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OECD Nuclear Energy Agency (NEA) activities in follow-up to the TEPCO Fukushima Daiichi nuclear accident

Extracts from *NEA News*

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NUCLEAR ENERGY AGENCY

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1 February 1958. Current NEA membership consists of 30 OECD member countries: Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, Norway, Poland, Portugal, the Republic of Korea, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The European Commission also takes part in the work of the Agency.

The mission of the NEA is:

– to assist its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes, as well as
– to provide authoritative assessments and to forge common understandings on key issues, as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and sustainable development.

Specific areas of competence of the NEA include the safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information.

The NEA Data Bank provides nuclear data and computer program services for participating countries. In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has a Co-operation Agreement, as well as with other international organisations in the nuclear field.

Table of contents

Fukushima

by J. Nakoski and T. Lazo*

What happened

On 11 March 2011, a magnitude 9.0 earthquake hit the eastern coast of Japan. This caused the three operating units (units 1 to 3) at the Fukushima Daiichi nuclear power plant to automatically shut down as designed and also resulted in the loss of off-site power. Units 4 to 6 were already shut down for maintenance outages, with unit 4 having been defueled in November 2010. The emergency equipment began operating with the emergency diesel generators as the power supply.

Shortly after the earthquake, a tsunami estimated at 14-15 m high struck the site. The subsequent flooding at the plant caused the failure of the emergency diesel generators as well as some of the other equipment vital to cool the reactors at units 1 to 3 and the spent fuel stored in the pools for all six units. At unit 6, an air-cooled emergency diesel generator was quickly restarted and was able to provide electrical power to emergency equipment at units 5 and 6. Cooling was provided for the unit 2 and 3 reactors using turbine-driven pumps powered by steam from the reactors. However, as the accident progressed over the following days and the amount of steam generated decreased, the ability to cool the reactors at units 2 and 3 using these turbine-driven pumps was lost. At unit 1, after the loss of the emergency diesel generators, cooling was provided by an isolation condenser. With the loss of electrical power, water could not be added to the isolation condenser and the inventory that was available quickly boiled off. Once this occurred, the ability to cool the fuel in the unit 1 reactor was lost.

In order to protect the public living nearby, an evacuation order was issued on 11 March for persons within a 3 km radius of Fukushima Daiichi. As the situation at the site worsened, the decision was made on 12 March to extend the evacuation zone to 20 km.

Analyses performed as of 1 June 2011 indicate that at unit 1, the loss of cooling caused the temperature of the uranium dioxide fuel pellets to reach melting point (2 800°C) very shortly after the loss of all electrical power. When this occurred, the analyses have predicted that the molten fuel relocated from the core region to the lower reactor pressure vessel (RPV) head early on 12 March. The molten fuel then caused damage (small leaks) to the lower head. When cooling was later resumed, the temperature of the molten fuel dropped and further damage to the lower head of the RPV was prevented. However, the small leaks in the unit 1 lower RPV head require that water continue to be injected into the RPV at a rate higher than otherwise necessary to remove decay heat and to keep the fuel cooled. Updated analyses performed for units 2 and 3 indicate that significant fuel damage occurred, with the possibility that much of the fuel in these units also melted.

With the loss of all AC electrical power, the pressure in the reactor coolant systems of units 1 to 3 was being relieved by steam discharges through safety relief valves to the suppression chambers as designed. Without electrical power to operate the equipment for cooling the water in the suppression chambers, the temperature and the pressure within the primary containments began to rise. To protect the primary containments, venting of the containments for units 1 to 3 through ventilation piping that discharges to the site stacks began on 12, 15 and 13 March 2011 respectively. Included in the gases being vented from the primary containments was hydrogen generated from the reaction of the cladding (zirconium) with the steam at high temperatures when cooling capability was lost. Some of the hydrogen gas collected in the upper portion of the reactor buildings (secondary containment) where the spent fuel pools are located at units 1 and 3, and within the reactor building near the suppression chamber in unit 2. The specific leakage path for the hydrogen that collected within the reactor buildings was not known at the time of writing. However, the venting occurred at containment pressures well above the design pressures which could have challenged the integrity of the containment penetrations or the hardened ventilation path to the unit stacks.

When the concentration of hydrogen reached the explosive limit, hydrogen explosions occurred on 12 March at unit 1, 14 March at unit 3 and 15 March at unit 2. In units 1 and 3, these explosions caused significant damage to the reactor buildings, destroying the upper structures of the buildings and exposing the spent fuel pools of units 1 and 3 to the atmosphere. The explosion in the unit 2 reactor building

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caused damage to the suppression pool and degradation of the primary containment. In addition to events occurring at units 1 to 3, an explosion occurred at unit 4 causing extensive damage to the upper portion of the reactor building. At the time of writing, the cause for the explosion at unit 4 was not clear. However, potential causes being discussed include the build-up of hydrogen generated by the overheating of fuel in the unit 4 spent fuel pool, back leakage of gases being vented from unit 3 through a common unit 3/unit 4 ventilation pathway to the shared stack, or materials used during maintenance activities being conducted at unit 4.

