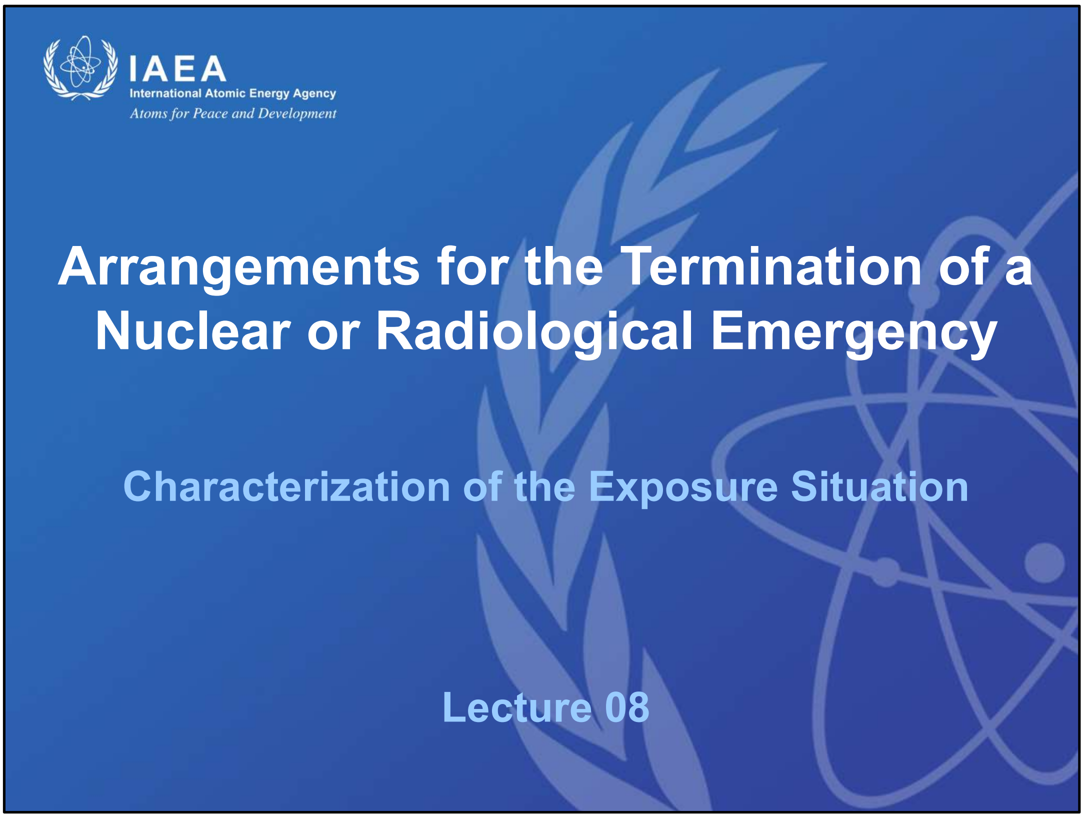
Arrangements for the Termination of a Nuclear or Radiological Emergency



Lecture: 08. Characterization of the Exposure Situation

Purpose of the presentation:

- Present and discuss arrangements for characterizing the exposure situation during the transition phase

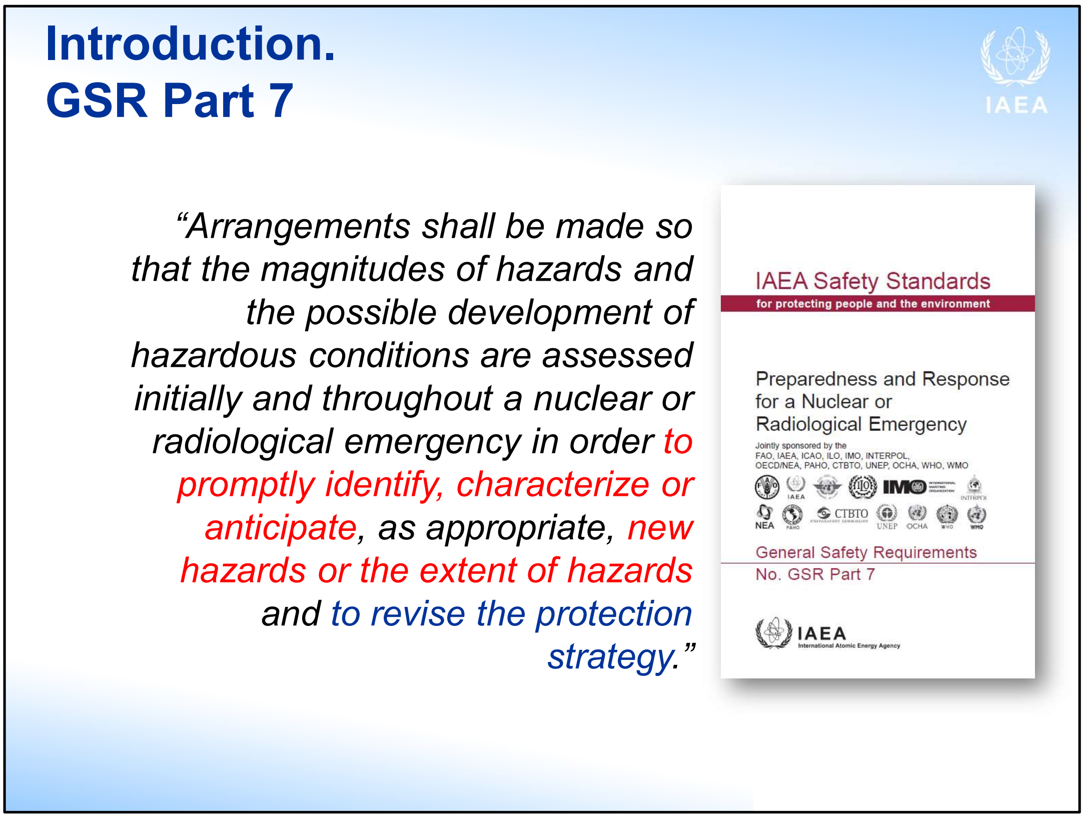
Learning objectives:

- Recognize essential arrangements for characterizing the exposure situation during the transition phase
- Recognize the uncertainties, issues and challenges associated with characterizing the exposure situation
- Identify essential elements of a monitoring strategy for the transition phase

Duration: 60 minutes

References:

1. International Atomic Energy Agency, Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSR Part 7, IAEA, Vienna (2015).
2. International Atomic Energy Agency, Arrangements for the Termination of a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSG-11, IAEA, Vienna (2018).

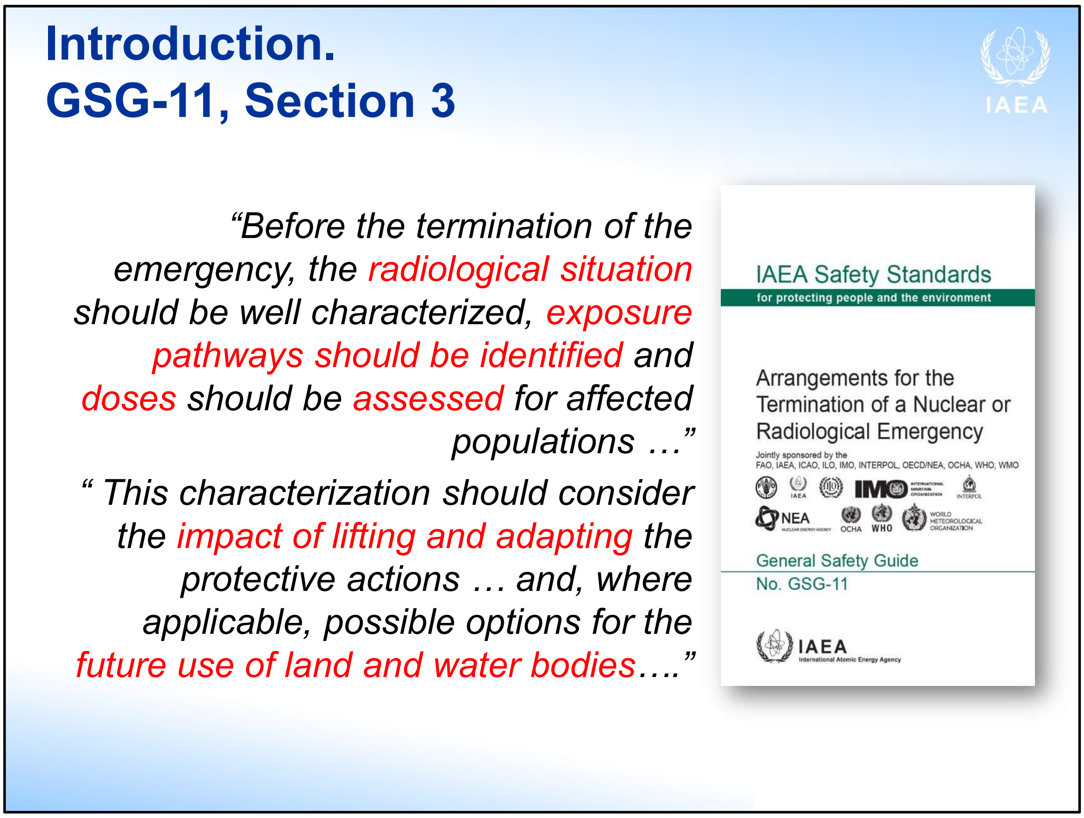


Lecture notes:

It is a requirement that arrangements are made so as to be able to characterize the situation following an emergency in order to identify the nature of hazards present and to revise the protection strategy accordingly.

