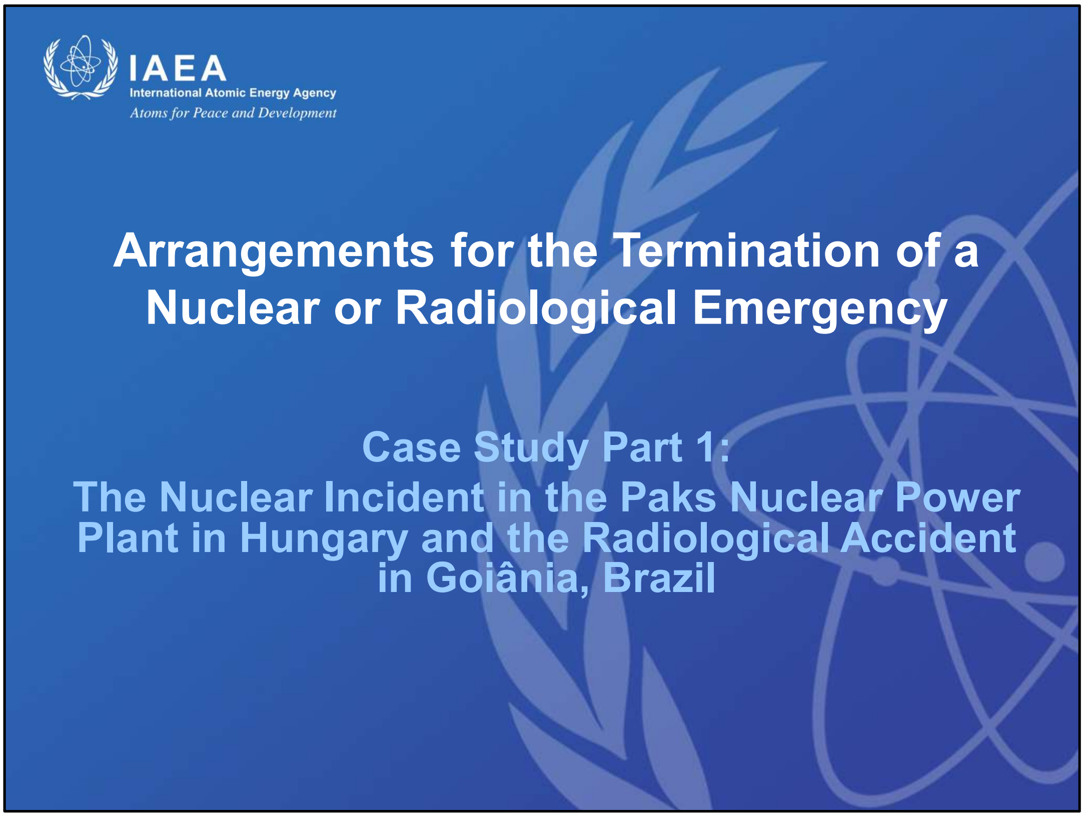
Arrangements for the Termination of a Nuclear or Radiological Emergency



Case Study: Part 1. The Nuclear Incident in the Paks Nuclear Power Plant (NPP) in Hungary in 2003 and the Radiological Accident in Goiânia, Brazil in 1987

Purpose of the Presentation:

- To present and discuss the emergency response to the nuclear incident in the Paks NPP in Hungary in 2003 and to the radiological accident in Goiânia, Brazil, in 1987
- To analyze these events in the context of transitioning to a planned exposure situation and to an existing exposure situation

Learning Objectives:

In the context of past experience, participants should be able to differentiate between:

- Different situations of exposure and
- Transition to a planned exposure situation and transition to an existing exposure situation

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 Radiological Accident in Goiânia, IAEA, Vienna (1988).
3. Hungarian Atomic Energy Authority, Report to the Chairman of the Hungarian Atomic Energy Commission on the Authority's Investigation of the Incident at Paks Nuclear Power Plant on 10 April 2003 (2003).
4. International Atomic Energy Agency, Report of the Expert Mission 'To Assess the Results of the Hungarian Atomic Energy Authorities Investigation of the 10 April 2003 Fuel Cleaning Incident at Paks NPP' (16–25 June 2003).
5. Operational Safety Review Team (OSART) Mission, 8–25 October 2001 to the Hungarian Atomic Energy Authority and Paks Nuclear Power Plant, Hungary; and Follow-Up Visit, 21 February–1 March 2005 (TC Project HUN/9/022, IAEA-TCR 02581, IAEA NSNI 112F), IAEA, Vienna (2005).
6. International Atomic Energy Agency, OECD–IAEA, Paks Fuel Project: Final Report, IAEA, Vienna (2010).

Purpose

- To present and discuss the emergency response to the nuclear incident in the Paks NPP in 2003 in Hungary and to the radiological accident in 1987 in Goiânia, Brazil.
- To analyze these events in the context of transitioning to a planned and an existing exposure situation.

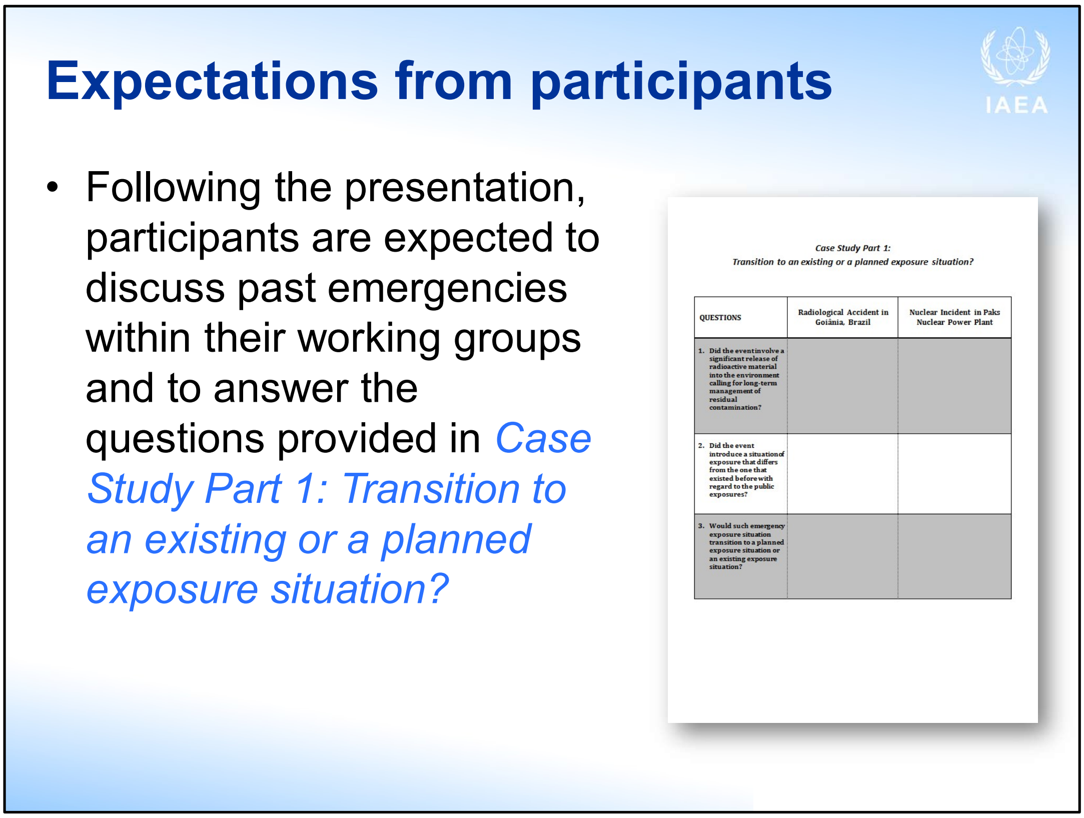
*The Case Study is **not** an assessment of the emergency response to these events but an opportunity to illustrate transitioning from an emergency exposure situation to either a planned or an existing exposure situation in the context of IAEA Safety Standards Series No. GSG-11.*