Temporary pumps and other equipment necessary to help cool the fuel in the reactors were used to inject seawater into the reactors at units 1 to 3. Seawater injection began on 12 March at unit 1 and on 14 March for units 2 and 3. Seawater was also used to add water to the spent fuel pools using a variety of methods including dropping water into the pools from helicopters and spraying water into the pools using specialised fire fighting equipment and concrete pumping trucks. Once the ability to inject water into the reactors at units 1 to 3 and into the spent fuel pools at all the units was reestablished (at first with seawater, then with fresh water), continuing damage to the fuel could be minimised and recovery efforts could focus on minimising the spread of radioactive materials beyond the site.

Activities are currently progressing to restore electrical power to plant equipment, to minimise the spread of additional radioactive materials offsite, to provide for site clean-up and decontamination, and to continue cooling the reactors at units 1 to 3 and the fuel in the spent fuel pools. The small leaks in the unit 1 RPV lower head continue to represent a challenge to maintaining water inventory within the reactor vessel and preventing further damage at unit 1. However, at the time of writing, it appears that sufficient cooling water is being provided to prevent further damage to the unit 1 reactor vessel. The primary containment at unit 2 appears to have been damaged, contributing to the large releases of radioactive material to the surrounding environment, primarily to the sea. The high levels of contamination and radiation levels in the reactor and turbine buildings of units 1 to 4 have significantly hampered recovery activities. Specialised equipment is being brought to the site to support further recovery and clean-up efforts.

Radiation exposure from the accident

The radiological consequences from the Fukushima accident stem from the gaseous and liquid radioactive materials that have been released to the atmosphere and to the sea. Gaseous radioactive material released to the atmosphere is carried and dispersed by the wind. As it travels, it can irradiate people over whom it passes. The concentration of radioactive material decreases as it is blown farther from the accident site, but radioactive materials from the Fukushima accident have been detected all over the northern hemisphere at extremely low but measurable concentrations. In addition to radiation coming from the cloud, which will eventually pass, radioactive particles like dust will also settle on the ground, plants, houses and roads. This radioactive material will remain for longer periods and can also irradiate people in the area. Liquid radioactive material that is released into the sea is dispersed by the currents in the ocean, and is generally not a direct hazard to humans (but can be indirect from consuming fish, crustaceans, algae, etc.).

At very high exposures, radiation exposure may kill enough human cells to cause whole tissues (intestinal lining, bone marrow, brain cells) to cease functioning. These are termed deterministic effects which do not occur below a particular threshold, and are more serious as doses increase. These effects only occur at *very* high exposures (e.g. >1 000 mSv) and can result in serious illness and death. The dose rates reported in the areas off site in Japan are over a million times less than this threshold, such that it is impossible for these very serious effects to occur in exposed members of the public under the current exposure situation. Radiation exposure at lower levels can, however, increase an individual's risk of contracting fatal cancer or leukemia. Although it is not scientifically possible to distinguish a cancer or leukemia caused by radiation exposure from one brought on by other causes, it is possible to statistically identify, in large exposed populations, whether the measured cancer rate is higher than would be expected. These are termed stochastic effects, and the risk of their occurring is proportional to the exposure received. For large populations which have been exposed to about 100 mSv or more, it is statistically possible to see excess cancers, and in such circumstances the excess cancers may be considered to be radiation-induced. Here again, it seems that the current levels of public exposure would not be large enough to produce any statistically valid evidence of excess cancer caused by this accident. This is not to say that the exposed populations should not have their doses assessed or that no subsequent medical advice would be needed.

According to the current status of radioactive releases from the plant, the majority seem to have taken place before 19 April (see below for further details). In total, it is estimated that approximately 840 PBq (1 peta-Becquerel = $1x10^{15}$ Bq) have been released. This includes many different radionuclides, but of most concern with respect to exposure to the population are caesium (isotopes 137 and 134) and iodine (isotope 131). This amount of radioactive material is approximately 16% of that released by the Chernobyl accident in 1986.