Reference:

1. International Atomic Energy Agency, Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSR Part 7, IAEA, Vienna (2015).



Lecture notes:

General prerequisites, Section 3, GSG-11

"Before the termination of the emergency, the radiological situation should be well characterized, exposure pathways should be identified and doses should be assessed for affected populations (including those population groups most vulnerable to radiation exposure, such as children and pregnant women).

This characterization should consider the impact of lifting and adapting the protective actions implemented earlier in the emergency response and, where applicable, possible options for the future use of land and water bodies (e.g. imposing restrictions or identifying alternative ways in which the land and water bodies can be exploited). "

Reference:

1. International Atomic Energy Agency, Arrangements for the Termination of a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSG-11, IAEA, Vienna (2018).

Purpose

- Present and discuss arrangements for characterizing the exposure situation during the transition phase.

Learning Objectives

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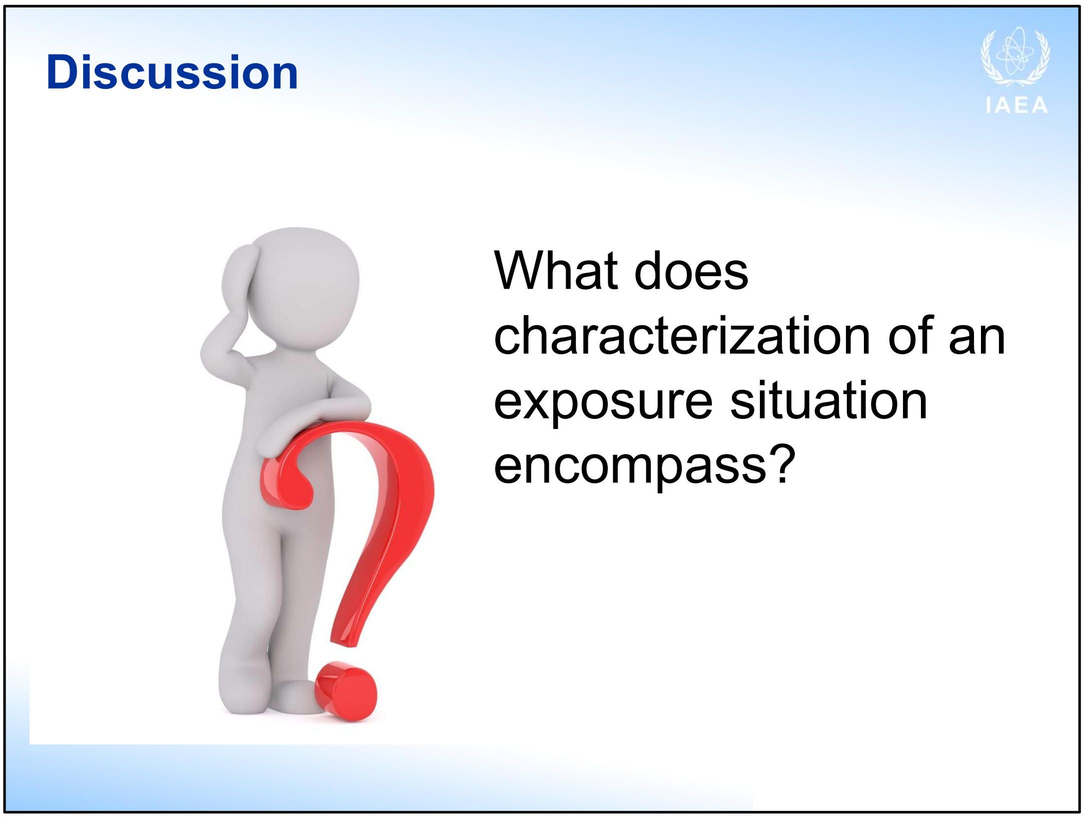
Contents

- Introduction
  - What is ‘characterization’?
  - Its role in decision making
- Considerations for developing a monitoring strategy at the preparedness stage
  - Exposure pathways
  - Monitoring resources
  - Use of decision-aiding tools and models
- Implementing the monitoring strategy during transition phase



Lecture notes:

Allow for about 3 mins. of discussion.

Introduction to characterization of the exposure situation

What does characterization of the exposure situation include?

- Dose rates and contamination mapped;
- Exposure pathways identified;
- Doses assessed.

➢ Past, Present, Future

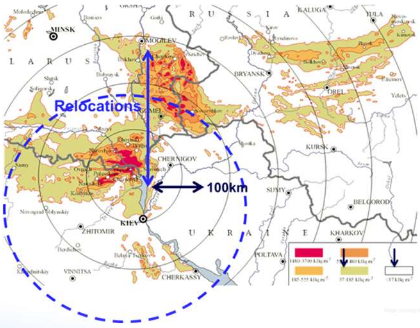
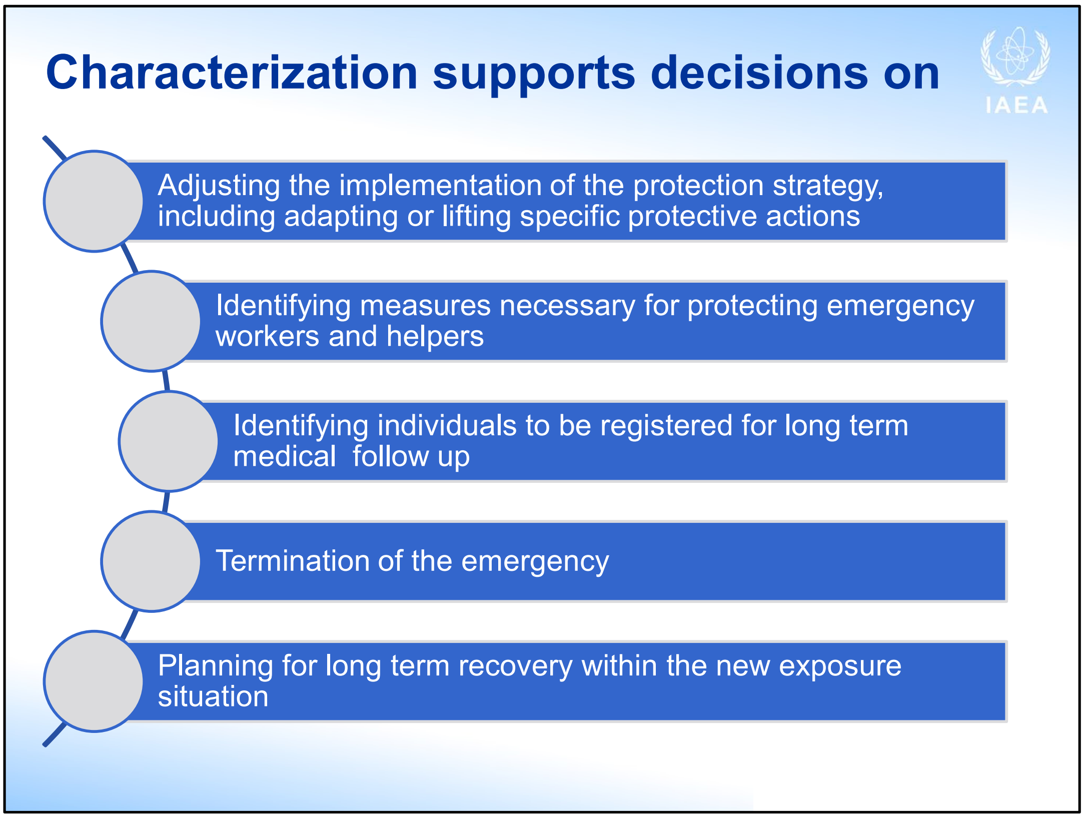


Image reproduced from Annex D, UNSCEAR (2008)

Lecture notes:

Before the termination of the emergency, the radiological situation should be well characterized, exposure pathways should be identified and doses should be assessed for affected populations (including those population groups most vulnerable to radiation exposure, such as children and pregnant women). This characterization should consider the impact of lifting and adapting the protective actions implemented earlier in the emergency response and, where applicable, possible options for the future use of land and water bodies (e.g. imposing restrictions or identifying alternative ways in which the land and water bodies can be exploited).

FIG: Map of Cs-137 deposition levels (kBq/m^2) in Belarus, the Russian Federation and Ukraine as of December 1989, United Nations Scientific Committee on the Effects of Atomic Radiation, Sources and effects of ionizing radiation, UNSCEAR, New York (2011)



Lecture notes:

In the context of emergency response generally, the general aim of monitoring is to assist the decision making, and to confirm or revise decisions on whether protective actions should be applied or adapted, and if so, when and where they should be applied or adapted.

During the transition phase, characterization of the exposure situation should be performed to support some key decisions and actions. This includes adjusting (or optimizing) the protection strategy based on the actual circumstances (bearing in mind that the strategy was developed and implemented in the early phase based on assumed circumstances and limited preliminary information) and provision of the necessary information for termination of the emergency and longer term recovery plans.

At the preparedness stage

- To characterize the exposure situation and assess doses, develop a monitoring strategy based on:
  - Results of hazard assessment and potential consequences identified;
  - Available resources.
- Strategy should stipulate priorities for different phases of emergency response:
  - Aligned with protection strategy.