Learning objectives

- In the context of past experience, to differentiate between:
  - Different situations of exposure;
  - Transition to a planned exposure situation and transition to an existing exposure situation.

Contents

- Nuclear incident in Paks Nuclear Power Plant in 2003
- Radiological accident in Goiânia, Brazil, in 1987
- Discussion and feedback session



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 5 mins or earlier if they are ready).

THE NUCLEAR INCIDENT AT THE PAKS NUCLEAR POWER PLANT, HUNGARY

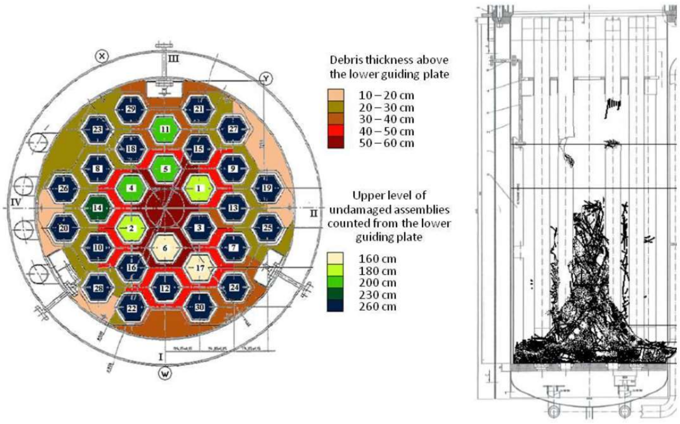


Image courtesy of the HAEA and Paks NPP

Lecture notes:

FIG: Extent of damage and location of fuel debris (courtesy of the Hungarian Atomic Energy Authority and the Paks nuclear power plant), International Atomic Energy Agency, Arrangements for the Termination of a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSG-11, IAEA, Vienna (2018)

10 April 2003
The event sequence

- 30 fuel assemblies of Unit 2 reactor of Paks NPP were being cleaned in a fuel cleaning tank adjacent to the fuel pool:
  - The aim was to remove magnetite deposition on fuel cladding.
- At 21:53 UTC, the noble gas monitors in the reactor hall indicated that the emergency level had been reached.

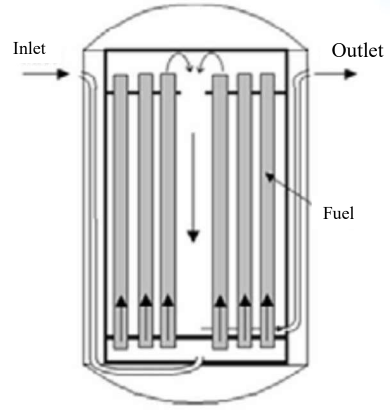
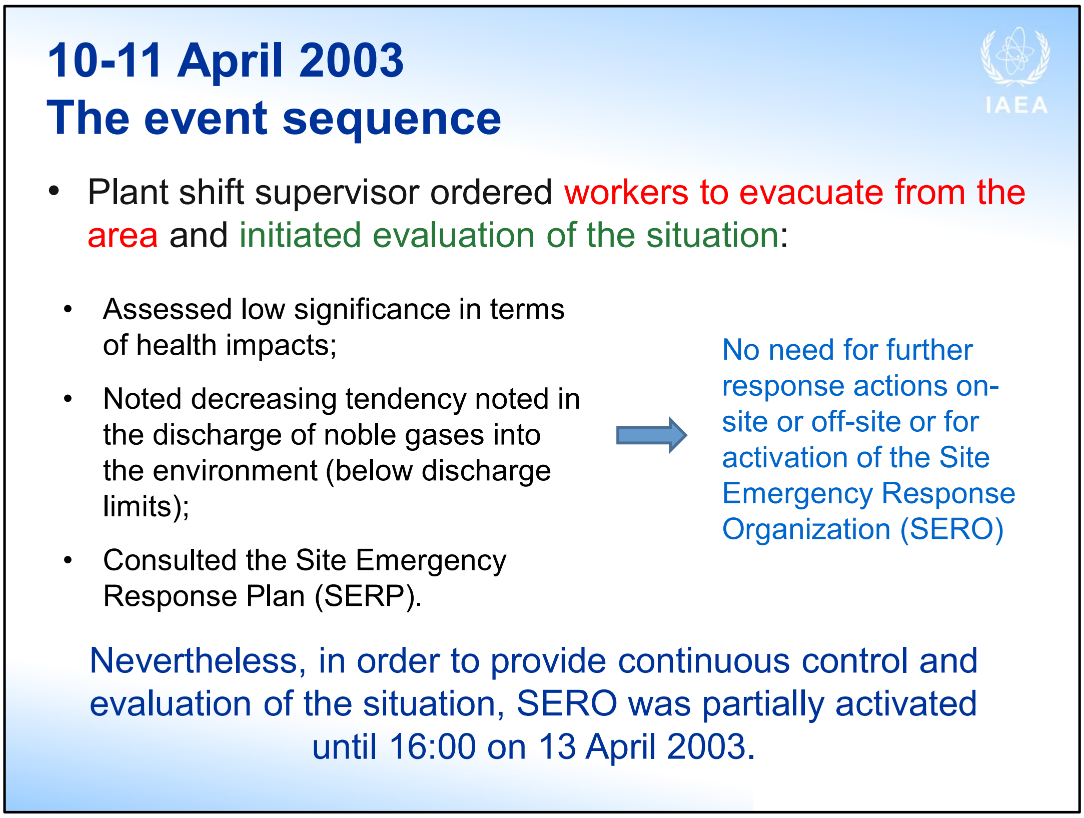


Image reproduced from OECD/IAEA, Paks Fuel Project: Final Report, IAEA, Vienna (2010)

Lecture notes:

On 10 April 2003, the external surfaces of thirty fuel assemblies that had been removed from the Unit 2 reactor at Paks NPP and placed in a fuel cleaning tank approximately 10 m under water in a shaft adjacent to the fuel pool were being cleaned to remove depositions of magnetite from the fuel assembly cladding. At 21:53 on 10 April 2003, workers detected an increase in the activity of ^{85}Kr from a measurement system installed in the cleaning circuit. At about the same time, the instruments measuring the activity concentrations of noble gases in the reactor hall indicated that the ‘emergency level’ had been reached.

