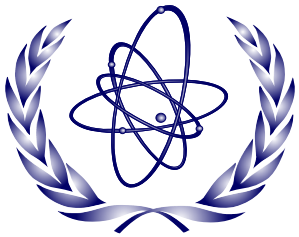
IAEA SAFETY ASSESSMENT TRAINING AND EDUCATION PROGRAMME

Fukushima Daiichi Accident
IAEA Report 2015



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Presentation content

- Background
- Content of the report
- High level observations and conclusions

Fukushima Daiichi Accident
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- This report presents an assessment of the causes and consequences of the accident at the Fukushima Daiichi nuclear power plant in Japan, which began on 11 March 2011. Caused by a huge tsunami that followed a massive earthquake, it was the worst accident at a nuclear power plant since the Chernobyl disaster in 1986.
- The report considers human, organizational and technical factors, and aims to provide an understanding of what happened, and why, so that the necessary lessons learned can be acted upon by governments, regulators and nuclear power plant operators throughout the world. Measures taken in response to the accident, both in Japan and internationally, are also examined.

Background

On 11 March 2011 The Great East Japan Earthquake occurred

- A section of the Earth's crust, estimated to be about 500 km in length and 200 km wide, was ruptured, causing a massive earthquake (**the main shock, with a magnitude of 9.0 [12], lasted for more than two minutes, with several significant pulses and aftershocks)** with a magnitude of 9.0 and a tsunami which struck a wide area of coastal Japan, including the north-eastern coast, where several waves reached heights of more than ten metres.
  - The earthquake and tsunami caused great loss of life and widespread devastation in Japan.
    - ✓ More than 15 000 people killed, over 6000 injured and, around 2500 people are still reported to be missing.
    - ✓ Considerable damage to buildings and infrastructure, along Japan's north-eastern coast.

Background (2/6)

Background (2/6)

- At the Fukushima Daiichi nuclear power plant, the earthquake caused damage to the electric power supply lines to the site, and the tsunami caused substantial destruction of the operational and safety infrastructure on the site.
  - loss of off-site and on-site electrical power,
  - Consequently loss of the cooling at the three operating reactors as well as at the spent fuel pools.
  - The four other nuclear power plants along the coast were also affected to different degrees by the earthquake and tsunami, but all operating reactor units at these plants were safely shut down.
- The reactor cores in Units 1–3 at the Fukushima Daiichi plant overheated, the nuclear fuel melted and the three containment vessels were breached.
- Hydrogen was released from the reactor pressure vessels, leading to explosions inside the reactor buildings in Units 1, 3 and 4 that damaged structures and equipment and injured personnel.

Background (3/6)

- Radionuclides were released from the plant direct to the sea and to the atmosphere and were deposited on land and on the ocean.
- People within a radius of 20 km of the site were evacuated, and those within a radius of 20–30 km were instructed to shelter before later being advised to voluntarily evacuate.
- Restrictions were placed on the distribution and consumption of food and the consumption of drinking water.
- Following stabilization of the conditions of the reactors at the Fukushima Daiichi NPP, work to prepare for their eventual decommissioning began.
- Efforts towards the recovery of the areas affected by the accident, including remediation and the revitalization of communities and infrastructure, began in 2011.

Background (4/6)

- The IAEA undertook cooperative activities in Fukushima through a memorandum of cooperation between the IAEA and Fukushima Prefecture to provide basis for cooperation on radiation monitoring and remediation, human health, and emergency preparedness and response.
- The IAEA organized an International Ministerial Conference on Nuclear Safety in June 2011, which resulted in a Ministerial Declaration on Nuclear Safety.
  - Outlined were measures to further improve nuclear safety, emergency preparedness and radiation protection of people and the environment worldwide.
  - IAEA Member States expressed the firm commitment to ensure that these measures were taken.
  - The Ministerial Declaration also requested the Director General to prepare a draft IAEA Action Plan on Nuclear Safety to strengthen the global nuclear safety framework, which was unanimously endorsed by the 55th IAEA General Conference in 2011.