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Lecture notes:

GSR Part 7 requires that monitoring in response to a nuclear or radiological emergency “be carried out on the basis of a strategy to be developed at the preparedness stage as part of the protection strategy. Arrangements shall be made to adjust the monitoring in the emergency response on the basis of prevailing conditions.”

For small scale accidents involving a lost source, minor transport accidents or minor spills of radioactive materials, a single individual skilled in radiological monitoring techniques with a basic radiation monitoring kit may be all that is required.

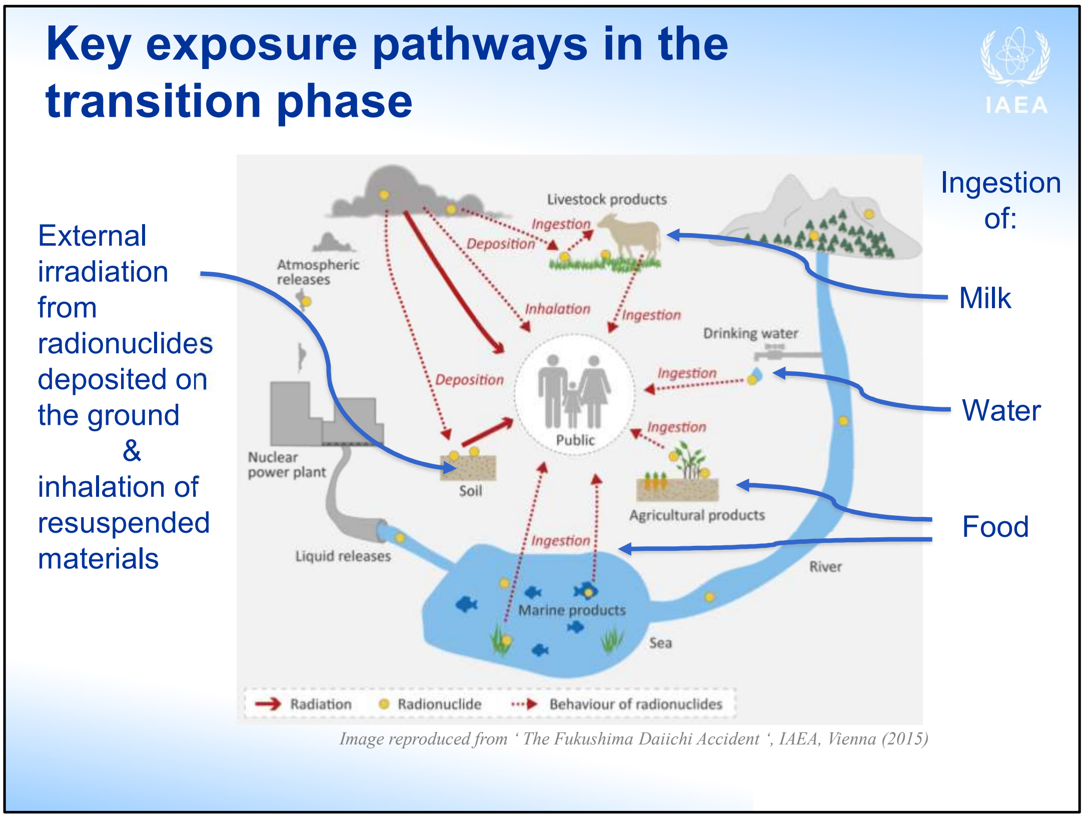
In a severe nuclear accident, prompt monitoring of a large area (100 - 1000 km^2) may be required. Therefore, it is necessary to consider the scenarios being planned for and then design a strategy that considers the resources available (or that can be developed in preparedness) in terms of specialist personnel, equipment and laboratory facilities.

Lecture notes:

As the emergency progresses, the dominant exposure pathways change, resulting from deposited rather than airborne activity. In the early response phase, priority will be placed on determining whether protective actions initiated in the urgent response phase are sufficient and whether they continue to be justified – for example, determining the activity levels and dose rates in areas immediately beyond those from which people have been evacuated to ensure that the evacuation area does not need to be extended and to establish the areas where restrictions on food and water are needed.

During the transition phases, the priority is on establishing a detailed understanding of the radiological situation in order to determine whether, for example, people can return to areas from which they were evacuated or to determine the measures (e.g. decontamination) that would be necessary to allow them to do so.

FIG.: Courtesy of International Atomic Energy Agency

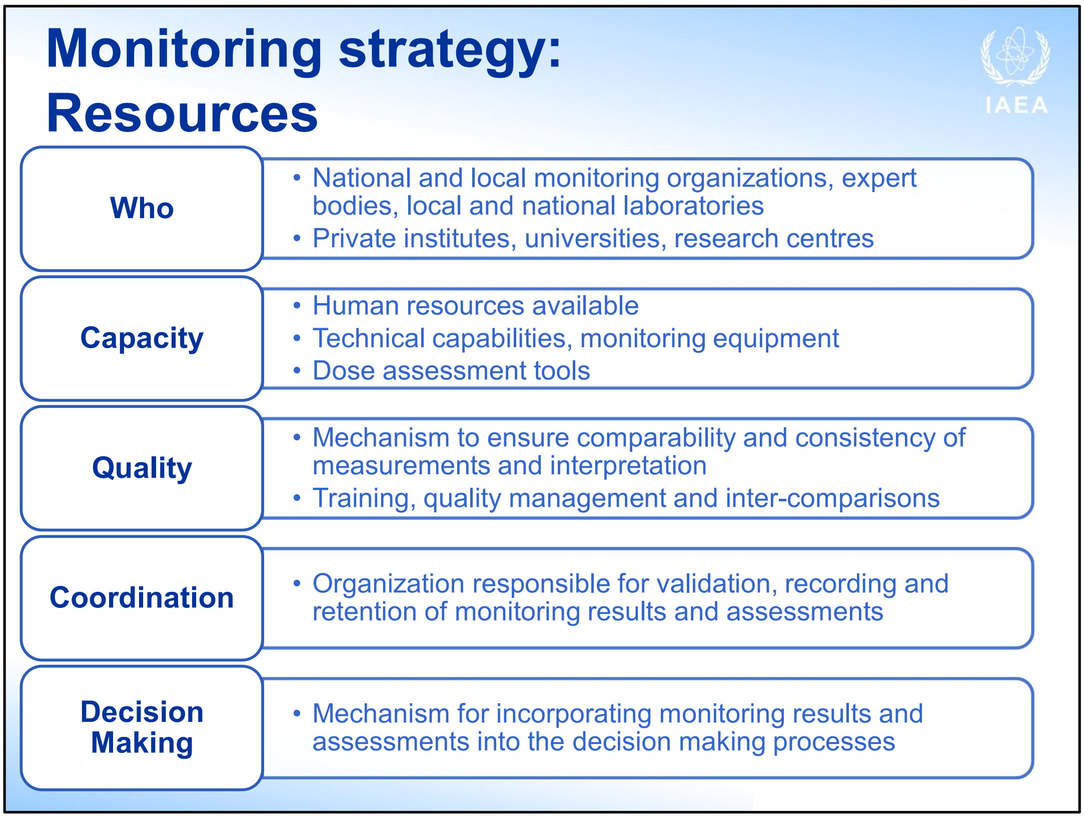


Lecture notes:

The exposure pathways that should be targeted in the transition phase are:

- External exposure from deposited radioactivity;
- Internal exposure from ingestion of food, milk, drinking water;
- Internal exposure due to inhalation of resuspended contaminated materials.

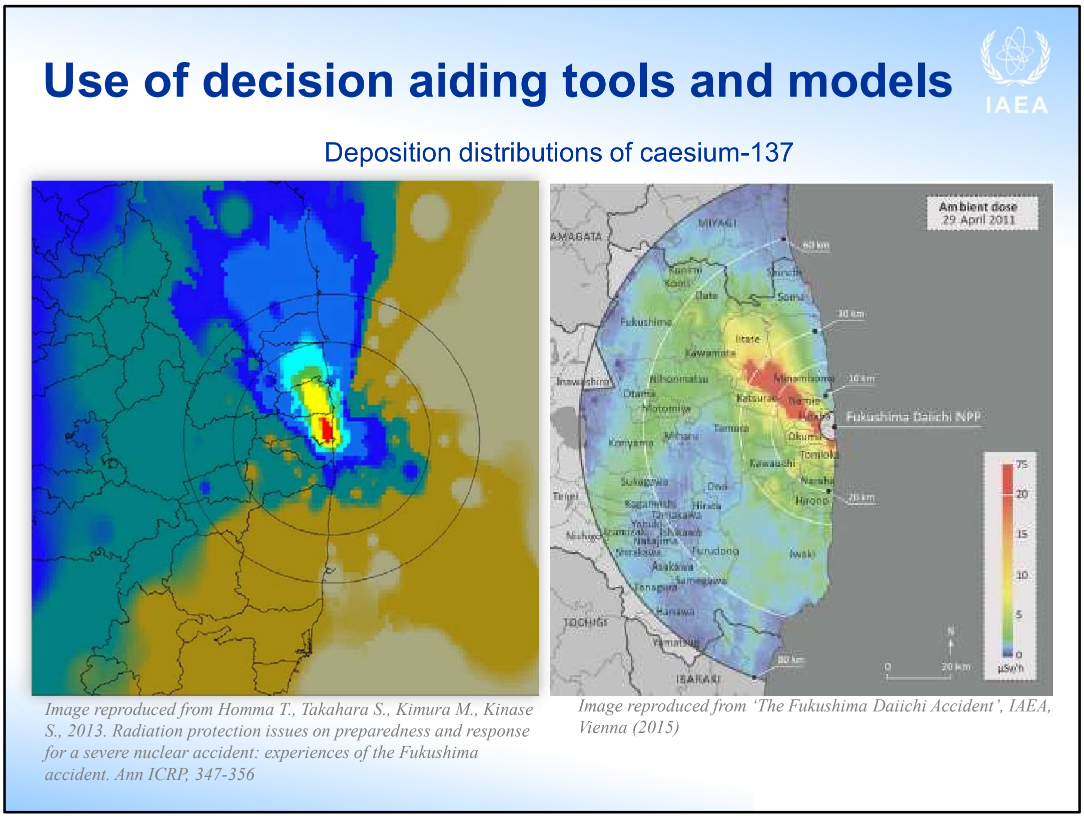
FIG.: Main exposure pathways relevant to a nuclear accident, International Atomic Energy Agency, The Fukushima Daiichi Accident, Technical Volume 4/5, Radiological Consequences, IAEA, Vienna (2015)



