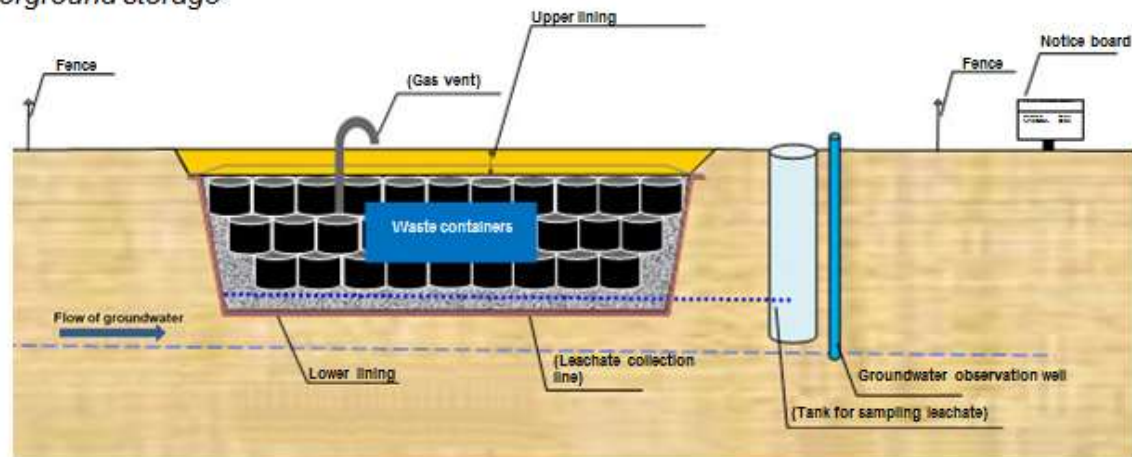
\*The items in parenthesis to be installed as needed

*Semi-underground storage*



\*The items in parenthesis to be installed as needed

*Underground storage*



\*items in parenthesis to be installed as needed

FIG. 6: Conceptual diagrams of three types of TSS (Image adapted from Technical Guidelines for temporary storage sites, Fukushima Prefecture).

- The systematic safety assessment process followed using the SAFRAN software included assessment of all credible hazards and technical issues and provided confidence that no significant issues were omitted or disregarded. It also provided a framework for explaining why certain systems and processes are considered safe and why certain improvements of safety and countermeasures are necessary.
- The results gained from the safety assessments for TSS in the Prefecture clearly indicated that as long as appropriate operating procedures were followed and appropriate measures are put in place, all radiation doses are expected to be well below the relevant dose limits.
- Discussions have been held between the IAEA international experts and Prefecture experts concerning waste retrieval strategies for waste stored in TSS, taking account of the ageing of waste bags.
- The IAEA provided assistance to the Prefecture on the development of a generic safety assessment methodology that could be applied to specific sites of former TSS from which the waste had been removed.

#### 4. INFORMATION DISSEMINATION TO THE PUBLIC

As part of the Practical Arrangements, the IAEA has provided assistance to the Prefecture on the use of radiation monitoring data to develop maps for the public. The IAEA has also provided assistance more generally on strengthening efforts in information dissemination to provide information to the public in the Prefecture, in Japan and abroad in a timely and understandable manner. The advice provided is based on global experience in dealing with accidental releases of radiation to the environment as well as in communication good practices.

To strengthen efforts in information dissemination, the IAEA and the Prefecture have organized several activities under the scope of each topic under the Practical Arrangements.

Prior to the start of the activities under the Practical Arrangements in 2013, the Prefecture maintained a website that made radiation monitoring data available to the public. The website provided detailed information on air dose rate measurements and measurements of radioactivity concentrations in material from several different sources.

The Prefecture wished to present the information in a simpler manner, making it easier to understand and complement it with other communication outputs.

