Arrangements for the Termination of a Nuclear or Radiological Emergency

Case Study: Part 2. The Fukushima Daiichi Nuclear Power Plant (NPP) Accident in 2011

Purpose of the Presentation:

- To present and discuss the emergency response to the Fukushima Daiichi NPP accident in Japan in 2011
- To analyse the nuclear accident in the context of the guidance given in IAEA Safety Standards Series No. GSG-11 for the transition to an existing exposure situation

Learning Objectives:

- To analyse the emergency response to this nuclear accident against the guidance given in IAEA Safety Standards Series No. GSG-11
- To identify different stages of response to the nuclear accident
- To analyse when the prerequisites for transition to an existing exposure situation were fulfilled and when the emergency could have been terminated

Duration: 60 min

References:

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).
2. International Atomic Energy Agency, The Fukushima Daiichi Accident, Report by the IAEA Director General, IAEA, Vienna (2015).
3. International Atomic Energy Agency, The Fukushima Daiichi Accident, Technical Volume 3/5, Emergency Preparedness and Response, IAEA, Vienna (2015).

Purpose

- To present and discuss the emergency response to the Fukushima Daiichi NPP accident in Japan in 2011.
- To analyse the nuclear accident in the context of the guidance given in IAEA Safety Standards Series No. GSG-11 for the transition to an existing exposure situation.

*The Case Study is **not** an assessment of the emergency response to this nuclear accident but an opportunity to illustrate fulfillment of the prerequisites given in the IAEA Safety Standards Series No. GSG-11 for transition to an existing exposure situation.*

Learning objectives

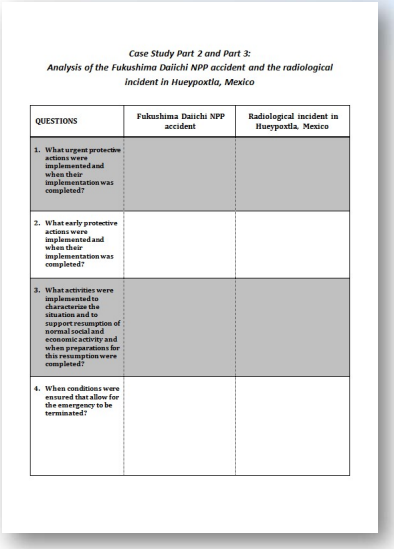
- To analyse the emergency response to this nuclear accident against the guidance given in IAEA Safety Standards Series No. GSG-11;
- To identify different stages of response to the nuclear accident;
- To analyse when the prerequisites for transition to an existing exposure situation were fulfilled and when the emergency could have been terminated.

Contents

- Overview of the emergency response to the Fukushima Daiichi Nuclear Power Plant accident in 2011
- Discussion and feedback session

Expectations from participants

- Following the presentation, participants are expected to discuss the emergency response to this accident within their Working Group and to answer the questions provided in *Case Study Part 2 and Part 3: Analysis of the Fukushima Daiichi NPP accident and the radiological incident in Hueypoxtla, Mexico.*



Case Study Part 2 and Part 3:
Analysis of the Fukushima Daiichi NPP accident and the radiological incident in Hueypoxtla, Mexico

QUESTIONS	Fukushima Daiichi NPP accident	Radiological incident in Hueypoxtla, Mexico
1. What urgent protective actions were implemented and when their implementation was completed?		
2. What early protective actions were implemented and when their implementation was completed?		
3. What activities were implemented to characterize the situation and to support resumption of normal social and economic activity and when preparations for this resumption were completed?		
4. When conditions were ensured that allow for the emergency to be terminated?		

Lecture notes:

The participants should be guided to review the print-out distributed to them with the questions and to get familiar with the questions before the Case Study is presented (for about 2-3 mins).

References

Published : August 2015

Vol. 1 : Description and Context of the Accident

Vol. 2 : Safety Assessment

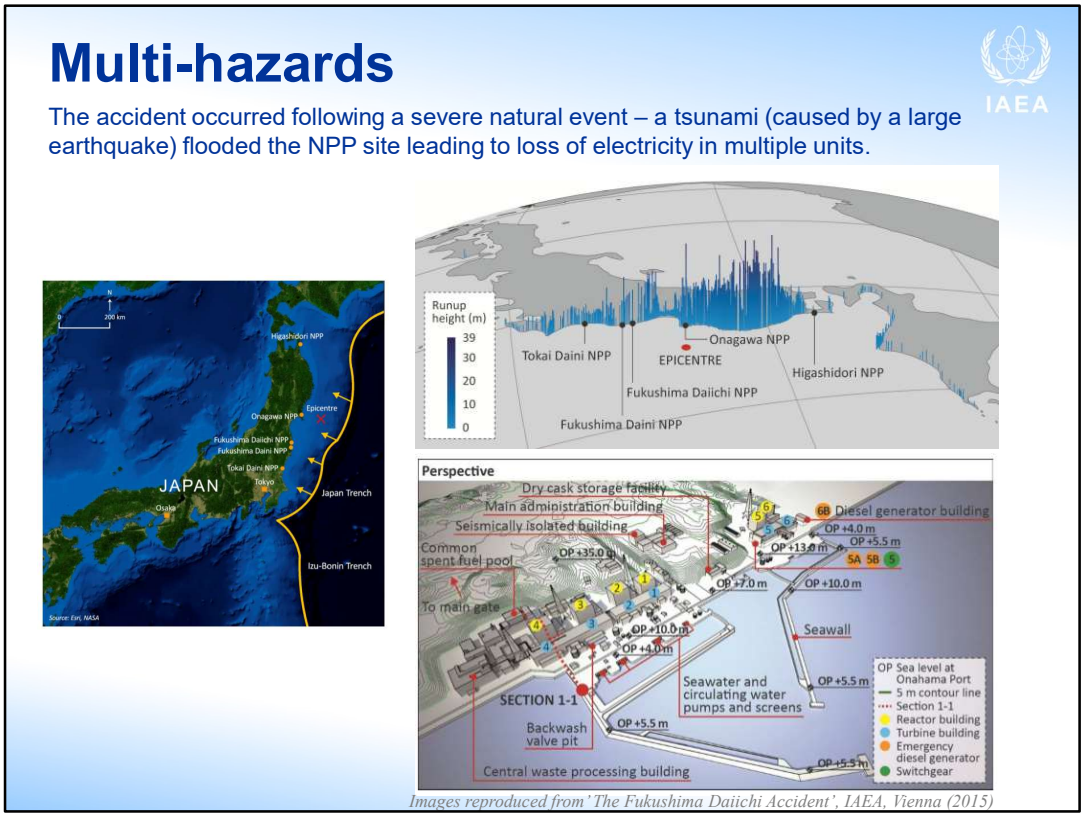
Vol. 3 : Emergency Preparedness And Response