Lecture notes:

As part of the monitoring strategy, the available resources for monitoring should be identified and should include, but not be limited to:

- The organizations, expert bodies, local and national laboratories, private institutes, universities and research centers responsible for implementing the monitoring strategy;
- The availability of human resources and technical capabilities (including monitoring equipment and dose assessment tools) in each of these entities for implementing the monitoring strategy;
- Mechanisms for ensuring the comparability and consistency of measurements and for their interpretation, including training, quality management and intercomparing exercises;
- An organization designated as responsible for the validation, recording and retention of monitoring results and assessments;
- A mechanism for incorporating monitoring results and assessments into the decision making processes.



Lecture notes:

The monitoring strategy may be supported by decision aiding tools and models in assessing and adjusting the priorities for monitoring in order to allow for the effective and efficient use of available (but usually limited) resources and capabilities.

However, monitoring should ultimately be conducted in all geographical areas and not just in those areas indicated by modelling tools as there are inherent uncertainties in the model results, as illustrated by the example shown here from Fukushima Daiichi.

The objective of using such tools and their limitations should be clearly communicated to all concerned parties and documented in the monitoring strategy.

FIG.1: Deposition distribution of Cs-137, Homma T., Takahara S., Kimura M., Kinase. S., 2013. Radiation protection issues on preparedness and response for a severe nuclear accident: experiences of the Fukushima accident. Ann ICRP, 347-356

FIG. 2: Dose rate at 1 m above ground level (μSv/h) normalized to 29 April 2011, International Atomic Energy Agency, The Fukushima Daiichi Accident, Technical Volume 3/5, Emergency Preparedness and Response, IAEA, Vienna (2015)

Use of decision aiding tools and models (cont'd)

- Ensure that use and limitations of models and other tools are documented and communicated at the preparedness stage:
  - Models valuable in guiding monitoring priorities;
  - Not appropriate as a tool to decide on public protection actions in response;
  - Used in public communication only with suitable explanations.

Image reproduced from 'The Fukushima Daiichi Accident', IAEA, Vienna (2015)

Lecture notes:

The figure shows dose projection results from the SPEEDI model based on environmental monitoring available at the time. The results represent the integrated dose for the period of 12–24 March. However, it was not explained that this information was not available when decisions on evacuation and sheltering were made on 12 March. Some misunderstandings arose as a result. For example, some people evacuated from a 20 km radius of the accident site to an area to the northwest of the site (later found to be contaminated) mistakenly claimed that non-disclosure of this information led to them receiving exposures that could have been prevented.

FIG.: Model dose estimation results, International Atomic Energy Agency, The Fukushima Daiichi Accident, Technical Volume 3/5, Emergency Preparedness and Response, IAEA, Vienna (2015)

Uncertainties in monitoring results

- Technical sources of uncertainty include:
  - Variability of procedures for sampling, processing and measurement;
  - Spatial and temporal variability;
  - Variability of calibration techniques.

As illustrated in the following slides with some examples from the Fukushima Daiichi accident

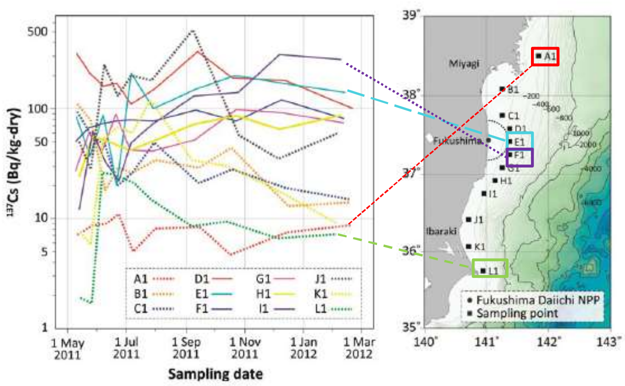
IAEA

Lecture notes:

Examples from the Fukushima Daiichi accident are used, because it is the accident for which illustrative figures are most readily available.

Spatial and temporal variability

IAEA



Images reproduced from 'The Fukushima Daiichi Accident', IAEA, Vienna (2015)

Variation in activity concentrations of Cs-137 in sediment samples between May 2011 and March 2012 around the Fukushima Daiichi NPP

Lecture notes:

This slide shows the spatial and temporal variability in activity concentrations of Cs-137 in sediment around the Fukushima Daiichi NPP starting on 1 May 2011 (1.5 months after beginning of the accident) until 1 March 2012 (around 1 year after the accident).

The build up of activity over time depends on the inputs into the marine system and the transport mechanisms for water and sediment.

Inputs [p. 32, Technical Volume 4]:

- Deposition from atmospheric release (12 – 30 March)
- Various releases directly into the marine system (1 – 11 May)
- Continuing releases of e.g. contaminated ground water

Timing and location of peaks vary due to variations in transport.

Lecture notes:

In general terms, the higher activities were measured close to the site (notably F1 and E1 – shown by the purple and turquoise lines) and the lower activities measured at greater distances (A1 and L1, the red and green lines, respectively).

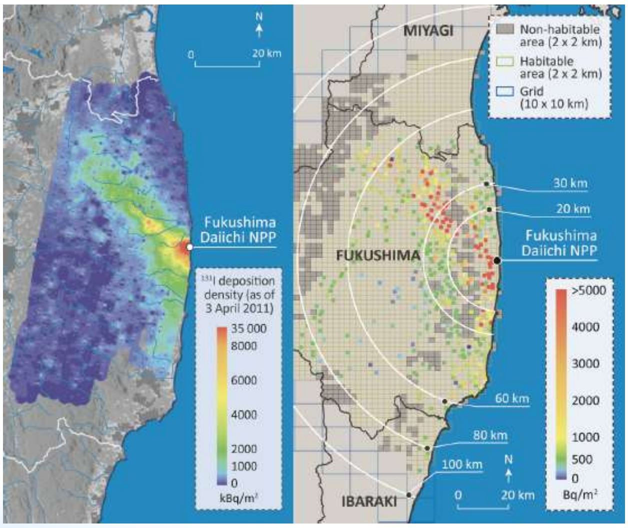
FIG.: Spatial and temporal distribution of Cs-137 concentrations in sediment samples collected on the dates indicated , International Atomic Energy Agency, The Fukushima Daiichi Accident, Technical Volume 4/5, Radiological Consequences, IAEA, Vienna (2015)

Variability of procedures

Deposition density of I-131 measured by different methods

Aerial survey

(normalized to 2 April 2011)



Soil sampling and analysis

(normalized to 14 June 2011)

Images reproduced from 'The Fukushima Daiichi Accident', IAEA, Vienna (2015)

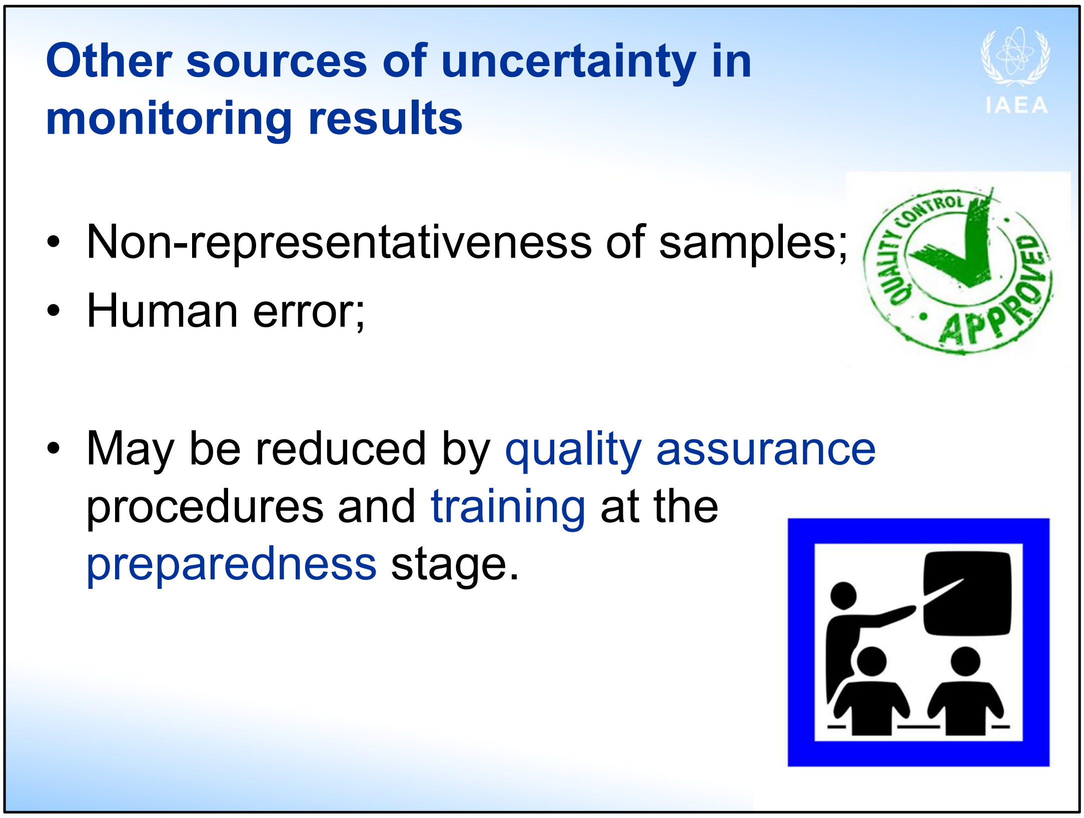
Lecture notes:

These figures are illustrative only – they were prepared at different times and for different purposes. They are also presented in different units (on the left in kBq/m^2; on the right in Bq/m^2).

The plot on the left was prepared in the early days of the accident. It was based on an aerial surveys – may be performed relatively quickly.

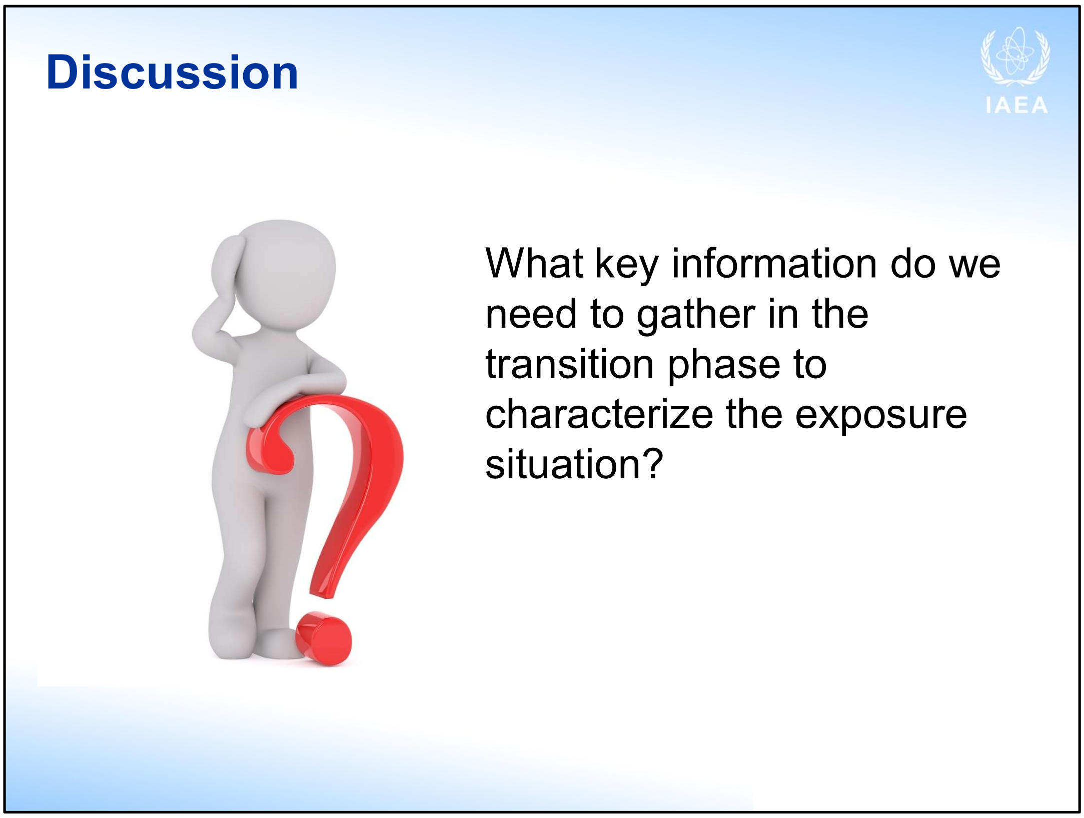
The plot on the right was prepared following an intensive soil sampling and analysis – a process that requires significantly more time (an input to detailed characterization and longer term decision making).

FIG.: Deposition density of I-131, International Atomic Energy Agency, The Fukushima Daiichi Accident, Technical Volume 4/5, Radiological Consequences, IAEA, Vienna (2015)



Lecture notes:

Appropriate quality assurance requirements should be agreed on at the preparedness stage to reduce such technical uncertainties as much as possible, and these quality assurance requirements should be observed by all parties providing measurements during the emergency response. To reduce human errors, the individuals involved in radiation monitoring should be periodically trained, and human interference in monitoring procedures should be minimized when appropriate.

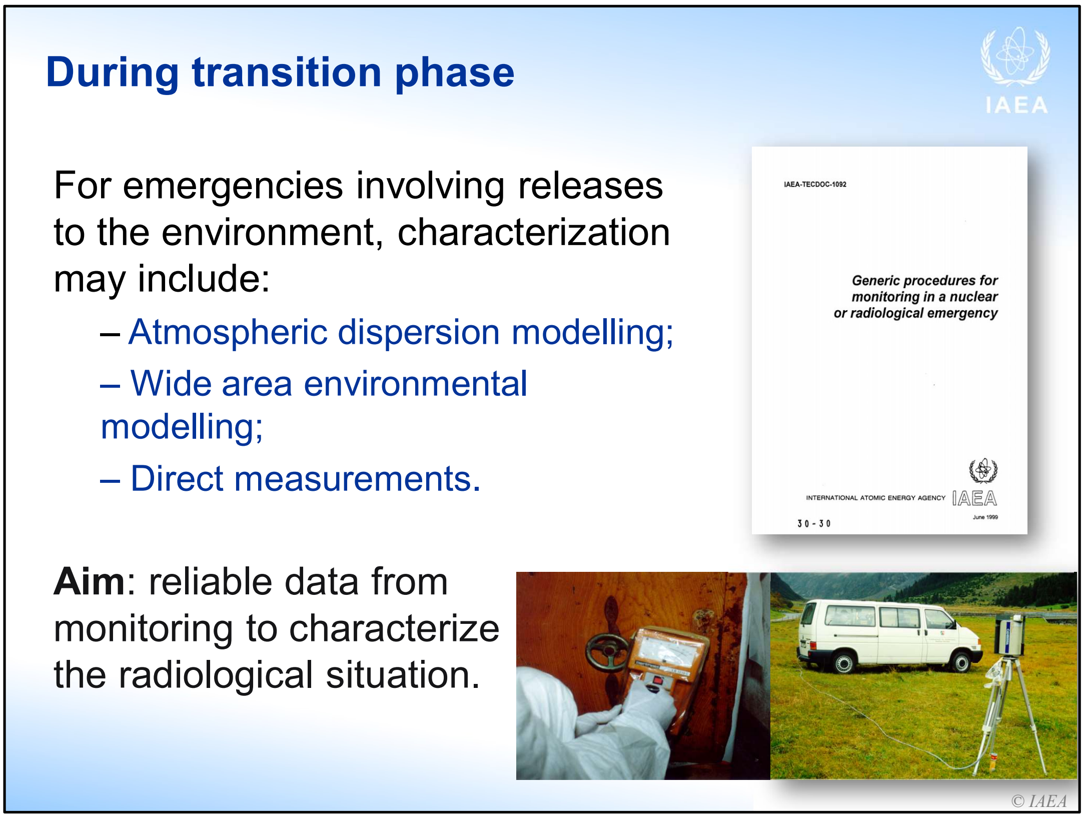


Lecture notes:

Allow for about 3 mins. of discussion.

Examples:

- Need to map external (gamma) dose rate and radionuclide-specific deposition patterns;
- Data on radionuclide levels in food, feed, milk, drinking water, crops, etc.
- Rainfall data during plume dispersion – to help look for hotspots.



Lecture notes:

What techniques to use and how to use them is beyond the scope of this workshop, but the IAEA has produced a number of guidance documents on this topic.

Procedures are intended to be used only by personnel who have been trained in their use.

During transition phase (cont’d)

- Radionuclide composition has a major impact on doses incurred and significance of different exposure pathways.

Aim: Identify radionuclide composition of release or contamination as early as possible

Lecture notes:

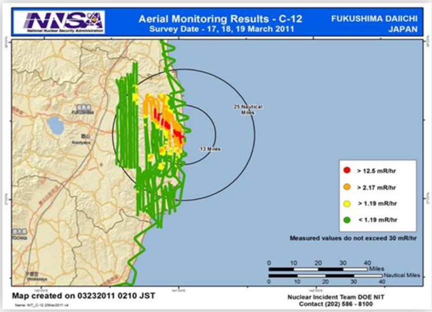
The radionuclide composition will be a major factor in determining current and future doses.

It affects which foods may be contaminated and which exposure pathways will dominate.

It is key to determine the radionuclide mix to be able to assess future doses and future protective actions needed as the situation transitions to an existing exposure situation.