FIG.: Flow scheme of the cleaning tank, International Atomic Energy Agency, OECD/IAEA, Paks Fuel Project: Final Report, IAEA, Vienna (2010)



Lecture notes:

The plant shift supervisor ordered the evacuation of workers from the area. Initially, it was suspected that a fuel assembly was leaking as a result of the cleaning operation. However, several days later, a video inspection indicated that most of the fuel had suffered heavy damage. About 16–17% of the fuel material was located at the bottom of the cleaning vessel in the form of debris.

Although the airborne release was higher than the normal situation, it exhibited a decreasing tendency and, according to the data available, did not approach the national prescribed discharge limits. When all of the information and release data had been collated and reviewed, the situation was re-evaluated, and it was confirmed that the event did not constitute an accident and to be of low significance in terms of health impacts.

After the incident had been identified, the SERO was partially set up to provide continuous control and evaluation of the occurrences.

16 April 2003
New insights

- Removal of the tank lid revealed extent of damage to the fuel assemblies within the tank.

- SERO activated until 20 April 2003 in partial response mode:
  - Assessment of situation;
  - Communication and coordination with authorities;
  - Increased readiness for full activation.

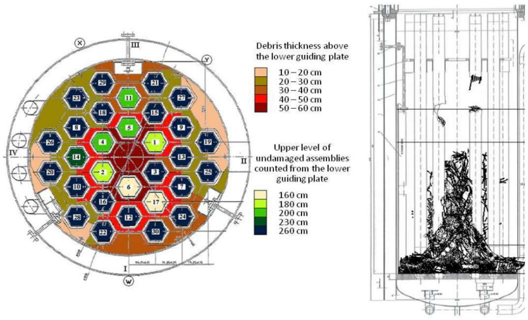


Image courtesy of the HAEA and Paks NPP

Lecture notes:

The SERO operated in accordance with the relevant procedures until 13 April 2003, when its operation was terminated. After the removal of the tank lid on 16 April 2003, the extent of the damage to the fuel assemblies within the tank was recognized and the SERO was reactivated. This status was maintained until 20 April 2003. During this period, the SERO operated in partial response mode at the emergency response centre and continually evaluated the situation, kept in contact with authorities and exercised readiness for full activation if the situation got worse.

The Figure shows the extent of damage and location of the fuel debris.

Major challenge faced by operator

- Inability to fully understand the situation and the nature of release at the time.
- No specific plan and procedures for dealing with such situations.

Lecture notes:

The operator faced two major challenges associated with the lack of clear understanding of the situation and specific arrangements to deal with such situation.

Off-site response

- Monitoring initiated in areas surrounding the Paks NPP as of 11 April 2003:
  – The results from the survey covering the period from 11 to 26 April 2003 confirmed that no significant release had occurred warranting public protective actions.
- Dose assessment initiated as of 16 April 2003:
  – Doses assessed to be less than the dose to the public from the exposure to natural background for one day.
- Provision of public information and issuing of press releases initiated as of 11 April 2003;

Lecture notes:

The off-site response actions were focused on monitoring off-site areas, dose assessment and public communication.

A coordinated environmental monitoring survey was initiated to assess the radiological situation in the areas surrounding the Paks nuclear power plant to determine whether any off-site protective actions were needed and to provide authentic, trustworthy and timely information to the public. The survey covered the entire period of the incident from 10 to 26 April 2003. On the basis of the measurements results and the assessment of the situation after the incident, it was concluded that no significant release had occurred and that no actions were needed for the protection of the public.

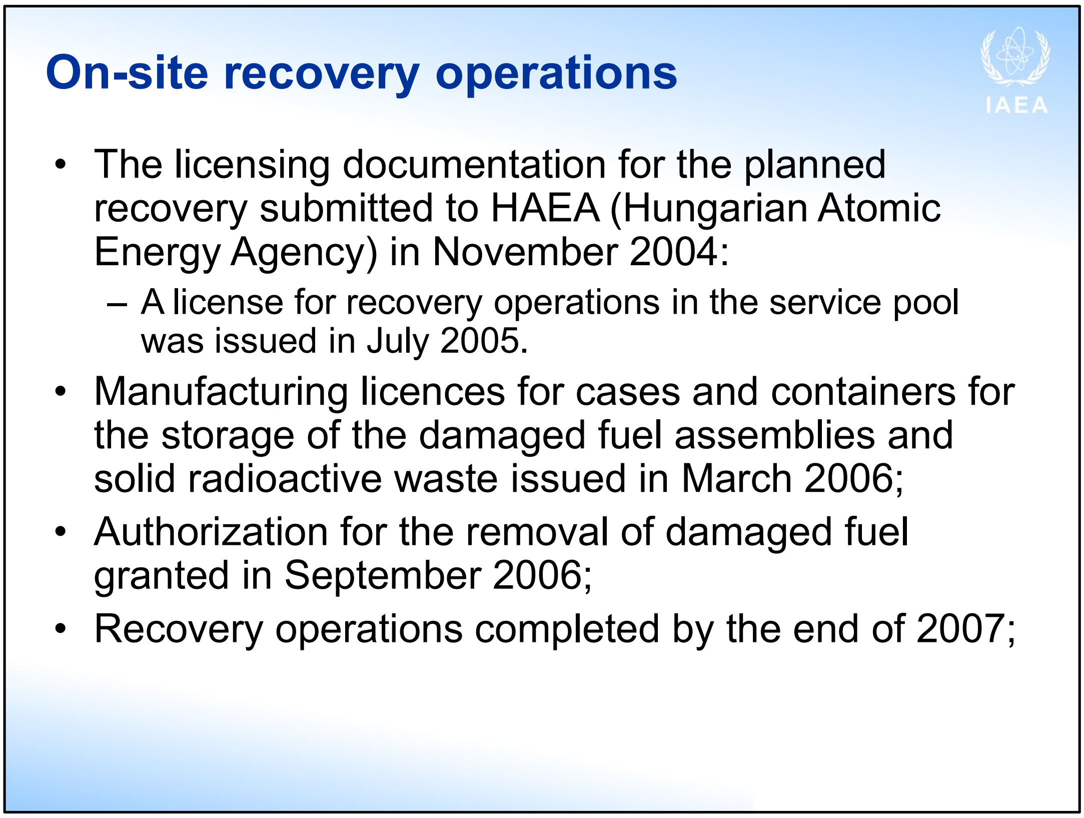
The national requirements and the nature of the hazard did not necessitate warning the public of impending protective actions. However, the incident was immediately communicated to the mayors of communities within a 30 km range of the power plant. The public was informed of the incident in the early morning of 11 April 2003. Particular emphasis was placed on public communications, and all locally available channels of communication were used for this purpose.