Vol. 4 : Radiological Consequences

Vol. 5 : Post-accident Recovery

Lecture notes:

The information presented is based mainly on the report by the Director General and on Technical Volume 3 (Emergency Preparedness and Response), with some information on the longer-term situation based on Technical Volume 5.



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

Lecture notes:

This accident was unusual in involving multiple hazards that affected multiple sites and multiple units at the Fukushima Daiichi NPP site:

1. The Great East Japan Earthquake (magnitude 9.0) led to tsunamis that struck a wide area of coastal Japan, notably along the north-eastern coast, which led to the loss of many lives (15 000 people killed, over 6000 injured) and widespread damage to buildings and infrastructure (see map on the left);
2. A number of nuclear power plants are located along this coast (map on left), and while a number of them experienced waves heights considerably in excess of 10 m (see map – upper right hand side), only Fukushima Daiichi experienced a sustained loss of power on-site following inundation by the tsunami. The conditions at the other sites were such that they were able to withstand the tsunami or able to recover power;
3. At Fukushima Daiichi, the sea wall was at a height of between 5 to 10 m above normal sea level, and essential equipment, including the emergency diesel generators, were at a lower or similar level (see map – lower right hand side) and were flooded and rendered inoperable by the tsunami;

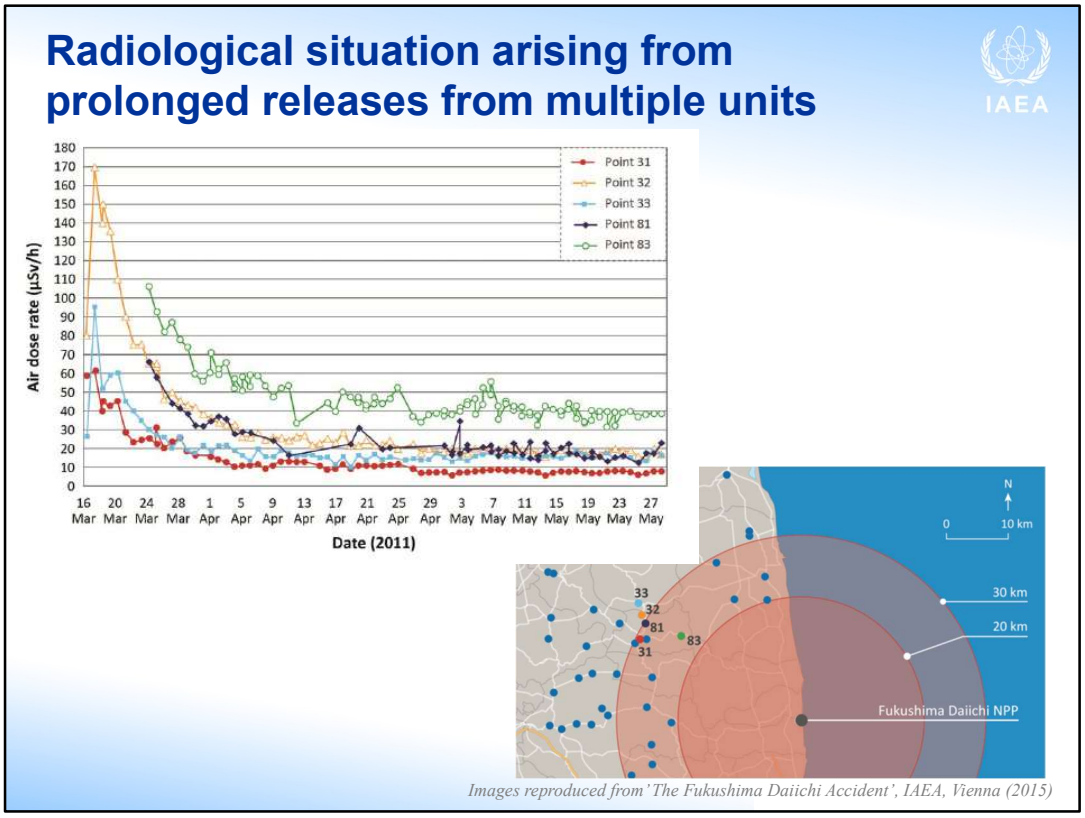
Lecture notes:

Despite efforts of the operators, the reactor cores in Units 1 – 3 overheated, nuclear material melted and the three containment vessels were breached, leading to a complex series of releases to the atmosphere. There were also releases to the marine environment.

FIG. on the left: The epicenter of the Great East Japan Earthquake and the NPPs nearby, International Atomic Energy Agency, The Fukushima Daiichi Accident, Report by the IAEA Director General, IAEA, Vienna (2015)

FIG. on the top right: The variation of tsunami wave impact, inundation (top) and runup (bottom), based on the coastal geography and topography, International Atomic Energy Agency, The Fukushima Daiichi Accident, Report by the IAEA Director General, IAEA, Vienna (2015)

FIG. on the bottom right: The elevations and locations of structures and components at the Fukushima Daiichi NPP, International Atomic Energy Agency, The Fukushima Daiichi Accident, Report by the IAEA Director General, IAEA, Vienna (2015)



Lecture notes:

The accident was characterized by a prolonged series of releases from different units, leading to a complex pattern of environmental contamination, depending on the release, weather patterns and the distance and direction from the site.