The workers on site are the population most highly at risk from radiation effects, due to both immediate deterministic effects from extremely high exposures, and longer-term stochastic (cancer-inducing) effects from smaller doses. Under normal working conditions, any worker who is exposed to radiation as part of his or her job is allowed no more than 100 mSv of exposure over a five-year period, with exposure in no single year exceeding 50 mSv. In emergency situations, however, this legal dose limit is relaxed for the cases of workers who attempt to save lives or who are working to prevent large collective doses from occurring. Under these extreme and emergency situations, international recommendations allow emergency workers to receive up to 500 mSv. Current Japanese regulations only allow worker's emergency exposures to reach 100 mSv. However, the Ministry of Economy, Trade and Industry (METI) and the Ministry of Health, Labor and Welfare declared on 15 March that emergency workers in this situation were allowed up to 250 mSv. As of 15 June, approximately 2 400 workers have been exposed as a result of recovery work at the Fukushima plant. Of these, 8 have received exposures over 250 mSv. All worker exposures will continue to be monitored, and those exceeding the emergency criteria will most likely be medically followed, although radiation effects such as cancer and leukemia remain unlikely even in these workers. Workers with exposures below 250 mSv should not experience any immediate, serious illnesses, and their longer-term risks of cancer should not be significantly greater than the risks from their normal work.

Characterisation of radiation and contamination levels

Although many measurements of radiation and contamination levels have been made, the complete characterisation of the radiological situation has not been completed. It is expected that contamination will be very unevenly distributed, mostly due to uneven patterns of rain as the radioactive cloud passed over the Japanese countryside. Detailed maps will be needed to fully understand the best way to manage the situation in the months and years to come.

The measurements of radiation levels in the prefectures near the plant suggest that the dose rates are returning to the levels prevalent before the accident. These dose rates correspond to natural radiation, for example uranium naturally found in the soil, or radon. The highest levels of radiation dose outside Fukushima prefecture were measured in Ibaraki prefecture, and these reached about 0.35 µSv/h on 22 March. If this dose rate had persisted for a full year, the resulting exposure of the Ibaraki population would have been about 2.25 mSv. The dose rate in other prefectures around Fukushima also peaked on 22 March, at about 0.2 µSv/h. However, all the dose rates in these prefectures have significantly decreased, and have now broadly reached the normal background dose rate for natural radiation of 0.01 µSv/h to 0.075 µSv/h.

In the Tokyo area, the dose rate peaked on 23 March at approximately 0.14 µSv/h. Within 40 days, the dose rate was once again within its normal range. Taking the daily average dose rate during this period, the dose resulting from the Fukushima accident to the average individual in Tokyo would be approximately 89 µSv. To put this in perspective, the average annual dose to individuals in Japan is 1 100 µSv, a round-trip flight from Tokyo to New York is 200 µSv and a standard chest x-ray is about 50 µSv.

Measurements show that the highest levels of dose rate are in Fukushima prefecture, in the area north-west of the plant, and as far as 40 or 50 km from the plant. In some of these regions the dose rate exceeds 2.25 µSv/h, which would result in over 20 mSv of exposure in a year should such dose rates persist for that amount of time. Although long-term exposure to such dose rates would not be expected to result in public health issues, i.e. statistically significant increases in cancer incidence, if such doses can be avoided then no radiological risks would occur.

Public protection measures

Evacuation is a common countermeasure that is implemented in nuclear emergency and other emergency situations in order to move members of the public from an area of risk or potential risk to a safe area. The areas around the Fukushima Daiichi and Fukushima Daini nuclear power plants have been evacuated to 20 km and 10 km respectively. Because of the proximity of the two units, these two evacuation zones have significant overlap. In identifying evacuation areas, the benefits of evacuating (i.e. avoiding or reducing dose) and the risks of evacuating (i.e. possible transport accidents) are taken into account.

Evacuation of the population within 20 km of the Fukushima Daiichi plant was ordered on 12 March. As a result of the evacuation efforts around these two plants, approximately 78 000 people were evacuated. It is not clear at this time how long this evacuation will be maintained. Radiological characterisation of the area has been slowly undertaken, but access to the area is limited because the conditions at the Fukushima Daiichi plant are still not fully under control, and the road and other infrastructure repairs have yet to be completed.

It should be noted that out of the 78 000 people evacuated, 133 needed to be monitored for contamination upon arrival outside the evacuation zone, and of these, 23 showed some level of contamination. These individuals were decontaminated with soap and water and sent on to the evacuation centre; no specific health or medical measures were necessary.

Another common nuclear emergency countermeasure is to ask members of the public to shelter, that is, to remain indoors and to close all doors and windows so that any contamination in the air outside does not result in individuals being contaminated or irradiated. This countermeasure is generally implemented for people beyond the evacuation zone who are projected to receive only small doses should radioactive material be released from the site in question. For these individuals, the risk of adverse consequences from evacuating outweighs the risks from the small doses they might receive. Sheltering of the population living between 20 and 30 km from the plant was ordered on 15 March and involved approximately 62 000 people. Because of the long duration of this sheltering order, many of the sheltered individuals voluntarily evacuated, and it is certain that those remaining in the zone have periodically left their homes to get food and water.