On-site response efforts

- Determination of the radiological situation in the reactor hall and ensuring stability;
- Measures for protection of on-site workers:
  - Within the requirements and dose limits for occupational exposure during normal operation.
- Planning for recovery operations:
  - 17 April 2003: Continuous cooling of the cleaning tank ensured;
  - Professional teams involving specialists from various fields of expertise were formed to identify alternatives for recovery:
    - An autonomous cooling system and an emergency boron system for the service pool were established during the first half of 2004.

Lecture notes:

The on-site response efforts focused on assessing the situation and ensuring that it remains stable, protecting the emergency workers and for planning the recovery operations.



Lecture notes:

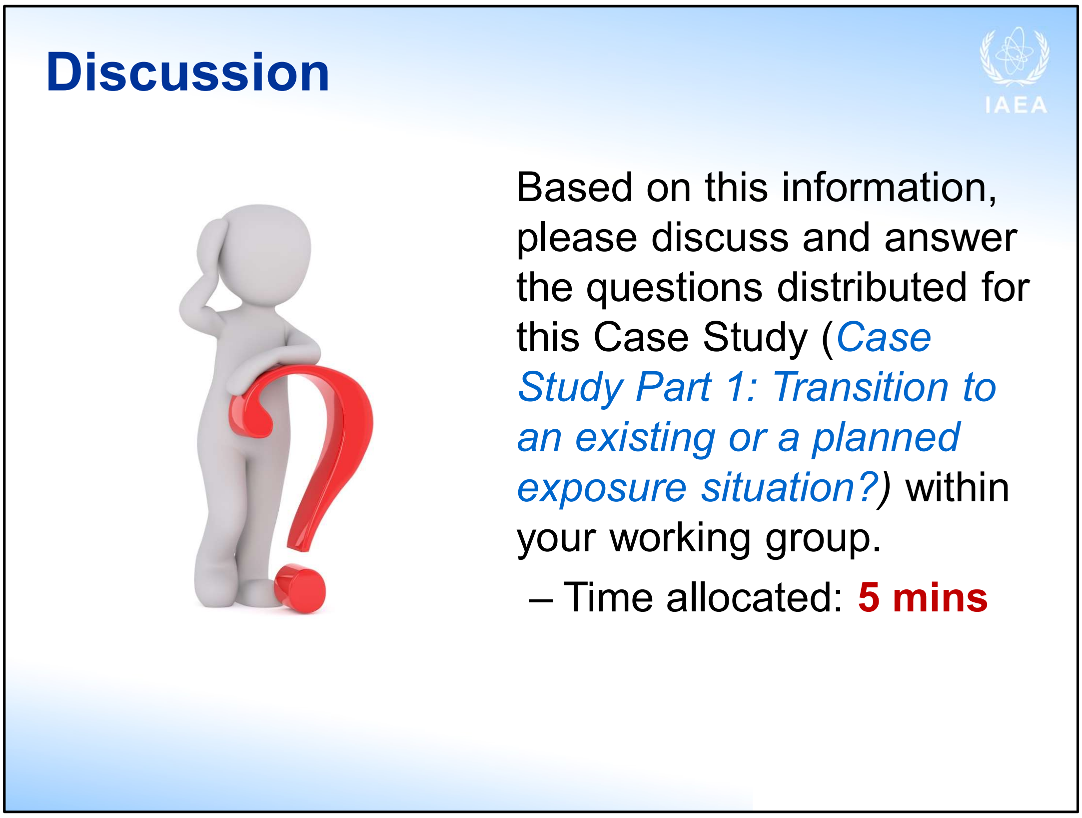
HAEA issued authorization/licence for the on-site recovery operations at various stages and the overall recovery was completed by the end of 2007.

Additional activities

- Independent investigations (national and international) during 2003:
  - Operator, HAEA, Parliamentary Committee;
  - IAEA to assess the results of HAEA investigation.
- Deficiencies in various areas in EPR identified and action plan developed following the IAEA mission in June 2003:
  - Action plan approved by HAEA and improvements (e.g. emergency classification, drills and exercises, training etc.) implemented by 2006.

Lecture notes:

The event was investigated (nationally and internationally) and lessons were identified already the same year, while the identified corrective actions were implemented by 2006.



Lecture notes:

Allow participants to discuss and answer the questions within the working groups for about 5 mins.

THE RADIOLOGICAL ACCIDENT IN GOIÂNIA, BRAZIL

Image reproduced from 'The Radiological Accident in Goiânia', IAEA , Vienna (1988)

13 September 1987
The initial event

- Person A and Person B dismantled a teletherapy unit found in an abandoned clinic in Goiânia, a small city located in central Brazil.

Images reproduced from 'The Radiological Accident in Goiânia', IAEA , Vienna (1988)

Lecture notes:

The event had its beginning on 13 September 1987 in the abandoned premises of a hospital that had moved to new buildings. A caesium-137 teletherapy unit was left in the old building and was found by two persons looking for scrap metal.

FIG. on the left: The derelict radiotherapy clinic in Goiânia from which the caesium source was taken., International Atomic Energy Agency, The Radiological Accident in Goiânia, IAEA, Vienna (1988)

FIG. on the right: Map of Goiânia showing the location of the source. International Atomic Energy Agency, The Radiological Accident in Goiânia, IAEA, Vienna (1988)

13 September 1987
Removal of the source

- These two persons removed the source rotating assembly and carried it to Person A’s house in a wheel barrow.
- In the evening, they both began to vomit.

Image reproduced from ‘The Radiological Accident in Goiânia’, IAEA , Vienna (1988)

Lecture notes:

These two persons took the source rotating assembly from the device and carried it to the house of one of them.

In the evening of the same day, both of them became sick and began to vomit.

FIG.: Map of Goiânia showing the movement of the source, International Atomic Energy Agency, The Radiological Accident in Goiânia, IAEA, Vienna (1988)

14 – 15 September 1987
Initial medical symptoms

IAEA

- Person B suffered from diarrhoea, felt dizzy and one of his hands was swollen (oedema), but his symptoms were diagnosed as being caused by an allergy.

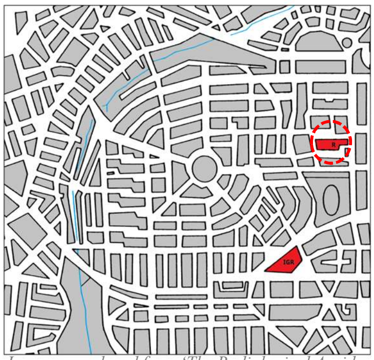


Image reproduced from 'The Radiological Accident in Goiânia', IAEA , Vienna (1988)

Lecture notes:

One the next day, one of the two suffered from diarrhoea, felt dizzy and had an oedema on one of his hands.