This slide shows a graph indicating the variation of ambient dose rate from 16 March to the end of May 2011 for each of the numbered/coloured points marked on the map at the bottom.

FIG. on the top: Dose rate results (μSv/h) measured from 16 March 2011 onwards at the monitoring locations indicated in the bottom figure, International Atomic Energy Agency, The Fukushima Daiichi Accident, Technical Volume 3/5, Emergency Preparedness and Response, IAEA, Vienna (2015)

FIG. on the bottom: Locations of dose rate measurements shown in the FIG. on the left, International Atomic Energy Agency, The Fukushima Daiichi Accident, Technical Volume 3/5, Emergency Preparedness and Response, IAEA, Vienna (2015)

Lecture notes:

Key points from the slide:

1. Earthquake: damaged electrical equipment off-site. Automatic shutdown of nuclear reactors and start up of emergency generators – according to plans;
2. Tsunami: flooding resulted in station blackout (complete loss of power) – declared immediately followed by declaration of nuclear emergency an hour later due to failure of core cooling at 2 units;
3. Public protective actions initiated 4 hours later by local authorities – then extended by national government almost immediately to evacuation within radius of 3 km and sheltering in the radius 3 – 10 km.

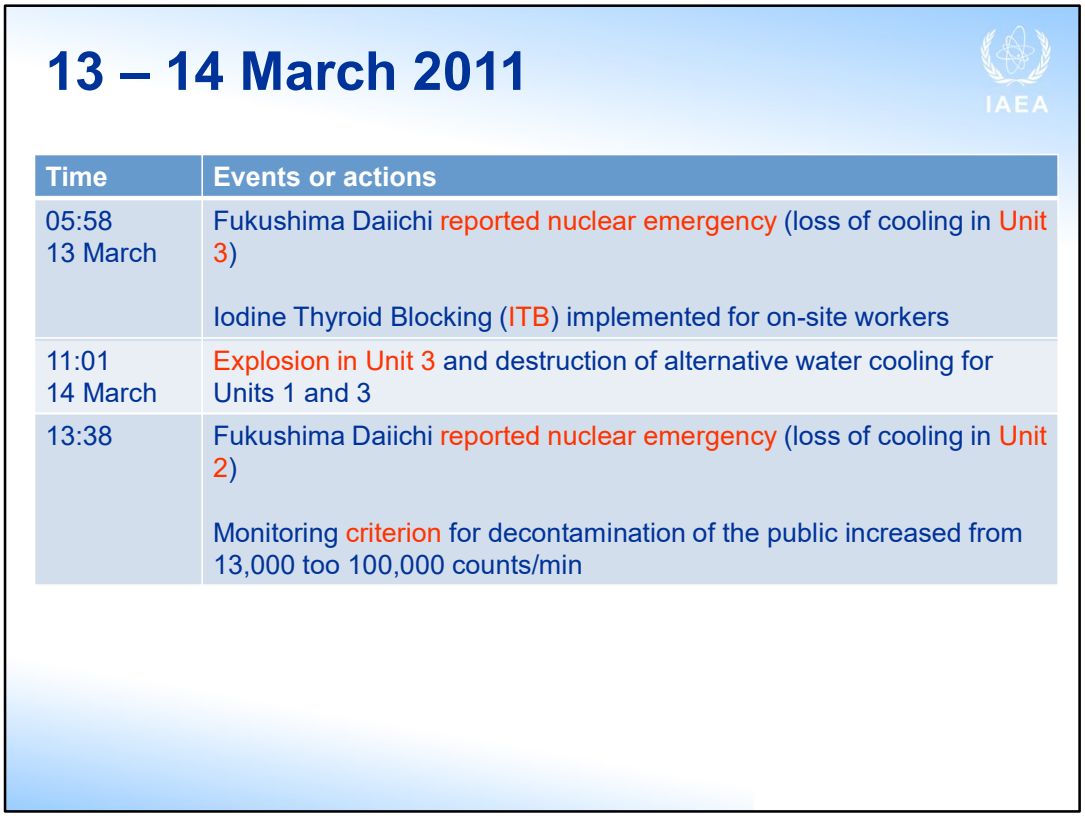
12 March 2011

Time	Events or actions
05:44	National government issued evacuation order for 10 km around the Fukushima Daiichi site
15:36	Hydrogen explosion in Unit 1, destruction of water and power provisions, degraded on-site conditions
18:25	National government issued evacuation order for 20 km around the Fukushima Daiichi site Fukushima Prefecture began monitoring evacuees (decontamination criterion 13,000 counts/min applied)

Lecture notes:

Key points from the slide:

1. Early on the 2nd day of the accident, the national government issued orders for the sheltering population to be evacuated (within 10 km of the site). Later in the day, following deterioration of the situation on-site, the evacuation order was extended to a distance of 20 km of the site;
2. The local government began monitoring evacuees – this proved a challenge to the limited monitoring resources; the processes led to delays in evacuees gaining access to evacuation centres.



Lecture notes:

Key points from the slide:

1. Early on the 3rd day of the accident, the operator reported a nuclear emergency in a third unit (Unit 3) due to loss of core cooling. This resulted in an explosion at this unit on the following day and subsequently in loss of the temporary arrangements to pump water into the reactor cores in Units 1 and 3. Later on the same day, the cooling system on Unit 2 fails. Seawater injection into Unit 2 began, and connection of a portable generator to the venting system began on the 4th day of the emergency;
2. Regarding protective actions, ITB of emergency workers on-site was initiated and the decontamination criterion for the public was increased.