#### OUTCOMES

- The availability of accurate and up to date information on the radiation situation in the Prefecture is important both for the local population and visitors. While maps available on the Prefecture website gave a general view of how air dose rates are reducing with time, people also want more localized information regarding the location where they live, work or are visiting. The revised website that was finalized in 2016 made this information available in a form that is easy to understand and prioritized the most recent data, while also ensuring that historical data is also available for those who wish to review it. Clickable maps allow users to access data from specific points on a map (see Figure 7). Air dose rates and the results of environmental sampling are displayed on the same map.
- The provision of information through a website is only one component of the Prefecture's communication strategy. It has been recognised that the Prefecture needs to provide information and advice to residents of the Prefecture as well as tourists from Japan and abroad on the expected reduction in air dose rates with time. This has to take into account natural reductions due to the physical half-life of radiocaesium and also the effectiveness of any applied countermeasures. Such calculations are site specific and the uncertainties in the estimates of the future situation must also be provided. The key take aways arising from the cooperation with IAEA were:
  - The most efficient way of getting messages across is to move away from one way information dissemination to engagement.
  - An important task is to increase trust of the general public in the Prefecture itself, in Japan and abroad, enabling them to make informed opinions. This can be done through active public engagement and easily understandable communication products.
  - When reaching out to visitors to Japan, it is important to clarify that the term "Fukushima" does not refer to the Fukushima Daiichi nuclear power plant but to an entire Prefecture.
  - Given the importance of traditional media in Japan, and even more so in the Prefecture, communicating through mass media is important.



# Fukushima Prefecture Radioactivity measurement map

This site is operated by the Fukushima Pref. 

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Results of measurement  
of air dose rates

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FIG. 7: Clickable Radiation Measurement (Air dose rate) Map (Fukushima Prefecture website).

- In 2018, a series of flyers for the general public was published, explaining radiological trends and dose rates; steps undertaken by the Prefecture in radiation monitoring and
- mapping, remediation, decontamination and management of radioactive waste; radiation effects and comparison with other exposure situations globally; and the results of the IAEA–Fukushima Prefecture cooperation from 2013 to 2017.
- An information brochure for local hunters (see Figure 8) and another one for the general public who gather mushrooms in the forest, as well as distributors to stores and farmers’ markets have been developed. The key objective of the brochures is to inform the target audience about the restrictions on consumption and distribution, commercial and non-commercial, of wild game and different species of wild mushrooms and plants.

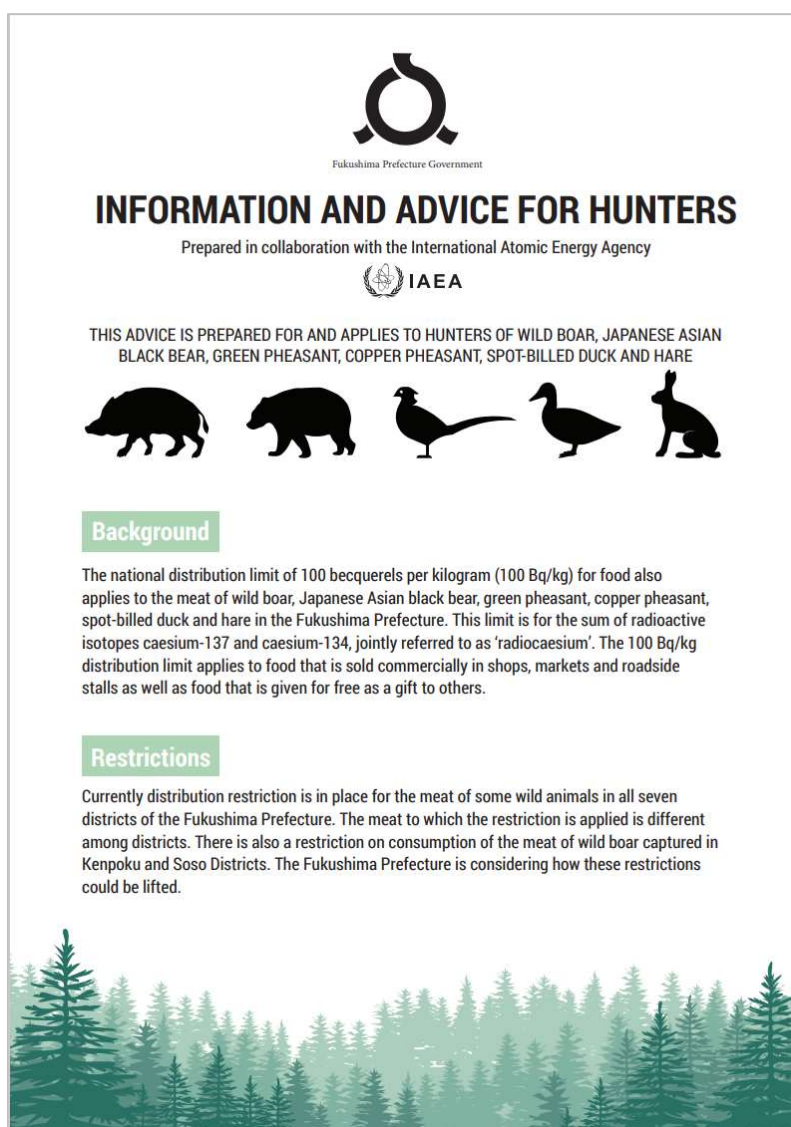


FIG. 8: An illustration of the front page of the informational brochures on advice and information for hunters ‘in English’ (Image: Fukushima Prefecture).