When he went to the doctor the day after, he was diagnosed with having an allergy.

FIG.: Map of Goiânia showing the movement of the source, International Atomic Energy Agency, The Radiological Accident in Goiânia, IAEA, Vienna (1988)

18 September 1987
Source damage

- In his garden, Person A worked to remove the source wheel from the rotating shutter, accidentally punctured the source capsule with a screwdriver and removed some of the material.

- Person A sold the pieces of the rotating assembly to Person C, the owner of a junkyard (JY I).

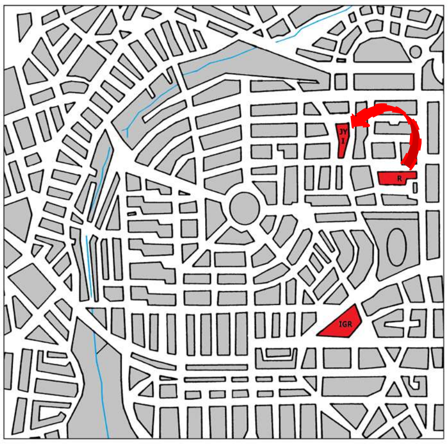


Image reproduced from 'The Radiological Accident in Goiânia', IAEA , Vienna (1988)

Lecture notes:

A couple of days later, the first person tried to remove the source wheel from the rotating shutter and accidentally punctured the source capsule with a screwdriver. He scooped out some of the material thinking that it was gunpowder and tried to ignite it, unsuccessfully of course.

FIG.: Map of Goiânia showing the movement of the source, International Atomic Energy Agency, The Radiological Accident in Goiânia, IAEA, Vienna (1988)

18 September 1987
Wider distribution of fragments

- Person C took the capsule into his house and invited neighbors, relatives and acquaintances to see the glowing blue light.

- He distributed fragments of the source to several families.

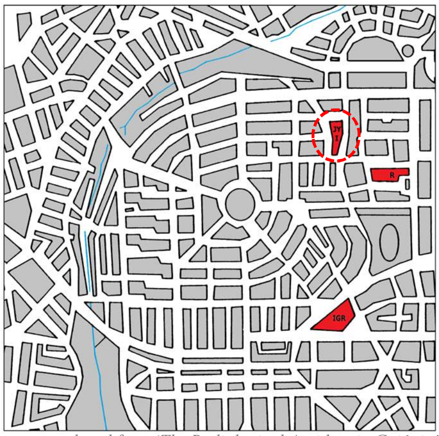


Image reproduced from 'The Radiological Accident in Goiânia', IAEA , Vienna (1988)

Lecture notes:

At night, the junkyard owner went outside and noticed a glowing blue light produced by the caesium powder. He brought the capsule home, invited neighbours and relatives to come and admire the phenomenon. And he distributed some specimens to several families.

FIG.: Map of Goiânia showing the movement of the source, International Atomic Energy Agency, The Radiological Accident in Goiânia, IAEA, Vienna (1988)

24 September 1987
Wider distribution of fragments (cont’d)

- Person C’s brother took some fragments to his home, located next to another junkyard (JY II).
- Most of the material remained at Person C’s house.

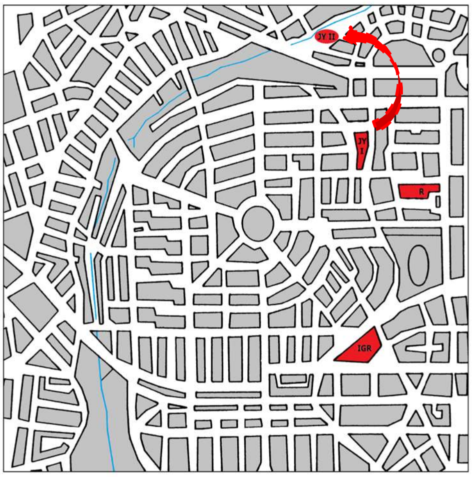


Image reproduced from ‘The Radiological Accident in Goiânia’, IAEA , Vienna (1988)

Lecture notes:

About one week later, the junkyard owner’s brother took some fragments back to his home. Most of material remained in the first junkyard.

FIG.: Map of Goiânia showing the movement of the source, International Atomic Energy Agency, The Radiological Accident in Goiânia, IAEA, Vienna (1988)

25 September 1987
Wider distribution of fragments (cont'd)

- Person C sold the lead shielding and the remnants of the source assembly to a third junkyard (JY III).

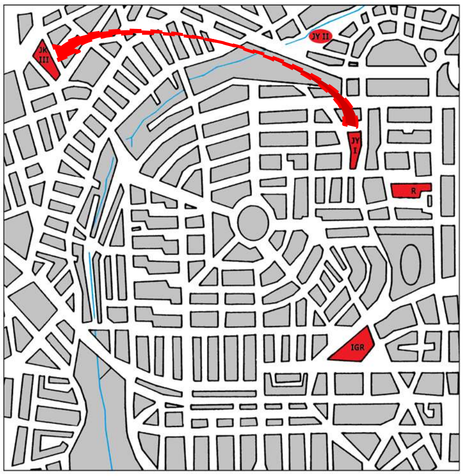


Image reproduced from 'The Radiological Accident in Goiânia', IAEA , Vienna (1988)

Lecture notes:

The junkyard owner sold the lead shielding and the remnants of the source assembly to a second junkyard.

FIG.: Map of Goiânia showing the movement of the source, International Atomic Energy Agency, The Radiological Accident in Goiânia, IAEA, Vienna (1988)

28 September 1987
Identification of a problem

- Person C's wife, suspecting the glowing powder to be the cause of the sickness of those who had had contact, reclaimed the materials from junkyard III and transported it in a bag, by bus, to the Vigilância Sanitária.

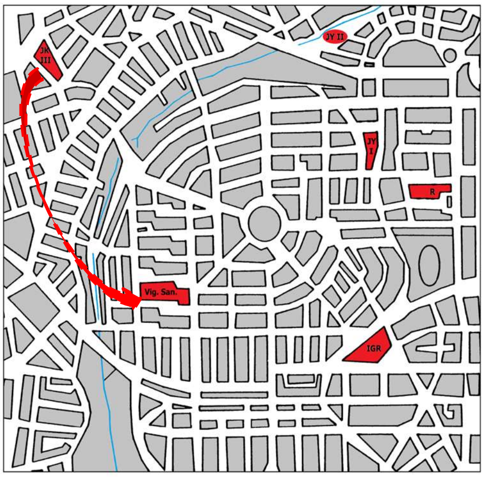


Image reproduced from 'The Radiological Accident in Goiânia', IAEA , Vienna (1988)

Lecture notes:

One week after people had started to handle the caesium powder, several of them became ill. The junkyard owner's wife suspected that these symptoms had been caused by the glowing powder. She therefore reclaimed the material from the third junkyard, put all of it in a bag and with the material went by bus to the Vigilância Sanitaria.