On 21 April, the Japanese government ordered that another area, north-west of the plant and beyond 30 km, should be evacuated within 30 days. This new area is termed the Deliberate Evacuation Zone and includes areas in five prefectures. This evacuation has been ordered because conservative calculations suggest that populations remaining in this area would receive over 20 mSv of dose over the next year. The Japanese government, citing the latest International Commission on Radiological Protection (ICRP) recommendations, chose the lowest dose criteria in the recommended range of between 20 and 100 mSv/year. In addition, most of the 20-30 km zone has been redesignated as the "Evacuation Prepared Area"; the population in this area has been ordered to be prepared to evacuate should the situation degrade further.

The last common protective countermeasure for nuclear emergency situations is to administer stable iodine tablets to members of the public. The thyroid gland uses iodine as part of its bio-chemical process for making proteins and hormones, and thus iodine that is ingested or inhaled tends to concentrate rapidly in the thyroid. Should radioactive iodine be emitted as a result of a nuclear power plant accident, it could be easily absorbed by individuals coming into contact with it, thereby irradiating their thyroids. This was a source of thyroid cancer following the Chernobyl accident.

Ingesting medical tablets of stable iodine, preferably before any exposure to radioactive iodine, will fill an individual's thyroid gland with stable iodine and thus any radioactive iodine absorbed by the individual will be eliminated rather harmlessly in the individual's urine, preventing irradiation of the sensitive thyroid gland. It should be noted, however, that taking concentrated stable iodine tablets can have medical side effects, and therefore should not be taken unless there is a serious risk of being exposed to radioactive iodine. In the case of the emergency situation at Fukushima, 230 000 units of stable iodine were distributed to evacuation centres as a precautionary measure but thus far have not been given to the evacuated members of the public.

Nuclear safety implications and NEA work

When assessing the safety implications of the accident at Fukushima Daiichi, it is important to recognise that the natural disaster that occurred was far more significant than the historical record for that area would have suggested was likely. The magnitude 9.0 earthquake was one of the largest on record for Japan. Even though the units at Fukushima Daiichi were designed for resisting a smaller earthquake, it appears that most of the equipment necessary to safely shut down the plant operated as designed. This should be seen as a positive indication of the robust nature of the design and construction of the nuclear power plants. An important factor to be considered as the NEA evaluates its work in this area is to understand what continued to function after the earthquake and why, to better inform the recommended safety improvements.

Had the initiating event at Fukushima Daiichi stopped with just the earthquake, the extent of the accident would have been significantly less, with most likely only minimal impact on the surrounding population and environment. This was demonstrated by the relatively minor releases of radioactive material and subsequently minor impact to the public and environment from the nearby Fukushima Daini nuclear power plant. At Fukushima Daini, the emergency diesel generators continued to operate after the event to provide power to the critical equipment needed to shut down and to cool the reactors. However, the 14-15 m high tsunami that struck the Fukushima Daiichi nuclear power plant was significantly larger than estimated in the design. When the tsunami hit, the flooding caused the on-site emergency diesel generators to fail. As a result, the equipment to cool the reactors and the fuel in the spent fuel pools was no longer able to operate. This led to core damage at units 1 to 3. As a consequence of the core damage, the leaks in the unit 1 lower RPV head and the explosions that damaged the reactor buildings and the unit 2 primary containment, the spread of radioactive material from Fukushima Daiichi was significant.

As the evaluation of the accident progresses, the NEA and other organisations need to look at what went wrong, what worked and what can be done to improve the ability of nuclear power plants to withstand beyond-design-basis events, or to redefine what external events should be included within the design basis. Some of the nuclear safety areas for which lessons can be learnt from this accident include:

- the methodology for identifying the external events that need to be considered in the design and construction of nuclear power plants;
- the impact of site characteristics on the ability of the nuclear power plant to cope with external events;
- the plant's response to an extended station blackout and station blackout coping techniques;
- severe accident management techniques and the use of alternative methods for cooling;
- the generation and transport of hydrogen following core damage;
- the impact of accidents on the ability to protect fuel stored in spent fuel pools.

To facilitate this evaluation effort, the NEA Committee on Nuclear Regulatory Activities (CNRA) established a senior task group to follow up on the impacts of the accident and in particular to:

- act as a focal point for the timely and efficient exchange of information on national and regional activities, such as reviews, audits and inspections of nuclear power plants in response to the Fukushima accident;
- act as a resource for Japan to communicate and collaborate with international regulatory bodies in a timely and efficient manner;
- identify lessons learnt from the accident as an international body of senior regulators;
- identify areas that the exchange of existing practices would assist in identifying commendable practices and areas that should be adapted based on insights from the Fukushima accident;
- identify areas and issues which would benefit from in-depth evaluation or research;
- identify short-term and long-term follow-on activities for the task group, current CNRA and NEA Committee on the Safety of Nuclear Installations (CSNI) working groups, or recommend the creation of a new temporary group.