## 5. SUMMARY

Practical Arrangements between the Fukushima Prefecture and the International Atomic Energy Agency have been established to define a cooperation framework for the IAEA to provide broad and extensive assistance to the Prefecture in areas related to radiation monitoring and remediation in order to ensure ongoing protection of people and the environment from ionizing radiation resulting from the 2011 Fukushima Daiichi accident. The activities and topics that are part of the Practical Arrangements under which IAEA has provided assistance to the Prefecture can be summarized as:

- Research and studies on radiation monitoring in terrestrial and aquatic environments, including application of environmental mapping technology by using unmanned aerial vehicles and long term monitoring of radioactive materials;
- Research and studies on the remediation of terrestrial and aquatic environments in the Prefecture;
- Research and studies on the management of radioactive waste from remediation;

To strengthen efforts in information dissemination, the IAEA and the Prefecture also organized several activities under the scope of each of the topics of cooperation.

The cooperation under the Practical Arrangements is designed to complement existing Japanese activities and to provide immediate assistance and support which will be of direct benefit to residents of the Prefecture as well as visitors to the Prefecture. The Final Report summarises the progress on the activities undertaken from 2013 through end of 2022.



## ANNEX

### OUTCOMES FROM WORK UNDERTAKEN UNDER THE FUKUSHIMA COOPERATIVE PROJECTS

The key outcomes as a result of the 10 years cooperation under the Practical Arrangement between IAEA and the Prefecture between 2013 and 2022 were summarized at the end of the final workshop held in the Prefecture between 31 January and 3 February 2023.

The outcomes were presented by the IAEA Technical Leader of the IAEA–Fukushima Prefecture Cooperative Project are given below.

#### **Monitoring of Radioactive Material in the Environment Associated Countermeasures Monitoring: forests**

##### *Radiocaesium in forests*

- Radionuclides deposited in the forests of the Prefecture are effectively retained within the forest ecosystem and the likelihood of transfers of radiocaesium to agricultural land appears to be low.
- Forest maintenance procedures are very effective at retaining radiocaesium within forests.
- The presence of clay minerals in the underlying forest soils has chemically bind the radiocaesium and limit its transfer to vegetation.
- Measures have been implemented to restrict the radiation exposure of forest workers.

##### *Monitoring in forests*

- Radiation monitoring in forest may be necessary for many more years.
- Optimization of forest monitoring is needed moving forward due to available resources.

##### *Monitoring of wild foods*

- Activity concentrations in wild foods are variable but there are high concentrations still being measured in 2022 that are >100 Bq/kg.
- Decline in Cs concentrations in wild mushrooms and other wild foods is slow and restrictions may be required for many years for some species and in some areas. Therefore, monitoring will need to continue in the long term to provide surveillance and reassurance and to remain vigilant to changes in forest systems.
- A non-destructive analysis method has been tested for matsutake mushrooms to avoid destroying expensive mushroom species.
- Although significant progress has been made over the past decade in lifting distribution restriction for inland fish, there are still restrictions on some fish species in some areas, where recreational fishing is not allowed to resume.

## **Monitoring of Radioactive Material in the Environment Associated Countermeasures Monitoring: terrestrial and aquatic environments**

### *Behaviour of caesium in aquatic systems*

- Environmental and climatic conditions in the Fukushima and Chernobyl regions are quite different but the behaviour of radiocaesium in the environment is similar. In particular, strong sorption of caesium to solids is observed and, in fresh waters, most of the  $^{137}\text{Cs}$  is found in suspended or bottom sediments.
- Survey data indicate a continuous decline in radiocaesium concentrations in rivers since 2011. Decline observed in the Prefecture and in other parts of the world agree reasonably well.
- Predictions using a simulation model for dynamics in rivers (TODAM) show agreement with measurements under base- and high-river flow conditions.
- In the Prefecture, loss of  $^{137}\text{Cs}$  due to runoff depends on the land use. The loss is low — about 1% in the year of deposition and well below 1% per year thereafter. This is in general agreement with the experience in other countries.
- A small number of caesium microparticles (CsMPs) have been found with low levels of radiocaesium bound to them. Caesium bioavailability is likely to be low and no significant impacts are likely.