Dose rate and deposition measurements

- An understanding of the distribution of the deposition is likely to be developed during both the early response phase and the transition phase:
  - Progressively more detailed dose rate and deposition measurements are possible as the emergency progresses.



Images reproduced from 'The Fukushima Daiichi Accident', IAEA, Vienna (2015)

Lecture notes:

As soon as possible, detailed radionuclide specific deposition maps and external gamma dose rate maps should be established and periodically updated, taking into account that the deposition of the radionuclides will be subjected to redistribution due to weathering effects or natural radioactive decay processes over time.

Heterogeneity of the deposition patterns is possible due to the variation in the spectrum of released radionuclides and the meteorological conditions prevailing during the emergency phase. In this regard, a comparison of the atmospheric releases and dispersion patterns with meteorological rainfall data may help to identify areas of potentially higher deposition.

Fukushima Daiichi – aerial dose rate monitoring

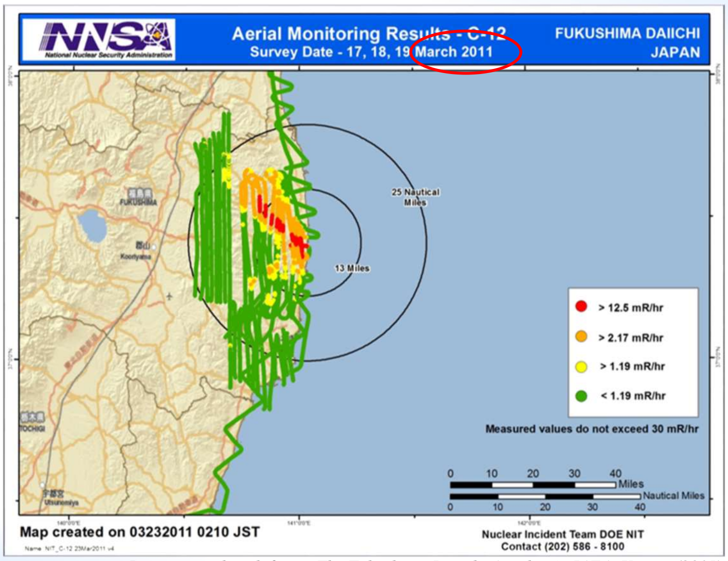


Image reproduced from 'The Fukushima Daiichi Accident', IAEA, Vienna (2015)

Initial measurements of gamma dose rate from aerial monitoring

A few days after the start of the accident

Lecture notes:

Initial aerial monitoring survey.

FIG.: Airborne measurements of the dose rate at 1 m above ground level (mR/h) taken between 17 and 19 March 2011, International Atomic Energy Agency, The Fukushima Daiichi Accident, Technical Volume 3/5, Emergency Preparedness and Response, IAEA, Vienna (2015)

Vehicle-borne dose rate measurements

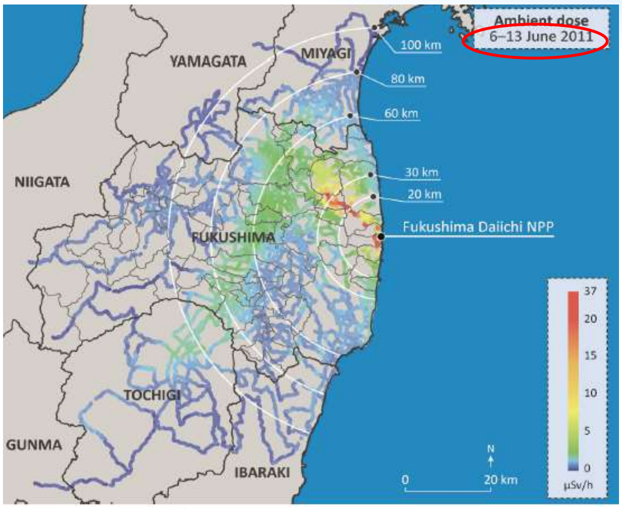


Image reproduced from 'The Fukushima Daiichi Accident', IAEA, Vienna (2015)

Results of vehicle-borne measurements of dose rates 1 m above ground taken 6–13 June 2011

Around 3 months after the accident

Lecture notes:

This slide shows a map of dose rate measurements constructed on the basis of measurements performed using vehicle-borne monitors. This demonstrates the greater spatial resolution of dose rate measurements than with aerial survey results. However, the map also shows the structure of the roads – demonstrating the dependence of this form of monitoring on the transport infrastructure.

FIG.: Vehicle borne measurements of the dose rate at 1 m above ground level (μSv/h) taken between 6 and 13 June 2011, International Atomic Energy Agency, The Fukushima Daiichi Accident, Technical Volume 3/5, Emergency Preparedness and Response, IAEA, Vienna (2015)

Measurements of surface concentration

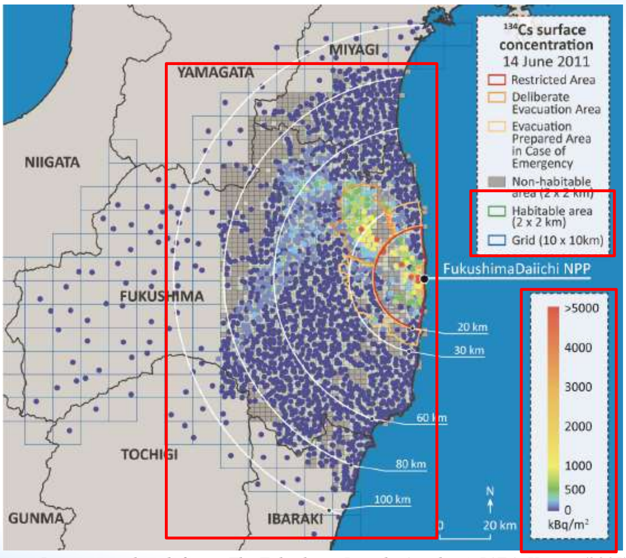


Image reproduced from 'The Fukushima Daiichi Accident', IAEA, Vienna (2015)

Derived from soil sampling and laboratory analysis (samples taken from 6 June to 8 July 2011)

- Surface samples (top 5 cm) were taken from about 2200 locations
- The sampling campaign involved more than 400 people from 94 organizations (incl. universities, medical institutions and private companies)

Lecture notes:

"About 3 months after the accident, a comprehensive sampling campaign was performed – the consistency between these results and those of the first areal survey provided confidence in the reliability of measurements on the pattern of deposition in the terrestrial environment" [Technical Volume 4, p. 25, IAEA Report on the Fukushima Daiichi Accident].

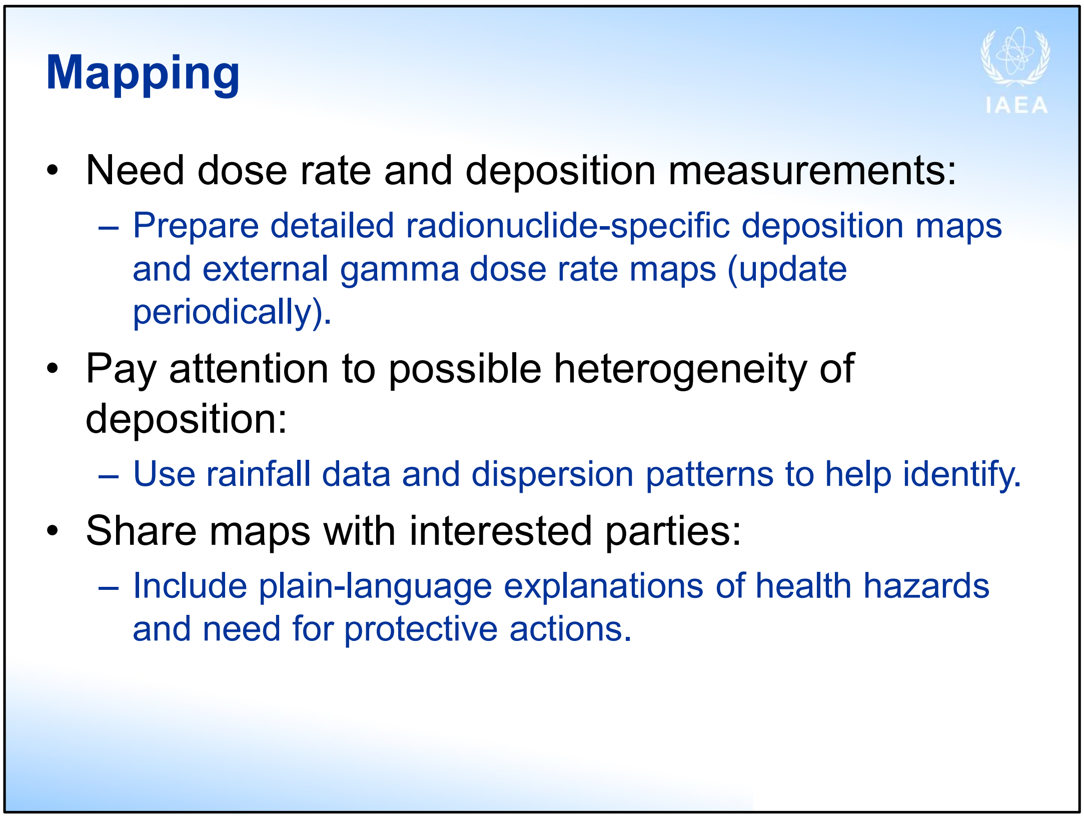
The animation runs as follows:

1. Box describing the number of samples taken and the number of people involved:
   - Surface samples (top 5cm) were taken from around 2200 locations;
   - The sampling campaign involved more than 400 people from 94 organizations (incl. universities, medical institutions and private companies),
2. Red box drawn around the relevant area on the map and text box which notes that:
   - The number of discrete points on the grids clearly shows the extent of monitoring undertaken;
   - The heterogeneity of the deposition is also clearly shown.