15 – 16 March 2011

Time	Events or actions
05:30 15 March	National government – TEPCO Integrated Response Office established
06:14	Sound in Unit 2 primary containment vessel, explosion in Unit 4 reactor building
09:00	Maximum radiation level measured at main gate (around 12 mSv/h)
11:00	National government issued order to shelter within 20 – 30 km of site
20:50	Dose rates of few hundred microSv/h measured in locations beyond 20 km evacuation zone
	Dose criterion for emergency workers increased from 100 to 250 mSv
16 March	Evacuation of 20 km zone around Fukushima Daiichi NPP completed

Lecture notes:

1. On the morning of the 5th day of the emergency, the government and the operator established an integrated respond office to improve coordination of activities;
2. Maximum dose rates were measured at the site, following sounds in Unit 2 and an explosion in the building of Unit 4 (subsequently thought to be due to gases passing into the building from Unit 3), indicating the occurrence of a significant release of radionuclides. Enhanced dose rates exceeding few hundred μSv/h (exceeding OIL2 for implementation of early protective actions) measured beyond 20 km (evacuation zone);
3. Worker protection: dose criterion increased to allow essential on-site mitigatory actions to be performed;
4. Public protective actions ordered included sheltering 10 km radius beyond evacuation zone of 20 km (evacuation completed on 6th day of accident);
5. Continuation of urgent protective actions in this period.

17 March – 17 April 2011

Date	Events or actions
17 March	Provisional Regulation Values established to restrict food and drinking water
20 March	National government received aerial monitoring data from USA Characterization of exposure situation began
21 March	National government began to issue restrictions on the distribution of specific foods
22 March	Residents advised not to allow infants to drink tap water at specified locations
25 March	National government recommended voluntary evacuation of residents within 20 – 30 km of the site
11 April	National government announced 20 mSv criterion for relocation from areas beyond 20 km zone
17 April	TEPCO issued Roadmap for on-site recovery

Lecture notes:

Key points from the slide:

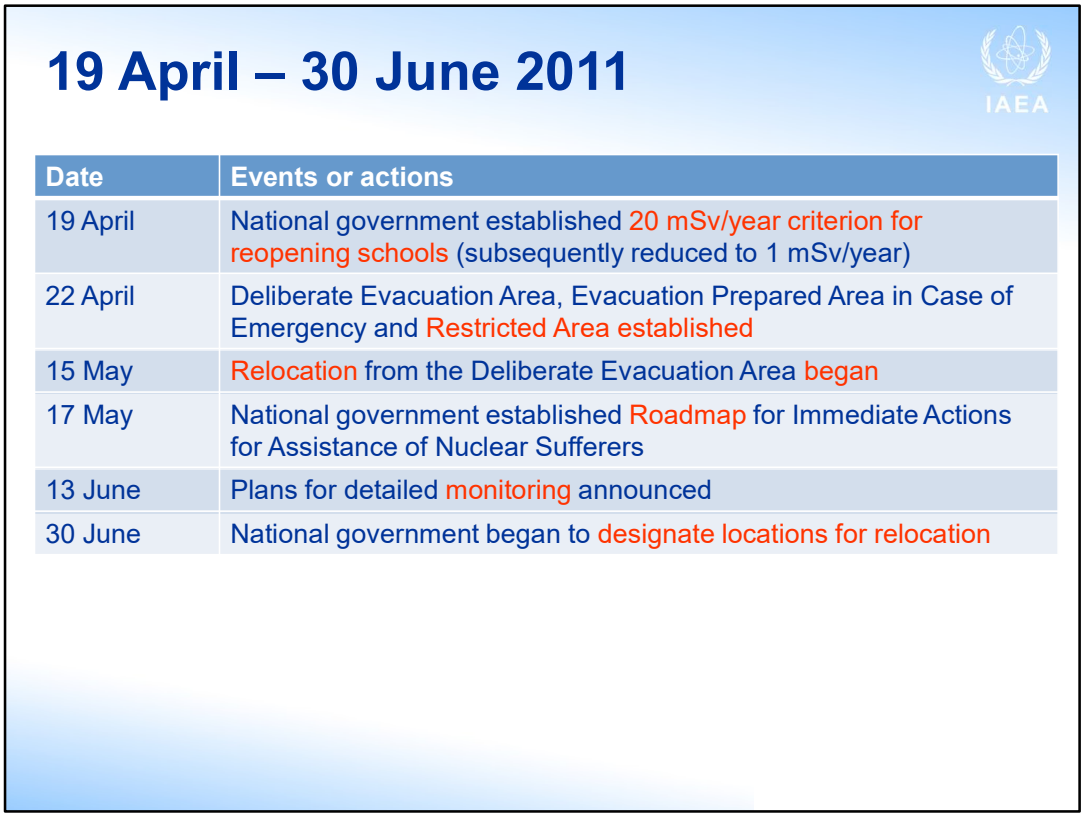
- Implementation of urgent protective actions for public protection continues 1 – 2 weeks after the start of the emergency;

Notably with:

1. The provision and application of values for restrictions on drinking water and foods;
2. The government recommended voluntary evacuation from the area in which people had previously been advised to shelter (20 – 30 km);
3. One month after the beginning of the emergency (11 April), the government began to make plans for early protective actions (with the announcement of the criterion for relocation beyond the zone already affected);

Lecture notes:

4. Shortly afterwards, the operator released the roadmap for on-site recovery (which specified measures to ensure stable cooling, the reduction of releases, prevention of accumulation of hydrogen and criticality) and including 2 conditions necessary to consider the stabilization of the on-site situation: (i) cold shut down (interpreted as significant reduction in releases and dose rates); and (ii) significant suppression of radioactive releases.



Lecture notes:

Key points from the slide:

NOTE TO LECTURER: In GSG-11 analysis, 22 April is considered the beginning of early response phase – please draw attention to the change of the focus of protective and other response actions in this period but do not explicitly identify this date – the participants will be expected to identify the approximate date during the exercise.

- In this period, the situation had become sufficiently stable that activities related to the establishment of normal life (opening of schools) are considered.

In addition, areas were delineated corresponding to the following areas:

1. Restricted: from which people have already been evacuated;
2. Deliberate evacuation: in which the early protective action of 'deliberate evacuation' (or relocation) was envisaged and began on 15 May (just over 2 months after the beginning of the emergency);

Lecture notes:

3. Evacuation prepared area: where there would be a need for further evacuation if the on-site situation was to deteriorate;
4. In addition, a strategy for the early response phase (the road map for immediate actions) was released, followed by plans to support characterization of the situation for longer-term decision making (monitoring plans).