Background (5/6)

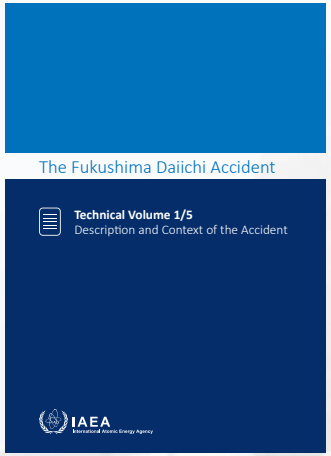
- The Action Plan consists of 12 main actions related to:
  - ✓ safety assessments;
  - ✓ IAEA peer reviews;
  - ✓ emergency preparedness and response;
  - ✓ national regulatory bodies;
  - ✓ operating organizations;
  - ✓ IAEA safety standards;
  - ✓ the international legal framework;
  - ✓ Member States planning to embark on a nuclear power programme;
  - ✓ capacity building;
  - ✓ the protection of people and the environment from ionizing radiation;
  - ✓ communication and information dissemination; and
  - ✓ research and development.

Background (6/6)

- At the IAEA General Conference in September 2012, the Director General announced that the IAEA would prepare a report on the Fukushima Daiichi accident.
- The report on the Fukushima Daiichi accident is the result of an extensive international collaborative effort involving five working groups with about 180 experts from 42 Member States and several international bodies.
- An International Technical Advisory Group provided advice on technical and scientific issues.
- A Core Group, comprising IAEA senior level management, was established to give direction and to facilitate the coordination and review of the report. Additional internal and external review mechanisms were also instituted.

2015 IAEA Report: The Fukushima Daiichi Accident

TECHNICAL VOLUME 1: DESCRIPTION AND CONTEXT OF THE ACCIDENT



1.1. SUMMARY OF THE ACCIDENT

1.2. CONTEXT WITHIN WHICH THE ACCIDENT OCCURRED

1.3. ONSET AND PROGRESSION OF THE ACCIDENT

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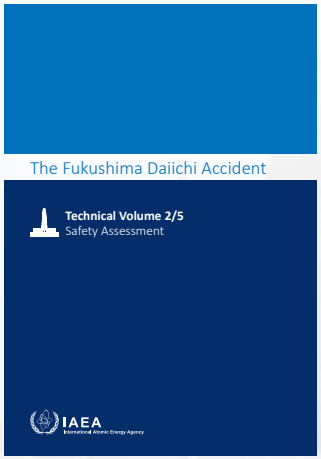

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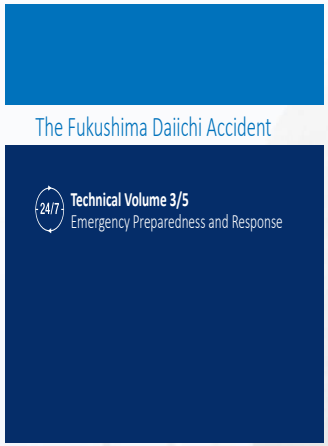

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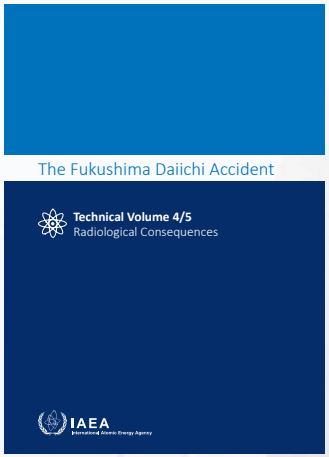

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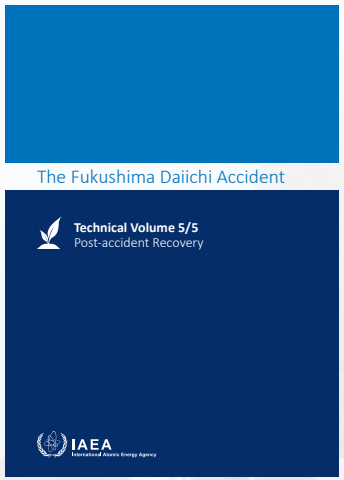

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NUCLEAR SAFETY CONSIDERATIONS
Vulnerability of the plant to external events