Lecture notes:

3. Red box around the definition of the grid resolution (top right hand side) and text box that notes that:
    - Resolution is defined by the type of area (habitable (2 x 2 m) otherwise (10 x 10 m).
4. Red box around the scale (bottom right) with text box indicating that:
    - Scale and mapping can be explained to non-specialists.

FIG.: Surface concentration of Cs-134 on soil (Bq/m^2) normalized to 14 June 2011, International Atomic Energy Agency, The Fukushima Daiichi Accident, Technical Volume 3/5, Emergency Preparedness and Response, IAEA, Vienna (2015)



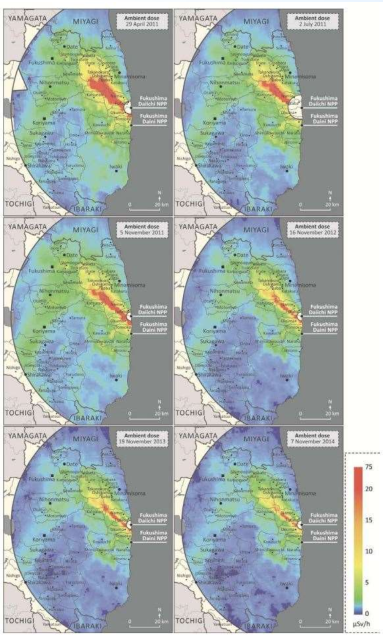
Lecture notes:

As soon as possible, detailed radionuclide specific deposition maps and external gamma dose rate maps should be established and periodically updated, taking into account that the deposition of the radionuclides will be subjected to redistribution due to weathering effects or natural radioactive decay processes over time.

Heterogeneity of the deposition patterns is possible due to the variation in the released radionuclides spectrum and the meteorological conditions prevailing during the emergency phase. In this regard, a comparison of the atmospheric releases and dispersion patterns with meteorological rainfall data may help to identify areas of potentially higher deposition.

In the transition phase, the public and communities will be making more and more decisions for themselves (compared to the urgent phase, when the authorities make the majority of decisions). Therefore, it's important that interested parties have access to the information that can help them take appropriate actions and understand (and contribute to) which decisions are being made. Sharing the dose/deposition maps and explanations of these will aid this process and help to build trust.

Fukushima Daiichi – examples of periodically updated maps



Images reproduced from 'The Fukushima Daiichi Accident', IAEA, Vienna (2015)

Measured aerial ambient dose equivalent rate from deposits (April 2011 – Nov. 2014)

Lecture notes:

Results of repeated aerial surveys undertaken show the reduction in dose rate with time. For example – shown here until end 2014.

FIG.: Measured aerial ambient dose equivalent rate (in μSv/h) resulting from deposits from the releases that spread in areas to the north-west of the plant, International Atomic Energy Agency, The Fukushima Daiichi Accident, Report by the Director General, IAEA, Vienna (2015)

Pattern of deposition from the Fukushima Daiichi NPP

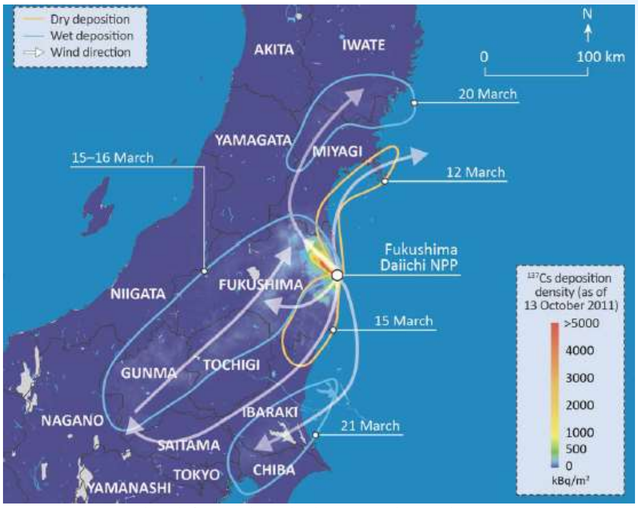


Image reproduced from 'The Fukushima Daiichi Accident', IAEA, Vienna (2015)

Higher deposition densities associated with wet deposition – the pattern will influence the monitoring strategy

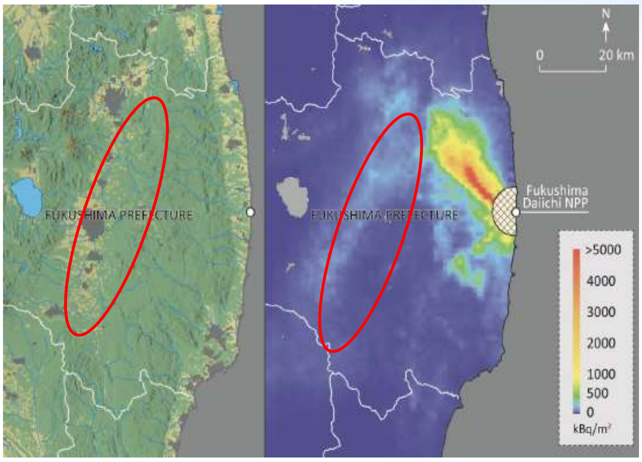
Lecture notes:

This slide summarizes the key events and factors influencing dispersion and deposition of radionuclides from the Fukushima Daiichi accident. A full description of these factors can also be found in Table 4.1-3 in Technical Volume 4 of the IAEA Report on the Fukushima Daiichi Accident (figure on page 9, and the table on pages 10–13).

Notable point: The higher deposition densities are associated with rainfall patterns; this is a factor that will influence monitoring strategies and subsequent decision making regarding protective actions.

FIG.: Timing and locations of the main deposition events, International Atomic Energy Agency, The Fukushima Daiichi Accident, Technical Volume 4/5, Radiological Consequences, IAEA, Vienna (2015)

Influence of topography



Images reproduced from 'The Fukushima Daiichi Accident', IAEA, Vienna (2015)

Pattern of deposition related to topographical features, e.g. mountains, which may also affect the monitoring strategy

Lecture notes:

Elevated levels were found in the mountainous region, which seems to have acted as a barrier, preventing significant transport of material further westwards.

Such topographical features may also need to be taken into account in preparing a monitoring strategy.

FIG.: Timing and locations of the main deposition events, International Atomic Energy Agency, The Fukushima Daiichi Accident, Technical Volume 4/5, Radiological Consequences, IAEA, Vienna (2015)

Food, water and milk contamination and resuspension

- Need to assess doses from ingestion of food, milk, drinking water:
  - Comprehensive environmental sampling and monitoring programme accounting for local diet (and farming practices).
- Inhalation of resuspended material may become more important in this phase:
  - Dose contribution of this pathway is normally small, but more significant in some circumstances (e.g. arid areas). Consider in monitoring programme.

Lecture notes:

There may be exposure from ingestion of contaminated food, milk and drinking water, depending on the abundance of locally produced food in the diet of people living in contaminated areas. To evaluate the ingestion dose for people living in long term contaminated areas, a comprehensive environmental sampling and monitoring programme should be carried out to allow for continuous monitoring of the presence of radionuclides in food, milk and drinking water, taking into account the local diet, as well as in crops and animal feed.

During the transition phase, internal exposure due to the inhalation of resuspended material can be expected. While the contribution of this pathway to the total effective dose is usually small, special circumstances (e.g. carrying out activities in an arid, windy environment or a dusty environment) may lead to it contributing significantly to total doses. This should be taken into consideration and monitoring for resuspended particles, as appropriate, included in the monitoring programme.

Lecture notes:

Doses should be reassessed using the monitoring results and the dose assessment tools/models foreseen in the monitoring strategy. The estimations should be carried out as realistically as possible, focussing on the doses to the representative person/groups and taking into account realistic habits, the real pattern of contamination and the food, milk and drinking water that are used by people in the contaminated areas. Assessed doses (either projected, received or residual) should be compared with the generic criteria and reference levels pre-set in the protection strategy or with dose restrictions applicable for emergency workers and helpers.