From the end of June longer-term actions begin – notably:

1. Relocation based on monitoring information (Specific Spots Recommended for Evacuation).

Accumulated deposition of Cs-137

By July 2011, a detailed understanding of the distribution of radionuclides deposited in the areas around the site had been established.

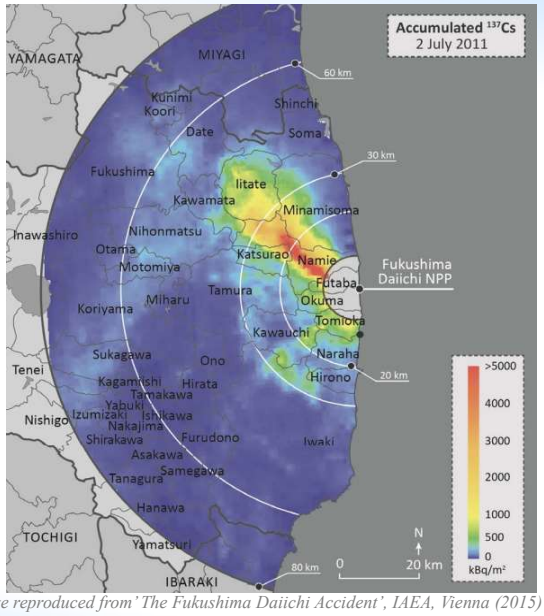


Image reproduced from 'The Fukushima Daiichi Accident', IAEA, Vienna (2015)

Lecture notes:

As a consequence of the monitoring strategy, by July, the distribution of activity was understood and could be used as a basis for longer-term decision-making.

FIG.: Actual Cs-137 deposition concentrations, International Atomic Energy Agency, The Fukushima Daiichi Accident, Technical Volume 3/5, Emergency Preparedness and Response, IAEA, Vienna (2015)

1 July – 30 September 2011

Date	Events or actions
July	Comprehensive medical check ups began
19 July	Basic Policy on Radiation Protection for Termination of Evacuation and Reconstruction issued
25 July	Radiation Monitoring Action Plan for Homecoming regarding the Evacuation Prepared Area established
4 Aug.	Nuclear Safety Commission issued views on termination of urgent protective actions
26 Aug.	Enactment of Act on Special Measures Concerning the Handling of Environmental Pollution Policies for decontamination works issued by NERHQ Guidelines for protection of emergency workers issued
19 Sept.	Disaster recovery programmes prepared for Evacuation Prepared Areas
30 Sept.	Evacuation Prepared Area lifted

Lecture notes:

Key points from the slide:

NOTE TO LECTURER: In GSG-11 analysis, 19 July is considered to mark the end of early response phase/beginning of transition phase – please draw attention to the change of the focus of protective and other response actions in this period but do not explicitly identify this date – the participants will be expected to identify the approximate date during the exercise.

- By 19 July the situation had effectively stabilized and the protection strategy for the longer-term has been developed (such actions are indicative of the beginning of the transition phase).

Notably:

1. The first condition for 'cold shutdown' – radiation doses in steady decline – was achieved on 19 July;
2. The policy for radiation protection for termination and reconstruction was issued.

Lecture notes:

On the basis of this, a monitoring plan was established and views on the termination strategy for urgent actions were released.

This is followed by the legislation necessary to implement longer-term protective actions, which also specifies which level of government is primarily responsible for preparing plans for future actions.

By the end of September – the Evacuation Prepared Area is lifted under conditions specified in the recovery programmes for these areas.

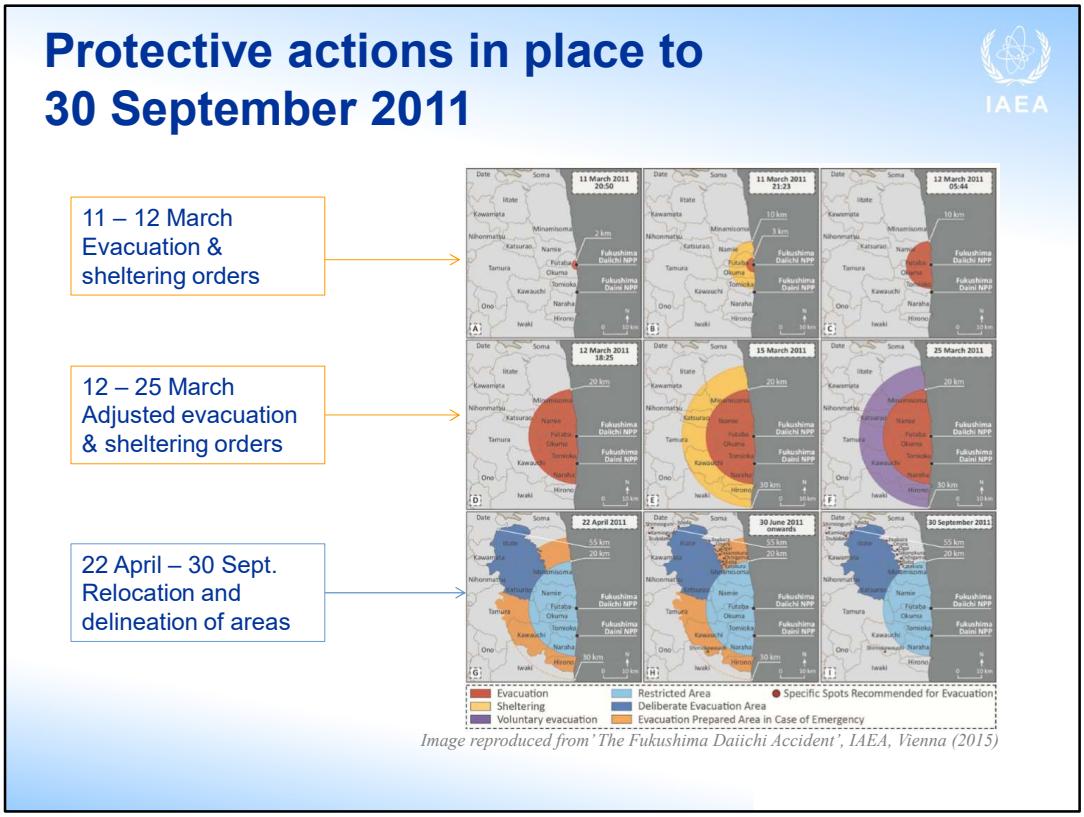


Image reproduced from 'The Fukushima Daiichi Accident', IAEA, Vienna (2015)

Lecture notes:

This slide summarizes the evolution of protective actions in place in the period from 11 March (beginning of the emergency) until 30 September.