- ***Worldwide operating experience has shown instances where natural hazards have exceeded the design basis for a nuclear power plant. In particular, the experience from some of these events demonstrated the vulnerability of safety systems to flooding.***
- **The assessment of natural hazards needs to be sufficiently conservative. The consideration of mainly historical data in the establishment of the design basis of nuclear power plants is not sufficient to characterize the risks of extreme natural hazards. Even when comprehensive data are available, due to the relatively short observation periods, large uncertainties remain in the prediction of natural hazards.**
- **The safety of nuclear power plants needs to be re-evaluated on a periodic basis to consider advances in knowledge, and necessary corrective actions or compensatory measures need to be implemented promptly.**

NUCLEAR SAFETY CONSIDERATIONS
Vulnerability of the plant to external events (CONT'D)

- **The assessment of natural hazards needs to consider the potential for their occurrence in combination, either simultaneously or sequentially, and their combined effects on a nuclear power plant. The assessment of natural hazards also needs to consider their effects on multiple units at a nuclear power plant.**
- **Operating experience programmes need to include experience from both national and international sources. Safety improvements identified through operating experience programmes need to be implemented promptly. The use of operating experience needs to be evaluated periodically and independently.**

NUCLEAR SAFETY CONSIDERATIONS
Application of the defence in depth concept

- ***The failure to provide sufficient means of protection at each level of defence in depth resulted in severe reactor damage in Units 1, 2 and 3 and in significant radioactive releases from these units.***
- **The defence in depth concept remains valid, but implementation of the concept needs to be strengthened at all levels by adequate independence, redundancy, diversity and protection against internal and external hazards. There is a need to focus not only on accident prevention, but also on improving mitigation measures.**
- **Instrumentation and control systems that are necessary during beyond design basis accidents need to remain operable in order to monitor essential plant safety parameters and to facilitate plant operations.**

NUCLEAR SAFETY CONSIDERATIONS
Assessment of the failure to fulfil fundamental safety functions

- ***The confinement function was lost as a result of the loss of AC and DC power, which rendered the cooling systems unavailable and made it difficult for the operators to use the containment venting system.***
- **Robust and reliable cooling systems that can function for both design basis and beyond design basis conditions need to be provided for the removal of residual heat.**
- **There is a need to ensure a reliable confinement function for beyond design basis accidents to prevent significant release of radioactive material to the environment.**

NUCLEAR SAFETY CONSIDERATIONS
Assessment of beyond design basis accidents and accident management

- ***Safety analyses conducted during the licensing process of the Fukushima Daiichi nuclear power plant, and during its operation, did not fully address the possibility of a complex sequence of events that could lead to severe reactor core damage.***
- Comprehensive probabilistic and deterministic safety analyses need to be performed to confirm the capability of a plant to withstand applicable beyond design basis accidents and to provide a high degree of confidence in the robustness of the plant design.
- Accident management provisions need to be comprehensive, well designed and up to date. They need to be derived on the basis of a comprehensive set of initiating events and plant conditions and also need to provide for accidents that affect several units at a multi-unit plant.

NUCLEAR SAFETY CONSIDERATIONS
Assessment of beyond design basis accidents and accident management (cont'd)

- **Training, exercises and drills need to include postulated severe accident conditions to ensure that operators are as well prepared as possible. They need to include the simulated use of actual equipment that would be deployed in the management of a severe accident.**

NUCLEAR SAFETY CONSIDERATIONS
Assessment of regulatory effectiveness

- ***The regulation of nuclear safety in Japan at the time of the accident was performed by a number of organizations with different roles and responsibilities and complex inter-relationships. It was not fully clear which organizations had the responsibility and authority to issue binding instructions on how to respond to safety issues without delay.***
- **In order to ensure effective regulatory oversight of the safety of nuclear installations, it is essential that the regulatory body is independent and possesses legal authority, technical competence and a strong safety culture.**

NUCLEAR SAFETY CONSIDERATIONS
Assessment of human and organizational factors

- ***Before the accident, there was a basic assumption in Japan that the design of nuclear power plants and the safety measures that had been put in place were sufficiently robust to withstand external events of low probability and high consequences.***
- ***The accident at the Fukushima Daiichi nuclear power plant showed that, in order to better identify plant vulnerabilities, it is necessary to take an integrated approach that takes account of the complex interactions between people, organizations and technology.***
- **In order to promote and strengthen safety culture, individuals and organizations need to continuously challenge or re-examine the prevailing assumptions about nuclear safety and the implications of decisions and actions that could affect nuclear safety.**
- **A systemic approach to safety needs to consider the interactions between human, organizational and technical factors. This approach needs to be taken through the entire life cycle of nuclear installations.**