### *Remediation of the terrestrial environment*

- Countermeasures that control release of  $^{137}\text{Cs}$  into surface waters (e.g. decontamination of upstream environments) can be an effective approach to prevent accumulation in sediments in aquatic systems.
- Gamma dose rates in forests, on agricultural lands and residential areas after decontamination are reduced by about 20–50%, both after the Chernobyl and Fukushima accidents.
- For reducing  $^{137}\text{Cs}$  levels in crops, a similar range of techniques was applied after the Chernobyl and Fukushima accidents. Where comparable, reduction factors are similar.

### *Control of dispersion in dynamic aquatic systems: engineering measures*

- Aquatic systems are complex and very site specific.
- Large scale engineering measures are costly and often difficult to implement.
- Natural sediment traps have been demonstrated to work well e.g. at the Yokokawa dam and at the Kiev reservoir in Ukraine due to calm waters with low water flows leading to high sedimentation.
- Removal of bottom sediments is an effective and globally applied measure for remediation of water bodies (including demonstration test in the Fukushima Prefecture).
- Removal of riverside sediments and vegetation (demonstration test in Kam-Oguni River) reduced gamma dose rates by a factor of about 2: this reduction persisted and was not affected by typhoons and flooding.

## **Management of Waste from Remediation Activities**

- After the 2011 Fukushima Daiichi accident, enormous amounts of materials were managed as radioactive waste
- A cumulative total of over 1000 Temporary Storage Sites (TSS) were established in the Prefecture based on “Technical Guidelines”.
- The waste was later moved to Interim Storage Facilities
- IAEA assisted FP by:
  - Explaining IAEA Safety Standards
  - Reviewing the Technical Guidelines
  - Sharing expertise and experiences from outside Japan
  - Training FP on assessing the safety of TSS
  - Reviewing and advising on FP’s research on Cs in incineration ashes
  - Training FP to assessing the safety of Cs-containing ash in landfills
  - Advising on the presentation and communication of information
- The Prefectures’ capabilities on radioactive waste management were significantly enhanced over the period of the project.
- The Technical Guidelines were used for procedures for safe waste management, comments were provided to the Prefecture on all the versions of the Technical Guidelines (version 6 is the version being used at the end of the project).
- Support was provided by the IAEA to the Prefecture for the safety assessment of Temporary Storage Sites (TSS) for normal and accidental situations and for all phases of their development.
- Assessed doses during operation of TSS and after waste removal are well below relevant dose limits and long term goals.

## **Information Dissemination to the Public**

IAEA’ s assistance on information dissemination interlinks with all the areas and activities of cooperation.

- IAEA’s assistance was provided on effective ways to communicate information to the public in a timely and understandable manner.
- Methodologies and expertise provided by IAEA were based on global experience in dealing with accidental releases.
- The most efficient way of getting messages across to the public and other interested parties is to move away from one way information dissemination to engagement with them.
- Concrete communication products were developed in order to better inform audiences about radiation levels, risks and the radiation levels in the Prefecture.
- The Prefecture websites was revised in line with IAEA recommendations, to provide a better user experience, higher search engine optimization and therefore a higher impact.

- The Google Analytics tool was used to obtain quantitative data on visitor rate, retention, revisiting rates, drill down and bounce rates.
- An important task is to increase trust of the general public in the Prefecture itself, in Japan and abroad, enabling them to make informed opinions. This requires the definition of target audiences, appropriate communication goals and tools and messages.
- It is essential to communicate accurate messages to the target audience without using too specific scientific concepts.
- To make outreach products easily understandable, it was recommended to simplify language and to use infographics, graphs, animations, videos, etc.
- Lesson learned were: to simplify information presented on the page of the website, to build information architecture/taxonomy, include more actionable items on main page (surveys, videos...), to focus on fresh news on regular basis.
- Radiation Safety Navigator was introduced as the new IAEA's online tool for effective communication about radiation safety. This tool can be utilized by the Prefecture, for example, in conveying messages about radiation doses.