NOTE TO THE LECTURER: Do not specify a specific phase when presenting the slide, as this is a task for participants.

The first two rows are primarily associated with urgent protective actions and their adjustment to address the evolving situation = urgent response phase.

The bottom row begins with the early response phase (with the specification of the different areas).

Between 30 June and 30 September – the on-site situation had stabilized (notable milestone 19 July – noted on previous slide) and the radiological situation had been sufficiently characterized to provide the basis for planning for termination and recovery = transition phase.

Lecture notes:

The transition phase (July – December 2011) included the following activities:

(a) Detailed monitoring to characterize the exposure situation and exposure pathways;

(b) Arrangements for the implementation of long-term health surveillance;

(c) Determination of the criteria for the termination of protective measures;

(d) Formalization of the long-term management of radioactive waste;

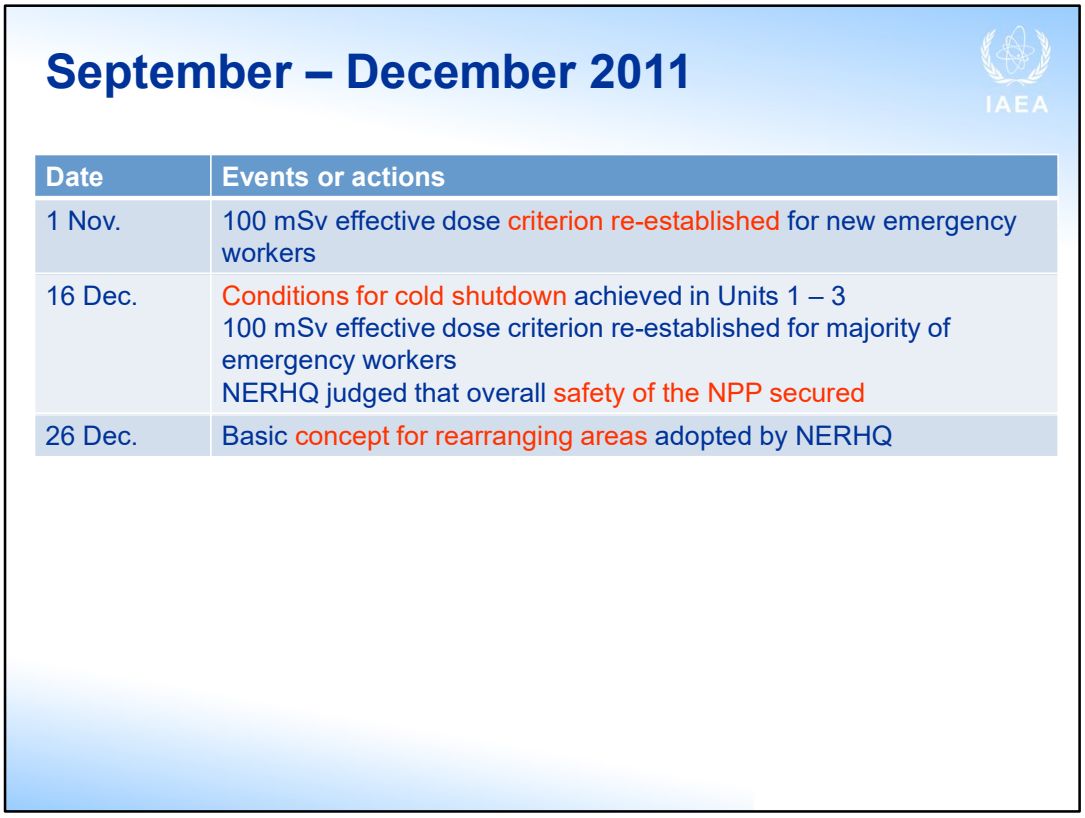
(e) Adjustment of arrangements for the protection of emergency workers, other workers and helpers, both on and off the site;

(f) Re-evaluation and rearrangement of areas in which protective actions were in place;

(g) Establishment of long-term plans for decontamination;

(h) Announcement that control of the situation had been regained at the plant.

FIG.: Areas and locations where protective actions were ordered or recommended until 30 September 2011, International Atomic Energy Agency, The Fukushima Daiichi Accident, Technical Volume 3/5, Emergency Preparedness and Response, IAEA, Vienna (2015)



Lecture notes:

Key points from the slide:

1. By 1 November, the on-site situation was sufficiently stable to allow the effective dose criterion to be re-established for new emergency workers, and for all but a few workers by mid-December;
2. On 16 December, the second condition for cold shutdown was reached, and the National Emergency Response HQ declared that the safety of the NPP had been secured.

NOTE TO LECTURER: Although no formal end to the emergency was declared at this time, these conditions, together with the review and establishment of necessary protective actions and the establishment of strategies for recovery, indicate that, according to GSG-11, the prerequisites for termination have been achieved by around 16 December 2011. This is the date participants will be expected to identify during the exercise.

January – April 2012

Date	Events or actions
1 Jan	Act on Special Measures came into force
1 April	Standard limits for activity concentrations in food and drinking water established based on dose criterion of 1 mSv/year
30 April	100 mSv effective dose criterion re-established for remaining group of workers
	…

Lecture notes:

Key points from the slide:

1. In the first quarter of 2012, the legislation to allow longer-term recovery (in an existing exposure situation) was in place. Standard criteria for food were also established. The pre-accident criterion for emergency workers was also re-established for the small group of workers still subject to the higher dose criterion, just over one year after the accident;
2. Recovery continues – based, among other things, on a continuing monitoring programme.