EMERGENCY PREPAREDNESS AND RESPONSE
Initial response in Japan to the accident

- ***At the time of the accident, separate arrangements were in place to respond to nuclear emergencies and natural disasters at the national and local levels. There were no coordinated arrangements for responding to a nuclear emergency and a natural disaster occurring simultaneously.***
- **In preparing for the response to a possible nuclear emergency, it is necessary to consider emergencies that could involve severe damage to nuclear fuel in the reactor core or to spent fuel on the site, including those involving several units at a multi-unit plant possibly occurring at the same time as a natural disaster.**
- **The emergency management system for response to a nuclear emergency needs to include clearly defined roles and responsibilities for the operating organization and for local and national authorities. The system, including the interactions between the operating organization and the authorities, needs to be regularly tested in exercises.**

EMERGENCY PREPAREDNESS AND RESPONSE
Protecting emergency workers

- ***At the time of the accident, the national legislation and guidance in Japan addressed measures to be taken for the protection of emergency workers, but only in general terms and not in sufficient detail.***
- ***Implementation of the arrangements for ensuring the protection of workers against radiation exposure was severely affected by the extreme conditions at the site. In order to maintain an acceptable level of protection for on-site emergency workers, a range of impromptu measures was implemented.***
- **Emergency workers need to be designated, assigned clearly specified duties, regardless of which organization they work for, be given adequate training and be properly protected during an emergency. Arrangements need to be in place to integrate into the response those emergency workers who had not been designated prior to the emergency, and helpers who volunteer to assist in the emergency response.**

EMERGENCY PREPAREDNESS AND RESPONSE
Protecting the public

- *National emergency arrangements at the time of the accident envisaged that decisions on protective actions would be based on estimates of the projected dose to the public that would be calculated when a decision was necessary, using a dose projection model (SPEEDI).*
- *However, in response to the accident, the initial decisions on protective actions were made on the basis of plant conditions. Estimates of the source term could not be provided as an input to SPEEDI owing to the loss of on-site power.*
- **Arrangements need to be in place to allow decisions to be made on the implementation of predetermined, urgent protective actions for the public, based on predefined plant conditions.**
- **Arrangements need to be in place to enable urgent protective actions to be extended or modified in response to developing plant conditions or monitoring results. Arrangements are also needed to enable early protective actions to be initiated on the basis of monitoring results.**

EMERGENCY PREPAREDNESS AND RESPONSE
Protecting the public (cont'd)

- **Arrangements need to be in place to ensure that protective actions and other response actions in a nuclear emergency do more good than harm. A comprehensive approach to decision making needs to be in place to ensure that this balance is achieved.**
- **Arrangements need to be in place to assist decision makers, the public and others (e.g. medical staff) to gain an understanding of radiological health hazards in a nuclear emergency in order to make informed decisions on protective actions. Arrangements also need to be in place to address public concerns locally, nationally and internationally.**

EMERGENCY PREPAREDNESS AND RESPONSE
Transition from the emergency phase to the recovery phase and analysis of the response

- ***Specific policies, guidelines, criteria and arrangements for the transition from the emergency phase to the recovery phase were not developed until after the Fukushima Daiichi accident.***
- **Arrangements need to be developed at the preparedness stage for termination of protective actions and other response actions, and for transition to the recovery phase.**
- **Timely analysis of an emergency and the response to it, drawing lessons and identifying possible improvements, enhances emergency arrangements.**

EMERGENCY PREPAREDNESS AND RESPONSE
Response within the international framework for emergency preparedness and response

- ***An extensive international framework for emergency preparedness and response was in place at the time of the accident, comprising international legal instruments, IAEA safety standards and operational arrangements.***
- **The implementation of international arrangements for notification and assistance needs to be strengthened.**
- **There is a need to improve consultation and sharing of information among States on protective actions and other response actions.**