FIG.: Map of Goiânia showing the movement of the source, International Atomic Energy Agency, The Radiological Accident in Goiânia, IAEA, Vienna (1988)

29 September 1987
Identification of a problem (cont’d)

- A visiting medical physicist identified the presence of a radioactive source.
- He evacuated the building and informed the Goiás State authorities and the Brazilian National Nuclear Energy Commission (CNEN) in Rio de Janeiro.

Image reproduced from ‘The Radiological Accident in Goiânia’, IAEA , Vienna (1988)

Lecture notes:

There, a visiting medical physicist identified the presence of a radioactive source using a scintillation counter. He evacuated the building and informed the Goiás State authorities and the CNEN.

FIG.: Map of Goiânia showing the movement of the source, International Atomic Energy Agency, The Radiological Accident in Goiânia, IAEA, Vienna (1988)

29 September 1987
Declaration of emergency & protective actions

- The Goiás State authorities were informed at 13:00.
- The Director of the Department of Nuclear Installations of CNEN was notified by phone at 15:00.

Emergency declared

Actions taken:

- Gathering more information about the source;
- Surveying the suspected areas;
- Alerting the police, fire brigades, ambulances and hospitals;
- Preparing for receiving contaminated people at the city stadium.

Image reproduced from 'The Radiological Accident in Goiânia', IAEA , Vienna (1988)

Lecture notes:

The Goiás State authorities were informed at 13:00 on 29 September, and the Director of the Department of Nuclear Installations of CNEN was notified by phone at 15:00.

An emergency situation was declared, and urgent protective actions were initiated, such as: gathering more information about the source and its moves through the city; implementing a radiological survey of the suspected areas; alerting the police, fire brigades, ambulances and hospitals; and preparing for receiving contaminated people at a single suitable location, the city stadium. It was now two weeks since the beginning of the event.

FIG.: Map of Goiânia showing the movement of the source, International Atomic Energy Agency, The Radiological Accident in Goiânia, IAEA, Vienna (1988)

30 September 1987
Further protective actions

- The first team of the CNEN arrived from Rio de Janeiro and São Paulo at 00:30 UTC.

Actions taken:

- Survey of the suspected areas;
- Evacuation of residents from areas > 2.5 μSv/h;
- Control of contamination
- Decontamination (shower, changing of clothes) and medical follow-up;
- Isolation of the source;
- Gathering more technical and human resources.

Image reproduced from 'The Radiological Accident in Goiânia', IAEA, Vienna (1988)

Lecture notes:

The first team of the CNEN arrived from Rio de Janeiro and São Paulo in the middle of the night and took over the management responsibility.

Its members continued with the survey the suspected areas and identified the most contaminated ones: the locations where the source had been punctured and where it had been moved after having been punctured, in addition to two other ones. They decided to order the evacuation of residents from those areas where the dose rate exceeded 2.5 μSv/h. It was calculated on the basis of 50 mSv/y, the limit for professionally exposed people at the time, divided by 2000 working hours (250 working days per year at 8h/day) and divided by 10 for the non-professionally exposed public.

They organized a contamination control, a decontamination and a medical follow-up when needed.

They isolated the source and asked for more human and technical resources.

FIG.: Map of Goiânia showing the movement of the source, International Atomic Energy Agency, The Radiological Accident in Goiânia, IAEA, Vienna (1988)

3 October 1987
The situation brought under control

- The situation under control:
  - The source had been isolated;
  - The most contaminated sites had been identified and evacuated;
  - The potentially exposed persons had been identified.
- The main concerns:
  - Further treatment of the injured individuals;
  - Improvement of the conditions at the sites of contamination;
  - Clean-up operations;
  - Waste management.

Lecture notes:

On 3 October, the situation was under control: the source had been isolated, the most contaminated sites had been surveyed and the potentially exposed persons had been identified.

We may consider that acute phase of the emergency was over, and that we entered the transition phase. The main objectives were to go ahead with the treatment of the injured people, improve the conditions at the sites of contamination, and start with the clean-up operation and the waste management.

As of 3 October 1987

- Plans and strategies for the recovery were prepared:
  - Resource needs (expertise, manpower, equipment and material) were assessed and resources were mobilized.
  - The logistic support (transport, housing, etc.) was organized in accordance with the expected increase of resources.
  - The dose criteria were re-evaluated and set up.
  - Further radiological surveys were conducted to build a comprehensive cartography of the contamination.
  - An environmental monitoring programme was organized.
  - Decontamination plans and procedures were developed, including waste packaging and storage.
  - A communication strategy was defined.

Lecture notes:

Plans and strategies for the recovery phase were prepared, meaning that:

- the resource needs (expertise, manpower, equipment and material) were assessed and resources were mobilized;
- the logistic support (transport, housing, etc.) was organized in accordance with the expected increase of resources;
- the dose criteria were re-evaluated and set up;
- further radiological surveys were conducted to build a comprehensive cartography of the contamination;
- a comprehensive environmental monitoring programme was set up;
- decontamination plans and procedures were developed, including considerations regarding the packaging and storage of waste;
- a communication strategy was defined.

As of 16 October 1987

- Medical response organized:
  - Measures to protect the medical staff from contamination;
  - Follow-up studies on the contaminated persons;
  - Prussian Blue administered to speed up excretion of ^{137}Cs.
- Clean-up operations taken:
  - Houses cleaned up or demolished;
  - Public places and vehicles decontaminated;
  - Fruits and soil also removed on the basis of soil profile measurements;
  - Waste segregated, classified and treated.
- Environmental monitoring implemented:
  - A car borne monitoring programme to monitor areas outside the main focuses of contamination, decontamination and follow-up surveys;
  - Samples of soil, vegetation (leaves, branches and fruits), water (from the nearby river, wells and public water supply), rainwater and air were collected and measured.