Estimated integrated dose (mSv) received in first year (up to 11 March 2012)

After 1 year, detailed assessment of doses received in areas around the site established

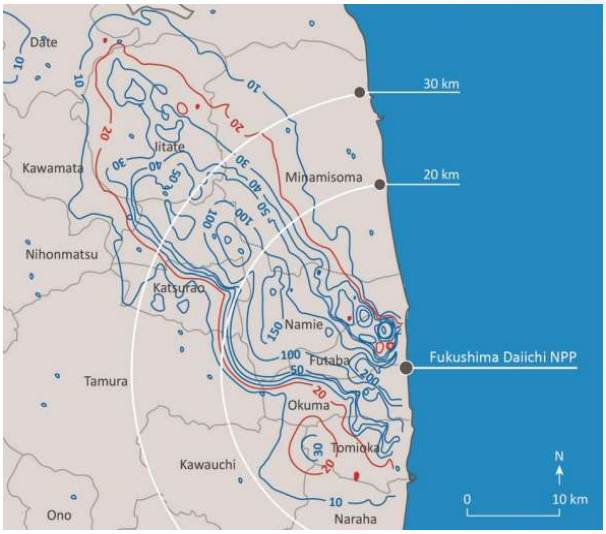


Image reproduced from 'The Fukushima Daiichi Accident', IAEA, Vienna (2015)

Lecture notes:

Key points from the slide:

1. Detailed characterization of the doses received as a function of location is a useful input into retrospective determination of the effectiveness of protective actions implemented and the need for further actions (e.g. medical follow-up, information provision).

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

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

Continued monitoring demonstrates the change in the radiological situation as a function of time

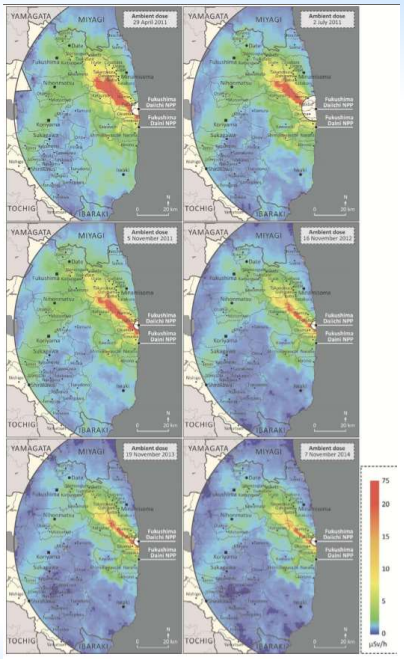


Image reproduced from 'The Fukushima Daiichi Accident', IAEA, Vienna (2015)

Lecture notes:

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)

Designation of areas

Areas designated to identify those where return is possible as an input to establishing priorities and responsibilities for undertaking activities to facilitate return

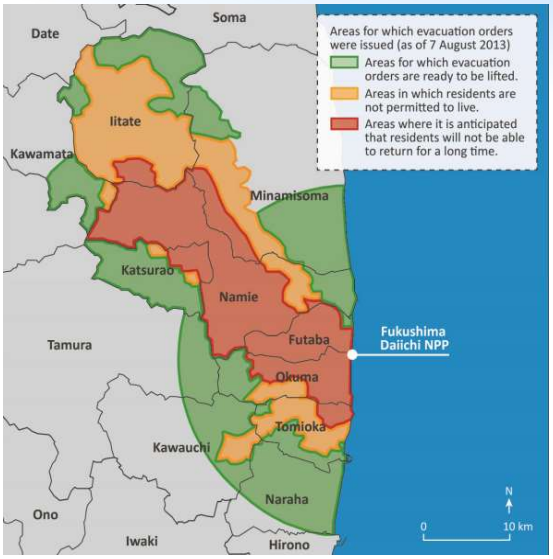


Image reproduced from 'The Fukushima Daiichi Accident', IAEA, Vienna (2015)

Lecture notes:

Key points from the slide:

1. The restricted areas and areas for which evacuation orders had been issued would be re-arranged into three areas: areas for which evacuation orders were ready to be lifted; areas in which the residents were not permitted to live; and areas where it was expected that the residents would not be able to return for a long time. The arrangement for the areas where evacuation orders had been issued was completed on 7 August 2013.

FIG.: Completion of the arrangement for areas where evacuation orders have been issued (7 August 2013), International Atomic Energy Agency, The Fukushima Daiichi Accident, Technical Volume 3/5, Emergency Preparedness and Response, IAEA, Vienna (2015)

Status of areas in SDA, December 2014

The status of remediation and evacuation orders in the 'Special Decontamination Area'

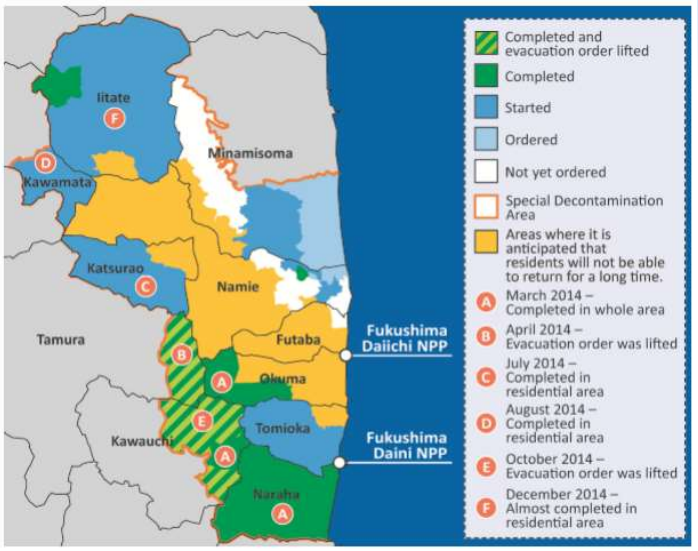


Image reproduced from 'The Fukushima Daiichi Accident', IAEA, Vienna (2015)

Lecture notes:

Key points from the slide:

1. The restricted areas and areas for which evacuation orders had been issued would be re-arranged into three areas: areas for which evacuation orders were ready to be lifted; areas in which the residents were not permitted to live; and areas where it was expected that the residents would not be able to return for a long time. The arrangement for the areas where evacuation orders had been issued was completed on 7 August 2013;
2. The map demonstrates the status of recovery activities and the status of the different areas 3 years after the accident.