The senior task group reported to the CNRA during the special Fukushima session at the 6-7 June 2011 CNRA meeting in Paris. It provided recommendations for consideration by the CNRA and the CSNI on areas and activities for follow-up by various NEA working groups and projects. The accident was also discussed during the 9-10 June 2011 CSNI meeting in Paris.

In addition, two high-level events were co-organised by the French Presidency of the G8-G20 and the NEA at the OECD Conference Centre on 7-8 June 2011: a G8 extended meeting of ministers on nuclear safety and a forum on the Fukushima accident. The main objectives of the forum were to provide the opportunity to exchange information on emerging lessons learnt, safety implications and national activities in response to the Fukushima accident, and to define areas in which international co-operation would be beneficial. Participants had the opportunity to meet with their counterparts from other countries and organisations to discuss current and future issues on this topic, to provide guidance to the CNRA and the CSNI for future activities, and to provide input for the IAEA ministerial conference on Fukushima, which will be held on 20-24 June 2011 in Vienna.

The Fukushima accident has resulted in safety reviews being conducted in all NEA member countries with operating nuclear reactors. In this context and on request of the Japanese authorities, the NEA will be supporting the safety reviews of operating reactors in Japan, with Fukushima Daiichi being subject to separate reviews. NEA safety experts met with Japanese regulatory authorities on 2-3 June 2011 in Tokyo to begin co-ordinating this review.

Radiological protection and NEA follow-up

Many lessons can also be learnt in the area of radiological protection, including on how to effectively communicate with external stakeholders during a crisis; the effectiveness of emergency planning and preparedness practices; and techniques to identify sources of contamination, to minimise the release of radioactive material and to protect workers from high radiation levels while taking action to respond to an accident.

The most difficult radiological aspect of the Fukushima accident will be the recovery process once the plant is fully safe, under control and radiological releases have stopped. For this work, the involvement of stakeholders in the management of consequences will be central to taking sustainable decisions. The NEA draws on significant study of population protection responses to the Chernobyl accident; on extensive experience from the organisation and assessment of international nuclear emergency exercises (the NEA INEX series); and the Agency's longstanding focus on stakeholder involvement in radiological protection decision-making. Using this experience as a starting point, the NEA Committee on Radiation Protection and Public Health (CRPPH) will consider the most beneficial options for further investigating stakeholder involvement in recovery decision-making, and offering the Japanese government its experience to facilitate decisions that will need to be taken in Japan.

In terms of emergency management, the CRPPH has since the Chernobyl accident actively studied the international aspects of nuclear emergencies, notably through the organisation of international nuclear emergency exercises, the INEX series. The CRPPH Working Party on Nuclear Emergency Management (WPNEM) met in early May and will propose to the CRPPH that, based on this experience and that of members with the Fukushima accident, the WPNEM should address how national emergency management decisions and recommendations could be better co-ordinated internationally, and how preparation plans now stand in NEA member countries.

Finally, the Information System on Occupational Exposure (ISOE) is a joint undertaking to share operational occupational exposure management experience among radiological protection experts at nuclear power plants. The ISOE programme has proposed to summarise this wealth of experience in terms of working in high radiation areas (as will be the case at the Fukushima plant for some time) to assist the Japanese in their on-site recovery efforts, and to be better prepared in all participating countries for accidents or other situations where work in high radiation areas is needed.

This article was sent to press on 16 June 2011. For the latest information on the Fukushima accident and the NEA response, please see www.oecd-nea.org.

Fukushima: liability and compensation

by X. Vásquez-Maignan*

On 11 March 2011, Japan endured one of the worst natural disasters in its history when a massive earthquake struck the Pacific coast of the country and was followed by a tsunami which led to considerable loss of lives. It also led to a major accident[1] at the Fukushima Daiichi nuclear power plant. Soon afterwards, the operator of the plant, Tokyo Electric Power Company (TEPCO), assumed responsibility and liability for the nuclear accident. On 28 April 2011, TEPCO established a dedicated contact line to provide consulting services for financial compensation related to the damage caused.[2]

Third party nuclear liability principles

The compensation procedure set up by TEPCO complies with the Japanese legislation governing third party liability for nuclear activities. Even though Japan is not party to any of the international nuclear liability conventions, it has solid national third party liability legislation whose main principles are as follows:

- The operator of the nuclear power plant where the nuclear accident occurred is strictly liable (which means that the operator is held liable regardless of fault, negligence or intention to harm).
- The operator is exclusively liable for the damages (i.e., no other person may be held liable for the damages caused by the nuclear accident).
- The operator's liability is not limited in amount.
- The operator is obliged to financially secure its liability up to a certain amount (JPY 120 billion for nuclear power plants, or approximately EUR 1.16 billion or USD 1.57 billion as of 27 September 2011).
- Where nuclear damage exceeds the financial security amount, the government may help a nuclear operator to compensate the damage to the extent authorised by the National Diet.
- All rights of action are fully extinguished 20 years following the date of the tort and the actions must be brought within three years from the date at which the person suffering damage had knowledge both of the damage and of the person liable.
- The victims may refer their claims directly to the operator concerned, to a local court or to the Dispute Reconciliation Committee for Nuclear Damage Compensation (the Reconciliation Committee), which the Japanese Ministry for Education, Culture, Sport, Science and Technology (MEXT) may establish following an accident and whose function is, on the one hand, to draft instructions to establish the scale of the nuclear damage as well as to actually assess them and, on the other hand, to mediate disputes concerning compensation claims.

In the case of the Fukushima accident, MEXT established the Reconciliation Committee in early April 2011.

Nuclear damage

According to the Act on Compensation for Nuclear Damage (the Compensation Act), nuclear damage means "any damage caused by the effects of the fission process of nuclear fuel, or of the radiation from nuclear fuel… however, any damage suffered by the nuclear operator who is liable for such damage… is excluded."

Damages to the operator concerned are explicitly excluded, with the operator having to assume the loss or damage to his own property (such as the nuclear installation itself). The purpose is to avoid the financial security being used to compensate the operator to the detriment of the victims.

As the law does not clearly define the nature of the damages to be compensated by the operator, the Reconciliation Committee has adopted guidelines that are not legally binding to determine the type of damages which give right to compensation. The "Preliminary guidelines for determination of the scope of nuclear damage due to TEPCO's Fukushima Daiichi and Daini nuclear power stations" adopted on 28 April 2011 defined the damages resulting from instructions issued by the central and local governments which may be compensated (e.g. evacuation instructions; restrictions of marine areas; restrictions of shipments of agricultural products and marine products).

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Summary of liability and compensation	
National third party liability legislation	Nuclear power plant operator subject to strict, unlimited liability and required to financially secure JPY 120 billion (EUR 1.16 billion) per site. Can be completed by government funds if approved by the Diet.
Indemnity agreement	Amount paid by the government to TEPCO: JPY 120 billion (EUR 1.16 billion).
Nuclear Damage Compensation Facilitation Corporation Established September 2011	Amount received by TEPCO from the Nuclear Damage Compensation Facilitation Corporation: JPY 558.7 billion (EUR 5.39 billion).
TEPCO	Estimated provisional compensation paid thus far: – JPY 52 billion (EUR 0.5 billion) to households; – JPY 43 billion (EUR 0.4 billion) to individuals for evacuation fees; – JPY 63 billion (EUR 0.6 billion) to farmers, fishermen and small- and medium-sized companies.

The "Second Guidelines" adopted on 31 May 2011 provide the method of calculating the damages listed in the first guidelines and define additional types of damages, such as damage suffered by workers, bankruptcies, costs of decontamination measures and damage caused by unfounded rumors. On 5 August 2011, the Reconciliation Committee adopted the "Interim guidelines governing nuclear disaster compensation due to the accident at Fukushima Daiichi and Daini Power Plants" pursuant to which TEPCO has drawn up the procedure to pay the "permanent compensation" amounts (as opposed to the "provisional compensation" which were paid up until recently as a measure of urgency).

Despite the official mandate of this Committee, it is the Japanese courts that will have the final decision on what qualifies as nuclear damage. However, in the past, out-of-court settlements have been successful in Japan thanks to the guidelines of the committees and the help of local governments. On 30 September 1999, a criticality accident took place in a uranium processing facility of JCO Co. Ltd. at Tokai-mura. As a result, approximately 8 000 claims were raised, most of which were compensated in out-of-court settlements according to the compensation guidelines.

As regards the Fukushima accident, it will be a challenge to distinguish damages directly linked to radiation exposure risks from those that were caused by the earthquake and tsunami. Evacuations were ordered, at first, to protect the population from the inundation, and one major difficulty will be to draw a clear line between victims of the natural disaster and those who have suffered nuclear damage in a stricter sense.

Exoneration of liability

The Compensation Act provides that the operator may be exempted from liability when "...the damage is caused by a grave natural disaster of an exceptional character...". Where this exoneration applies, the government shall take, pursuant to the Compensation Act, "the necessary measures to relieve victims and to prevent the damage from spreading".