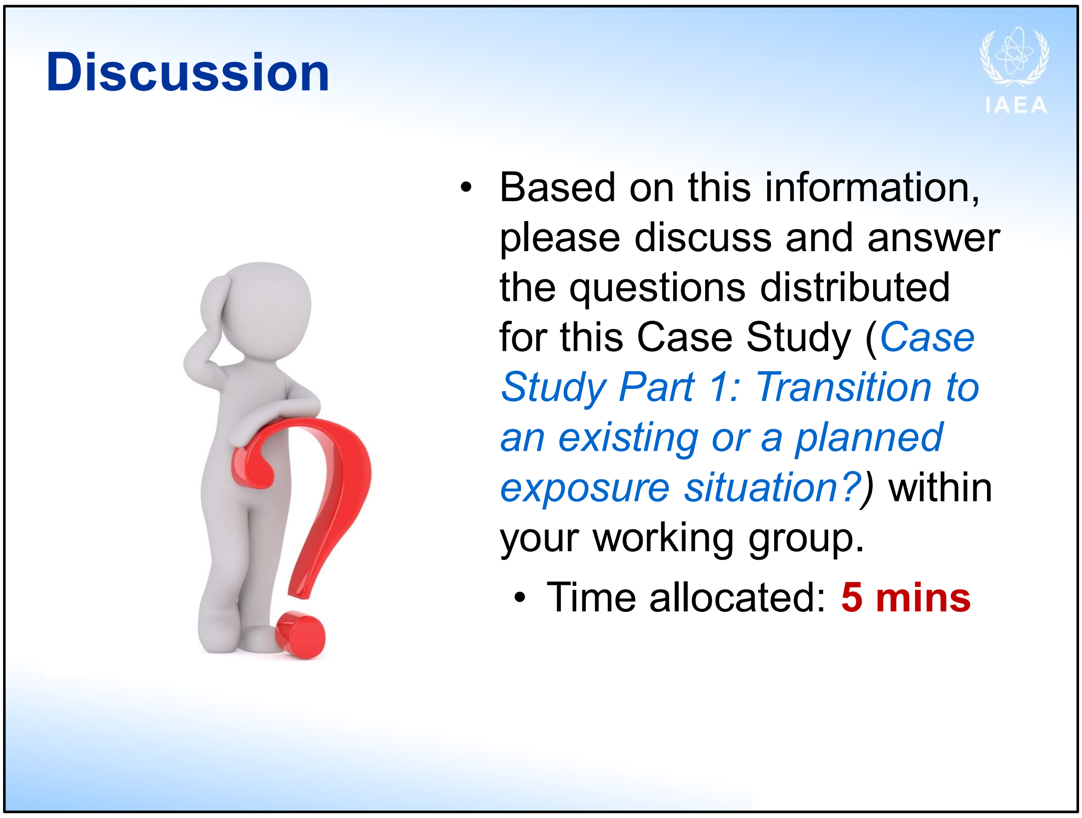
Lecture notes:

The persons identified as contaminated underwent followed-up and were submitted to bioassay and whole body counting. They received Prussian Blue, a specific binding agent to speed up the excretion of caesium from the body.

Measures were also taken for the protection of the medical staff against irradiation and contamination.

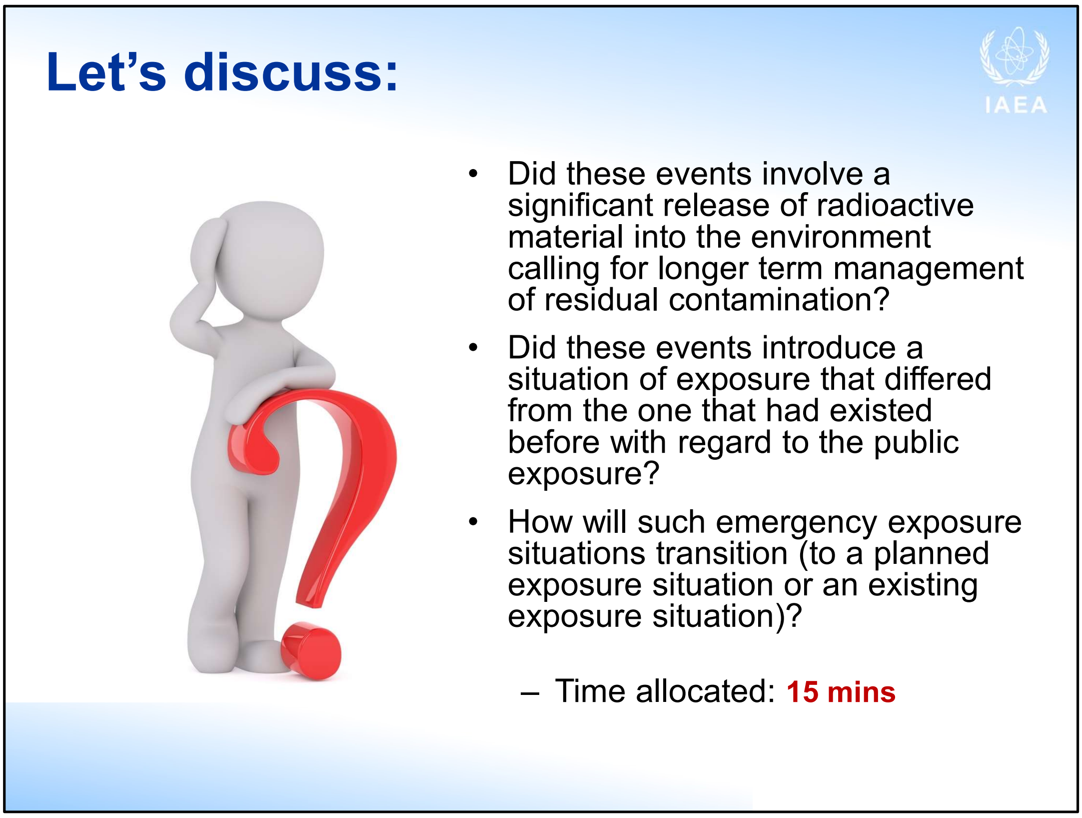
From 16 October onwards, we entered the post-accident phase management with an existing exposure situation. Clean-up and decontamination operations were conducted in private houses and public places. The waste generated by these operations was sorted, packed and stored temporally.

A comprehensive monitoring programme, also in areas outside the identified hotspots and in remediated places, was implemented. It included a car borne survey and a soil, vegetation and water sampling programme.