FIG.: Progress in remediation in SDAs up to December 2014, International Atomic Energy Agency, The Fukushima Daiichi Accident, Technical Volume 5/5, Post-accident Recovery, IAEA, Vienna (2015)

Discussion

- Based on this information, please discuss and answer the questions distributed for this Case Study (*Case Study Part 2 and Part 3: Analysis of the Fukushima Daiichi NPP accident and the radiological incident in Hueypoxtla, Mexico)* within your working group.
  - Time allocated: **15 min**

Lecture notes:

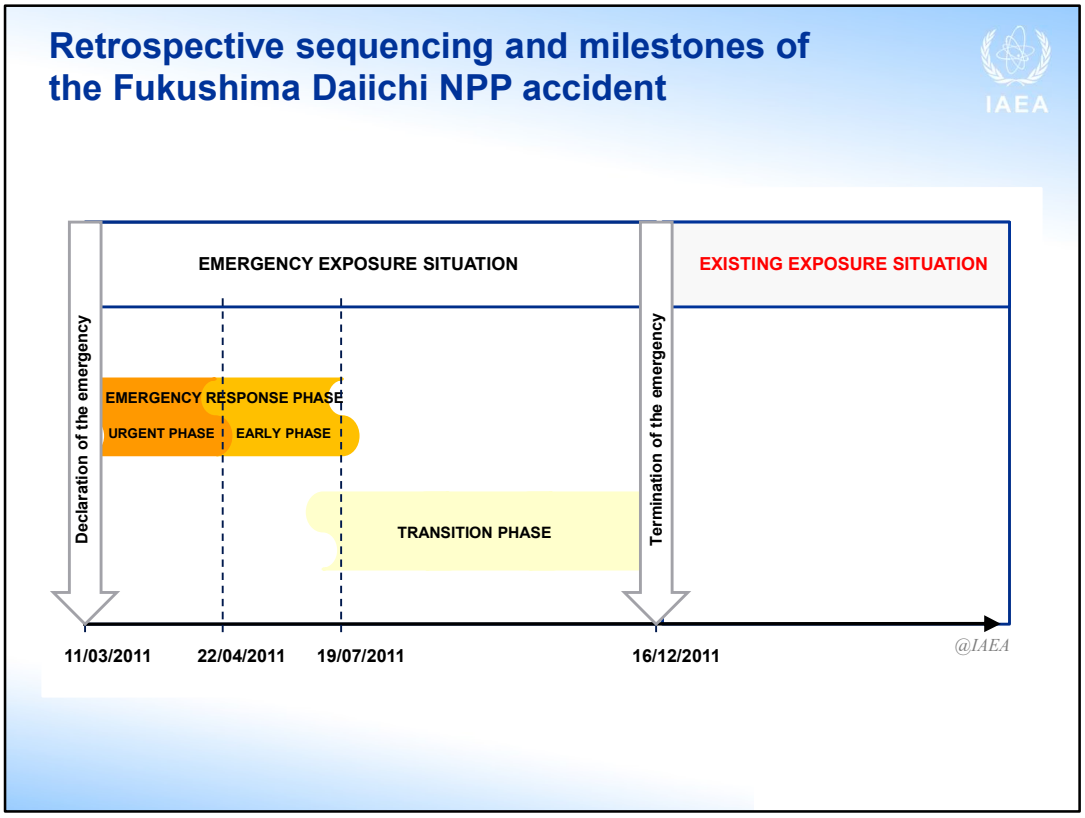
Allow participants to discuss and answer the questions within their working groups for about 15 min.

Let's discuss:

- What urgent protective actions were implemented and when was their implementation completed?
- What early protective actions were implemented and when was their implementation completed?
- What activities were implemented to characterize the situation and to support resumption of normal social and economic activity and when were preparations for this resumption completed?
- When were conditions ensured that allowed for the emergency to be terminated?
  - Time allocated: **20 mins**

Lecture notes:

After the time for discussion and answering questions has passed, pose each question and allow participants from different Working Groups to answer it and to provide the basis for their answers (for about 20 minutes). Only after all questions and answers are covered, move on and present the next slides.



Lecture notes:

This slide and the following one (giving the basis for the milestones) should be used after the participants of the workshop have considered and discussed the dates and the nature of the different phases for this case study.

These dates are based on the analysis in GSG-11. Attention should be drawn to the overlapping nature of the phases – the dates are approximate. There is no sharp distinction between them but a gradual evolution in the focus of protective actions and other response actions over time.

FIG.: Courtesy of International Atomic Energy Agency

Basis for the milestones

- Urgent protective actions, such as the evacuation and sheltering of people in the vicinity of the site were implemented after the emergency declaration (11 March 2011), and restrictions on the distribution and consumption of food and drinking water were implemented during the following days.
- Early protective actions, such as the relocation of people outside the evacuation areas and the relocation of people from locations at which hot spots of activity had been identified, were taken on the basis of detailed monitoring primarily during the first few months. Still, a few hot spots were detected as late as November 2011.
- Steady decline of radiation doses achieved during emergency response phase that lasted to about 19 July 2011.
- The following months (July – December) can be considered as the transition phase, during which policies and arrangements for the recovery phase were established.
- Conditions for cold shutdown / stable condition of the NPP were confirmed on 16 December 2011.

Case studies

- Detailed in Annex I of IAEA Safety Standards Series No. GSG-11 for further information

Lecture notes:

Thank you!