In light of the massive earthquake and the ensuing tsunami which led to the Fukushima accident, the question arises of a potential exoneration of TEPCO's liability. However, the government's current position does not suggest that TEPCO will be exonerated from liability due to the "exceptional" character of this natural disaster. When the Compensation Act was enacted, the conditions for the exemption due to natural disasters were described in the Congress as a "huge natural disaster beyond all expectations of humankind". As an earthquake-prone archipelago, Japan has a rather unique perception of what qualifies as a "grave natural disaster of an exceptional nature". For example, the earthquake in Kobe on 17 January 1995, which registered at 6.9 on the Richter scale and resulted in over 5 000 deaths, did not qualify as a grave natural disaster of an exceptional character.

Courts in civil proceedings will decide if the earthquake of 11 March 2011 qualifies as a natural disaster beyond all expectations of humankind, but only if TEPCO decides to invoke this exemption against claimants. TEPCO's latest statements do not suggest that it will invoke the application of this provision in its favour.

Liability amount

Pursuant to the Compensation Act, the operator has an unlimited liability and must maintain financial security either through i) a private nuclear liability insurance contract (the most common means of financial security) combined with an indemnity agreement to be entered into with the government for non-insurable risks (for which the operator shall pay a fee to the government), ii) a deposit (in cash or in security) or iii) any other arrangement approved by MEXT.

The six units at Fukushima Daiichi are treated as one site; the same applies to the four units at Fukushima Daiini. As a result, the financial security amounts to JPY 120 billion for each site.

Should damages exceed the JPY 120 billion of financial security, the operator still remains liable (unlimited liability). However, in that event and if approved by the National Diet, the government shall give the nuclear operator concerned such aid as required to compensate the (excess) damage when the government deems it necessary in order to attain the purpose of the Compensation Act.

Compensation of the Fukushima victims

As the Fukushima accident will have consequences which will exceed JPY 120 billion, on 13 May 2011 the Japanese government issued a framework for government financial support to TEPCO in which it recognises its social responsibility and essentially aims to minimise the burden to be placed on the public. This plan was then submitted to and approved by the National Diet on 3 August 2011 under the bill for the "Establishment of a Nuclear Damage Compensation Facilitation Corporation" (the Facilitation Corporation). This corporation, established in September 2011, will manage a fund which shall receive contributions from the government and the Japanese nuclear installation operators, and will support operators in providing compensation to victims of nuclear accidents. The operator requesting such support will be required to implement cost-cutting measures as a pre-requisite to benefit from this fund and will be expected to pay back over the years the amounts received.

On 28 October 2011, TEPCO applied in order to benefit from the Facilitation Corporation financial support and submitted to that effect a business plan with cost-cutting measures which was approved on 4 November 2011. According to TEPCO, on 15 November 2011 it received JPY 558.7 billion (EUR 5.39 billion or USD 7.2 billion) from the Facilitation Corporation pursuant to the approval of its business plan. Furthermore, on 22 November 2011 it received JPY 120 billion from the government under the indemnity agreement for non-insurable risks.

TEPCO has been paying "provisional compensation" amounts to the victims, but as from October 2011, "permanent compensation" shall be paid pursuant to new procedures that were established by TEPCO on 30 August 2011[3] (for the procedure applicable to damages suffered by individuals) and on 21 September 2011[4] (for the procedure applicable to damages suffered by sole proprietors and corporations).

According to the press, TEPCO has so far paid about JPY 52 billion (EUR 0.5 billion or USD 0.7 billion) in "provisional compensation" to 56 400 households, and an additional JPY 43 billion (EUR 0.4 billion or USD 0.56 billion) to individuals for fees they had paid to be evacuated. It has also paid about JPY 63 billion (EUR 0.6 billion or USD 0.8 billion) to farmers, fishermen and small- and medium-sized companies as "provisional compensation".[5]

Notes

1. For the technical description of the event, see *NEA News* No. 29.1.
2. www.tepco.co.jp/en/index-e.html.
3. www.tepco.co.jp/en/press/corp-com/release/11083007-e.html.
4. www.tepco.co.jp/en/press/corp-com/release/11092109-e.html.
5. *Reuters,* 26 September 2011.