RADIOLOGICAL CONSEQUENCES
Radioactivity in the environment

- ***The accident resulted in the release of radionuclides to the environment. Assessments of the releases have been performed by many organizations using different models. Most of the atmospheric releases were blown eastward by the prevailing winds, depositing onto and dispersing within the North Pacific Ocean. Uncertainties in estimations of the amount and composition of the radioactive substances were difficult to resolve for reasons that included the lack of monitored data on the deposition of the atmospheric releases on the ocean.***
- **In case of an accidental release of radioactive substances to the environment, the prompt quantification and characterization of the amount and composition of the release is needed. For significant releases, a comprehensive and coordinated programme of long term environmental monitoring is necessary to determine the nature and extent of the radiological impact on the environment at the local, regional and global levels.**

RADIOLOGICAL CONSEQUENCES
Protecting people against radiation exposure

- ***Following the accident, the Japanese authorities applied conservative reference levels of dose included in the recent ICRP recommendations. The application of some of the protective measures and actions proved to be difficult for the implementing authorities and very demanding for the people affected.***
- ***There were some differences between the national and international criteria and guidance for controlling drinking water, food and non-edible consumer products in the longer term aftermath of the accident, once the emergency phase had passed.***
- **Relevant international bodies need to develop explanations of the principles and criteria for radiation protection that are understandable for non-specialists in order to make their application clearer for decision makers and the public. As some protracted protection measures were disruptive for the affected people, a better communication strategy is needed to convey the justification for such measures and actions to all stakeholders, including the public.**

RADIOLOGICAL CONSEQUENCES
Protecting people against radiation exposure (Cont'd)

- **Conservative decisions related to specific activity and activity concentrations in consumer products and deposition activity led to extended restrictions and associated difficulties. In a prolonged exposure situation, consistency among international standards, and between international and national standards, is beneficial, particularly those associated with drinking water, food, non-edible consumer products and deposition activity on land.**

RADIOLOGICAL CONSEQUENCES
Radiation exposure

- In the short term, the most significant contributors to the exposure of the public were: (1) external exposure from radionuclides in the plume and deposited on the ground; and (2) internal exposure of the thyroid gland, due to the intake of iodine-131, and internal exposure of other organs and tissues, mainly due to the intake of caesium-134 and caesium-137. In the long term, the most important contributor to the exposure of the public will be external radiation from the deposited caesium-137.
- **Personal radiation monitoring of representative groups of members of the public provides invaluable information for reliable estimates of radiation doses and needs to be used together with environmental measurements and appropriate dose estimation models for assessing public dose.**

RADIOLOGICAL CONSEQUENCES
Radiation exposure

- While dairy products were not the main pathway for the ingestion of radioiodine in Japan, it is clear that the most important method of limiting thyroid doses, especially to children, is to restrict the consumption of fresh milk from grazing cows.
- A robust system is necessary for monitoring and recording occupational radiation doses, via all relevant pathways, particularly those due to internal exposure that may be incurred by workers during severe accident management activities. It is essential that suitable and sufficient personal protective equipment be available for limiting the exposure of workers during emergency response activities and that workers be sufficiently trained in its use.

RADIOLOGICAL CONSEQUENCES
Health effects

- ***No early radiation induced health effects were observed among workers or members of the public that could be attributed to the accident.***
- ***Prenatal radiation effects have not been observed and are not expected to occur, given that the reported doses are well below the threshold at which these effects may take place. Unwanted terminations of pregnancy attributable to the radiological situation have not been reported.***
- ***Some psychological conditions were reported among the population affected by the nuclear accident. Since a number of these people had suffered the combined impacts of a major earthquake and a devastating tsunami as well as the accident, it is difficult to assess to what extent these effects could be attributed to the nuclear accident alone.***
- **The risks of radiation exposure and the attribution of health effects to radiation need to be clearly presented to stakeholders, making it unambiguous that any increases in the occurrence of health effects in populations are not attributable to exposure to radiation if levels of exposure are similar to the global average background levels of radiation.**

RADIOLOGICAL CONSEQUENCES
Health effects (cont'd)

- After a nuclear accident, health surveys are very important and useful, but should not be interpreted as epidemiological studies. The results of such health surveys are intended to provide information to support medical assistance to the affected population.
- There is a need for radiological protection guidance to address the psychological consequences to members of the affected populations in the aftermath of radiological accidents. A Task Group of the ICRP has recommended that "strategies for mitigating the serious psychological consequences arising from radiological accidents be sought".
- Factual information on radiation effects needs to be communicated in an understandable and timely manner to individuals in affected areas in order to enhance their understanding of protection strategies, to alleviate their concerns and support their own protection initiatives.