Tap water monitoring results

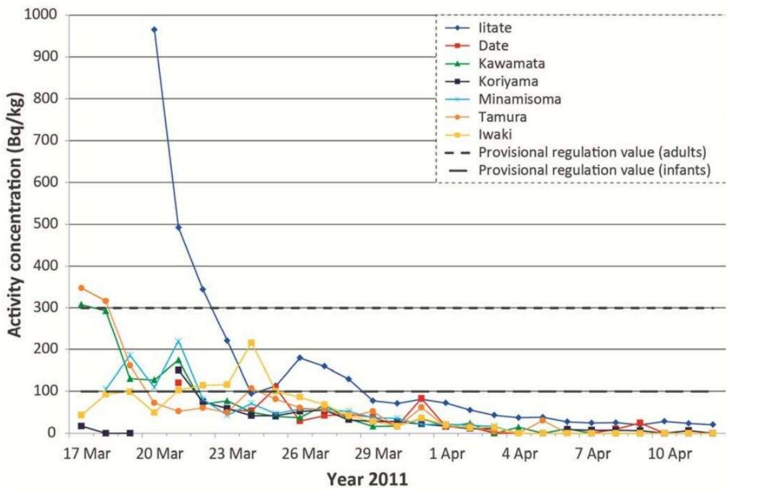


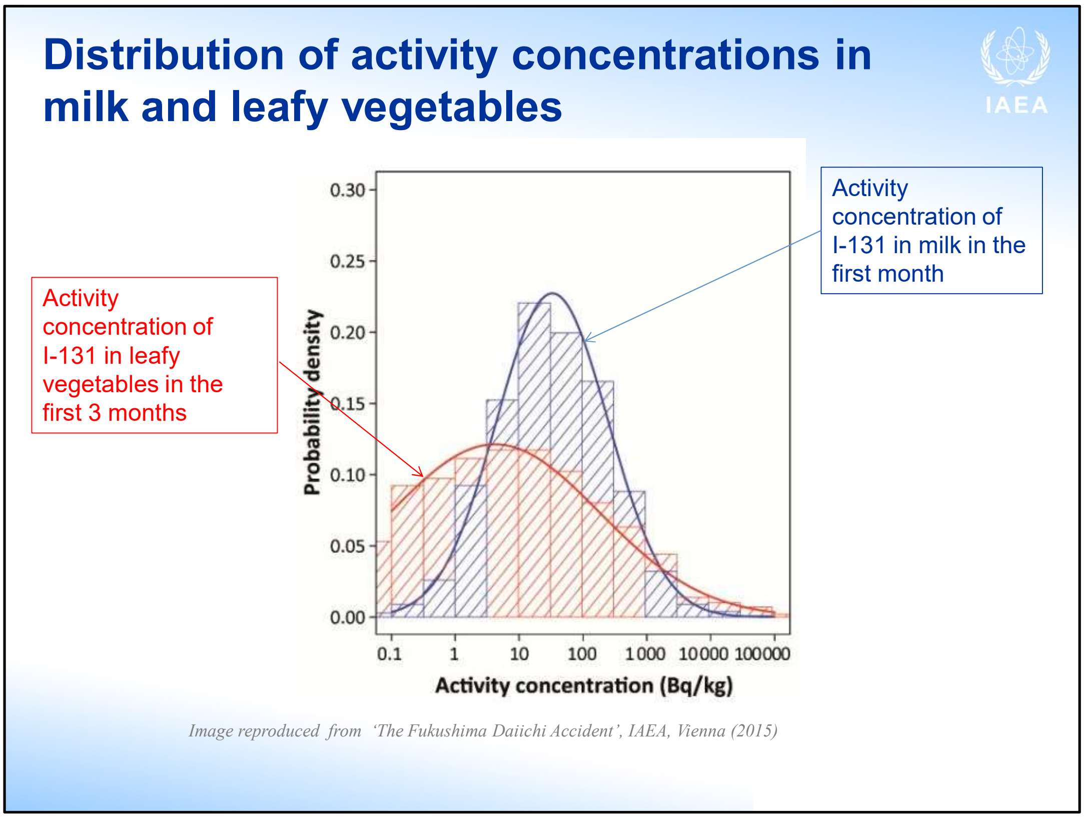
Image reproduced from 'The Fukushima Daiichi Accident', IAEA, Vienna (2015)

I-131 measurements in tap water supplies in Fukushima Prefecture (in the first year following in the accident)

Lecture notes:

The figure demonstrates the variation in the activity concentration of I-131 in tap water in Fukushima Prefecture in the first year following the accident in comparison with the provisional regulation values specified for adults and infants. In the first month following the accident, levels exceeded the regulation values (particularly those for infants) in several places but afterwards remained below these values. This type of information is essential for decision making on protective actions and will influence the priorities and strategies for monitoring.

FIG.: Levels of I-131 measured in tap water supplies in Fukushima Prefecture, International Atomic energy Agency, The Fukushima Daiichi Accident, Technical Volume 4/5, Radiological Consequences, IAEA, Vienna (2015)



Lecture notes:

This figure shows a statistical analysis of the distribution of activity concentrations of I-131 in milk (in the first month) and in leafy green vegetables in the first 3 months following the accident. These data include all measured foods (not only those marketed). In both cases, mean values are below those at which restrictions were required, but the 95th percentiles (of 7300 Bq/kg for leafy vegetables and 1800 Bq/kg for milk) are in excess, indicating the importance of introducing restrictions [Source: IAEA, Fukushima Daiichi Accident, TV 4].

FIG.: Log-normal probability distribution of I-131 activity concentration in milk and in leafy vegetables, International Atomic Energy Agency, The Fukushima Daiichi Accident, Technical Volume 4/5, Radiological Consequences, IAEA, Vienna (2015)

Monitoring locally grown rice

Images reproduced from 'The Fukushima Daiichi Accident', IAEA, Vienna (2015)

Lecture notes:

This picture shows a specially designed facility established in Fukushima Prefecture to measure radioactive caesium activity in packaged rice from the local area (using scintillation counters). The photographs also show that labels were affixed to confirm that the packages had passed the screening process.

FIG.: Bags of locally grown rice are screened for possible contamination in Motomiya City, International Atomic Energy Agency, Fukushima Daiichi Accident, TV 5/5, Radiological Consequences

Discussion

How can the characteristics of an impacted area and its affected populations contribute to doses to be received in an emergency?

Lecture notes:

Allow for about 3 mins. of discussion.

Other considerations for characterization and dose assessment

- Food production patterns;
- Local diets and food preferences;
- Activities carried out in an area:
  - e.g. those that may lead to additional exposures;
- Human behaviour;
- Characteristics of an area:
  - e.g. dusty or windy environment;
- Redistribution of radionuclides due to weathering or natural decay;

Lecture notes:

The slide lists various aspects that impact the exposure situation under consideration and the doses to be received.

Other considerations for characterization and dose assessment (cont'd)

- Make dose estimates as realistic as possible for comparison with relevant criteria;
- Reassess doses continually in light of new information as it becomes available;
- Place health hazards in perspective when sharing the results of dose assessment publicly;

Lecture notes:

The slide lists various aspects that impact the exposure situation under consideration and the doses to be received.

Fukushima Daiichi - estimated doses

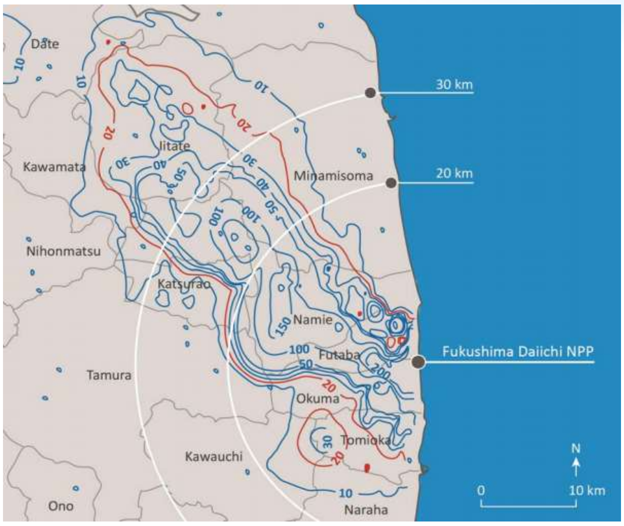


Image reproduced from 'The Fukushima Daiichi Accident', IAEA, Vienna (2015)

Estimated effective doses (mSv) received
in the first year (up to 11 March 2012)

Lecture notes:

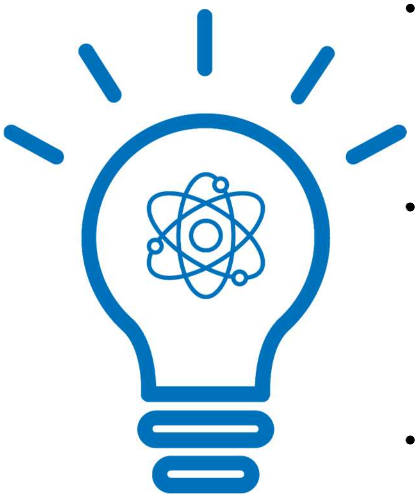
Cumulative effective dose from external exposure while living normally in the affected area for one year following the accident (dose rate multiplied by 0.6 to account for shielding in a wooden building for 16 hours per day). Issued on 16 May 2011.

The red line shows the boundary of the area where the integrated dose over the first year was estimated to exceed 20 mSv. The population remaining in this area was relocated after 11 May 2011.

FIG.: First year dose estimate (integrated dose, mSv, up until 11 March 2012), International Atomic Energy Agency, The Fukushima Daiichi Accident, Technical Volume 3/5, Emergency Preparedness and Response, IAEA, Vienna (2015)

Summary

IAEA



- The characterization of the exposure situation would require intensive monitoring. A monitoring strategy needs to be developed at the preparedness stage.
- Various aspects need to be taken into consideration in defining the priorities for monitoring and addressing uncertainties so that an informed adaptation of the protection strategy is possible.
- Deposition and dose rate maps shared publicly accompanied with plain language explanations that place health hazards and associated protective actions in perspective.

Lecture notes:

Summarize the key points from the presentation.

Lecture notes:

Thank you!