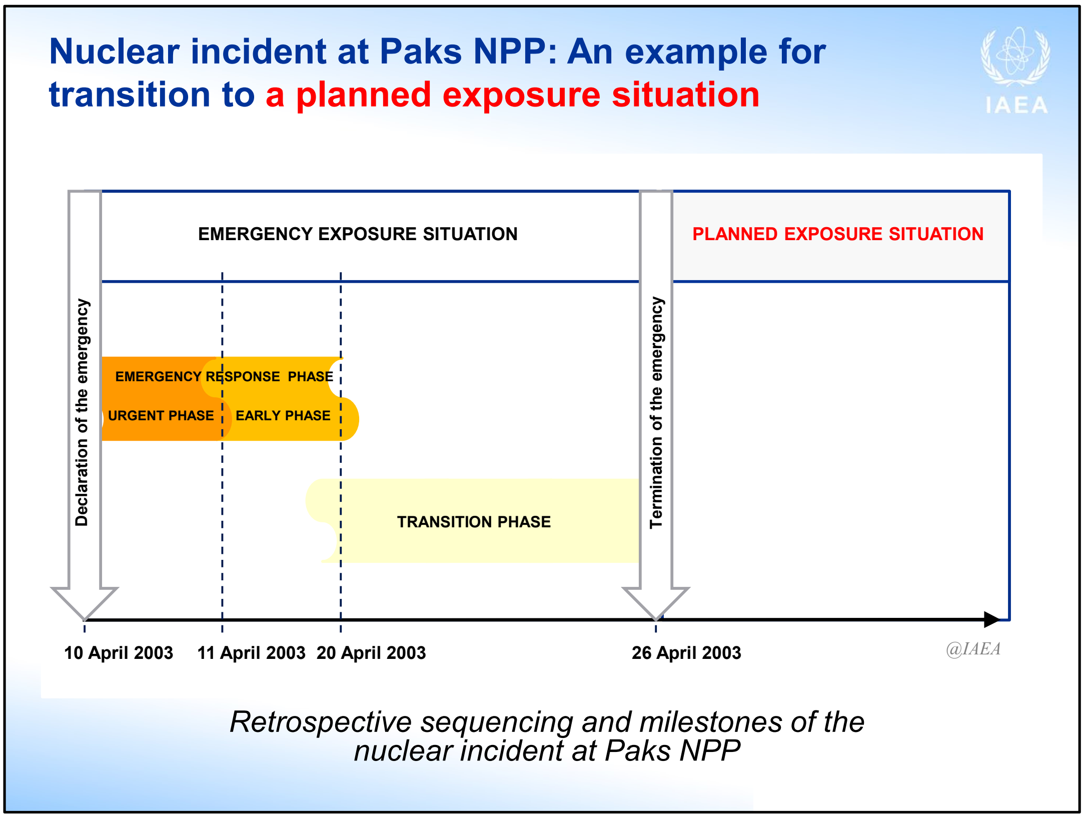
Lecture notes:

Allow participants to discuss and answer the questions within their working groups for about 5 minutes.



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 15 minutes). Only after all questions and answers have been covered, move on and present the next slides.



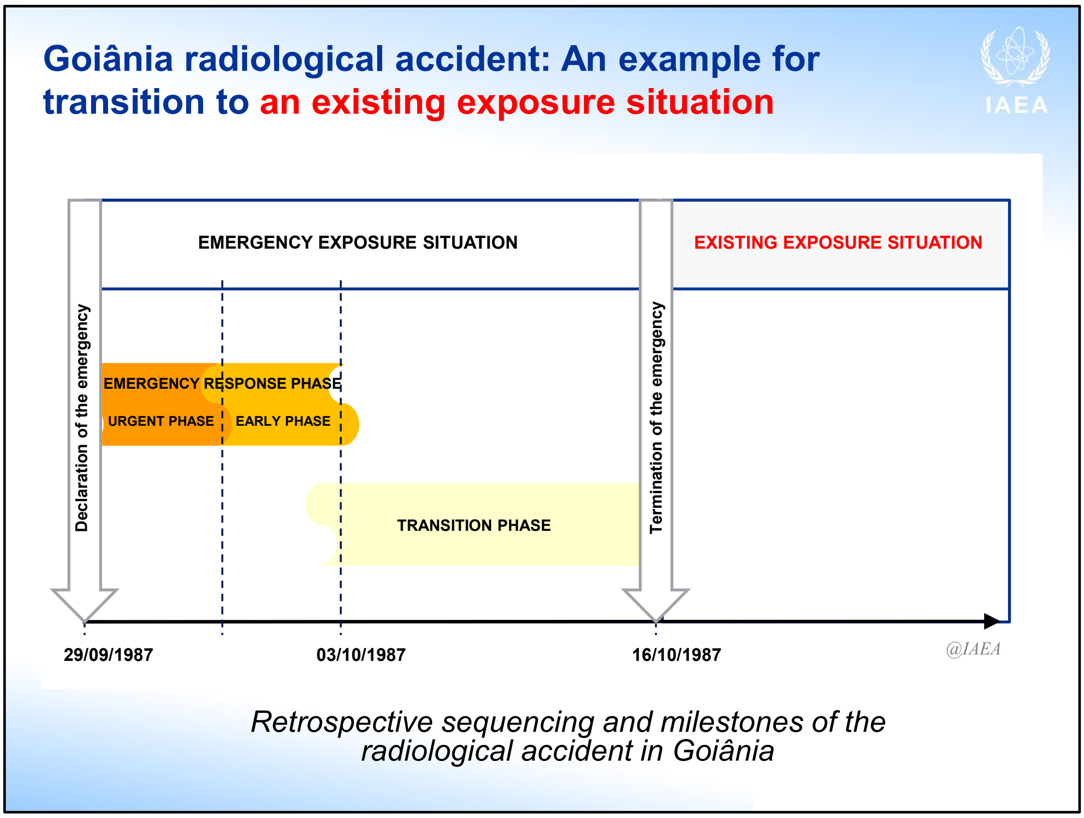
Lecture notes:

If we put the key milestones of the event on the general timeline of an emergency response, the incident was identified on 10 April, when limited urgent protective actions on the site were implemented for worker protection (urgent phase). The emergency phase continued until 20 April, when efforts focused on assessing the situation and on the effects of continuous cooling and monitoring to confirm the stability of the situation. The damaged fuel was brought under control by 26 April, and the consequences on-site and off-site were in the process of being re-assessed. Further planning for recovery and investigation continued in May.

FIG.: Courtesy of International Atomic Energy Agency

Basis for the milestones in the Paks fuel damage incident

- The incident was identified on 10 April 2003, when limited urgent protective actions on the site were implemented for worker protection (urgent response phase).
- The emergency phase continued until 20 April 2003, when efforts focused on assessing the situation and on the effects of continuous cooling and monitoring to confirm the stability of the situation (early response phase).
- The damaged fuel was brought under control by 26 April 2003, and the consequences on-site and off-site were being assessed (transition phase).
- Further planning for recovery continued, and normal operation resumed in the second half of 2005 (planned exposure situation).



Lecture notes:

The emergency response phase began on 29 September 1987, when the broken ^{137}Cs source was identified as the cause of the symptoms affecting those who had been in contact with it, and when the CNEN was notified. Urgent and early protective actions, such as the identification and care of severely exposed people, the identification and isolation of the source, the evacuation and cordoning off of the most heavily contaminated areas and the contamination control and decontamination of evacuees were carried out during the following days. The emergency response phase, during which all potential sources of contamination were brought under control, was completed by around 3 October 1987. The following two weeks, from 3 to 16 October 1987, can be considered to be the transition phase, during which the main focus of the response was to set up a general strategy for the overall recovery.

FIG.: Courtesy of International Atomic Energy Agency

Basis for the milestones in the radiological accident in Goiânia

- Emergency declaration on 29 September 1987 with the notification to the CNEN;
- The emergency response phase lasted until 3 October 1987, during which period:
  - The source had been isolated;
  - Contaminated areas had been evacuated and cordoned off;
  - Exposed people had been identified and dealt with.
- The transition phase lasted from 3 to16 October 1987, during which period a general strategy was established for recovery operations, including a decision for a temporary waste storage site.
- The recovery phase, aiming to restore normal living conditions, continued until March 1988.

Case studies

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

Lecture notes:

Thank you!