RADIOLOGICAL CONSEQUENCES
Radiological consequences for non-human biota

- ***No observations of direct radiation induced effects in plants and animals have been reported, although limited observational studies were conducted in the period immediately after the accident.***
- **During any emergency phase, the focus has to be on protecting people. Doses to the biota cannot be controlled and could be potentially significant on an individual basis. Knowledge of the impacts of radiation exposure on non-human biota needs to be strengthened by improving the assessment methodology and understanding of radiation induced effects on biota populations and ecosystems. Following a large release of radionuclides to the environment, an integrated perspective needs to be adopted to ensure sustainability of agriculture, forestry, fishery and tourism, and of the use of natural resources.**

POST-ACCIDENT RECOVERY
Off-site remediation of areas affected by the accident

- ***Prior to the Fukushima Daiichi accident, policies and strategies for post-accident remediation were not in place in Japan, and it became necessary to develop them in the period after the accident.***
- **Pre-accident planning for post-accident recovery is necessary to improve decision making under pressure in the immediate post-accident situation. National strategies and measures for post-accident recovery need to be prepared in advance in order to enable an effective and appropriate overall recovery programme to be put in place in case of a nuclear accident. These strategies and measures need to include the establishment of a legal and regulatory framework; generic remediation strategies and criteria for residual radiation doses and contamination levels; a plan for stabilization and decommissioning of damaged nuclear facilities; and a generic strategy for managing large quantities of contaminated material and radioactive waste.**

POST-ACCIDENT RECOVERY
Off-site remediation of areas affected by the accident (cont'd)

- **Remediation strategies need to take account of the effectiveness and feasibility of individual measures and the amount of contaminated material that will be generated in the remediation process.**
- **As part of the remediation strategy, the implementation of rigorous testing and controls on food is necessary to prevent or minimize ingestion doses.**
- **Further international guidance is needed on the practical application of safety standards for radiation protection in post-accident recovery situations.**

POST-ACCIDENT RECOVERY
On-site stabilization and preparations for decommissioning

- ***A comprehensive, high level strategic plan for stabilization and decommissioning of the damaged nuclear power plant was developed jointly by TEPCO and the relevant Japanese Government agencies. The plan was first issued in December 2011 and subsequently revised to reflect the experience gained and an improved understanding of the conditions of the damaged nuclear power plant, as well as the magnitude of the future challenges.***
- **Following an accident, a strategic plan for maintaining long term stable conditions and for the decommissioning of accident damaged facilities is essential for on-site recovery. The plan needs to be flexible and readily adaptable to changing conditions and new information.**
- **Retrieving damaged fuel and characterizing and removing fuel debris necessitate solutions that are specific to the accident, and special methods and tools may need to be developed.**

POST-ACCIDENT RECOVERY
Management of contaminated material and radioactive waste

- ***Stabilization of a damaged nuclear power plant and the on-site decontamination and remediation efforts in the surrounding areas result in large quantities of contaminated material and radioactive waste.***
- **National strategies and measures for post-accident recovery need to include the development of a generic strategy for managing contaminated liquid and solid material and radioactive waste, supported by generic safety assessments for discharge, storage and disposal.**

POST-ACCIDENT RECOVERY
Community revitalization and stakeholder engagement

- ***The nuclear accident and radiation protection measures introduced in both the emergency and post- accident recovery phases have had significant consequences for the way of life of the affected population.***
- ***Communication with the public on recovery activities is essential to build trust.***
- **It is necessary to recognize the socioeconomic consequences of any nuclear accident and of the subsequent protective actions, and to develop revitalization and reconstruction projects that address issues such as reconstruction of infrastructure, community revitalization and compensation.**
- **Support by stakeholders is essential for all aspects of post-accident recovery. In particular, engagement of the affected population in the decision making processes is necessary for the success, acceptability and effectiveness of the recovery and for the revitalization of communities.**

POST-ACCIDENT RECOVERY
Community revitalization and stakeholder engagement (cont'd)

- **An effective recovery programme requires the trust and the involvement of the affected population. Confidence in the implementation of recovery measures has to be built through processes of dialogue, the provision of consistent, clear and timely information, and support to the affected population.**

...Thank you for your attention