The NEA integrated response to the Fukushima Daiichi nuclear accident

by G. Lamarre, T. Lazo, D. Jackson, J. Nakoski and H.B. Okyar*

The 11 March 2011 earthquake and massive tsunami that struck the eastern coast of Japan, and ultimately resulted in the core-melt accidents of Fukushima Daiichi units 1-3 and serious cooling problems in the spent fuel pool of unit 4, have left an enormous challenge for the Japanese authorities to address and remediate. For the international nuclear safety community, questions abound as to what lessons can be drawn from this tragic accident to enhance the safety of current and future nuclear power plants worldwide, and to improve emergency response arrangements and strategies on the national and international levels. In the immediate aftermath of the Fukushima Daiichi accident, NEA member and associated countries looked to the NEA to bring together experts to begin addressing some of the lessons emerging from the accident.

Integrated NEA process for post-Fukushima actions

To ensure that the NEA facilitated an effective and efficient exchange of information and response to the Fukushima Daiichi accident, in December 2011 a meeting was organised among the bureaus of the three principal standing technical committees with responsibilities in the areas of regulatory oversight, nuclear safety and radiation protection and public health: the Committee on Nuclear Regulatory Activities (CNRA), the Committee on the Safety of Nuclear Installations (CSNI) and the Committee on Radiation Protection and Public Health (CRPPH), to discuss how best to co-ordinate and co-operate in responding to the 11 March events. All three committees had begun to consider, and in some cases to initiate tasks to address, some of the lessons being learnt from the accident, and the meeting enabled agreement as to how an integrated response process would work. This would also facilitate communication of a clear and comprehensive NEA Fukushima Daiichi safety enhancement programme to all internal and external stakeholders.

The three committees agreed that the CNRA would assume overall co-ordination of the NEA integrated response and that the CNRA Senior-level Task Group on Impacts of the Fukushima Accident (STG-FUKU), which had been constituted in the immediate aftermath of the accident, would assume the role of programme oversight and co-ordinator. In addition, the CSNI extended the scope of its Programme Review Group (PRG) to address cross-cutting activities related to the Fukushima accident. Further, the Expert Group on Radiological Protection Aspects of the Fukushima Accident (EGRPF) was established by the CRPPH as a focal point for co-operation with the committees mentioned above and among all relevant international organisations, in particular the International Atomic Energy Agency (IAEA) and the European Commission (EC), for radiological protection and emergency management issues. Direct support is also provided by the CRPPH Working Party on Nuclear Emergency Matters (WPNEM).

The three committees concluded that ongoing, approved work should largely continue unabated, but that all tasks should be considered to the extent possible through a multilateral lens, for example developing products that could satisfy or answer questions in more than one of the safety fields.

Elements of the action plan

Based on the inputs of the three standing technical committees, their working parties and expert groups, an action list of key safety issues was prepared, responsibilities were agreed and cross-committee co-ordination mechanisms were confirmed. The table hereafter provides an overview of the Integrated NEA Fukushima Actions for Safety Enhancements (INFASE) programme as of May 2012.

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Topical areas	Proposal	Status	CNRA	CRPPH	CSNI
1. Accident management and progression					
a. **Transition:** Development of programmes and procedures to address the transitional conduct of operations from normal to accident conditions, to severe accident conditions, and to the implementation of protective measures under the emergency preparedness plans. This includes onsite and offsite decision-making processes.	CNRA	P	L	S	S
b. **Accident progression:** Enhanced understanding of accident progression analyses methods and techniques.	CNRA	P	S	S	L
c. **Human performance:** Human and organisational performance issues under accident response conditions.	CNRA	P	S	S	L
d. **Offsite:** Improvement of offsite emergency preparedness by sharing knowledge on core-melt accident progression and source-term quantification to improve offsite emergency procedures and technical tools.	CRPPH	P	S	L	S
2. Crisis or emergency communications (primary information exchange between the CNRA and the CRPPH)					
a. **Public:** Communication with the public, media and other stakeholders.	CNRA	A	L	S	
b. **Regulators:** Communication with the regulators in other countries and with international organisations, such as the Inter-Agency Committee on Radiological and Nuclear Emergencies (IACRNE) and the International Atomic Energy Agency (IAEA).	CNRA	P	L	L	
c. **Onsite-offsite:** Crisis communications between onsite and offsite emergency response organisations.	CNRA	P	L	L	
3. Reassessment of defence-in-depth	CSNI	P	S		L
4. Evaluating the methodologies for defining and assessing initiating internal and external events, including coupled events, as well as methodologies defining the design-basis criteria	CSNI	P	S		L
5. Reassessment of operating experience and prior opportunities to identify or address conditions that could challenge nuclear safety					
a. **Operating experience:** Evaluation of operating experience for events that may be precursors to future events that could challenge the safety of nuclear power plants given the insights from Fukushima.	CNRA	A	L		S
b. **Research:** Review and gap analysis of safety research relevant to the analysis of the accident.	CSNI	A	S		L
6. Balancing deterministic and probabilistic approaches to regulatory decision making	CNRA	P	L		S
7. Regulatory infrastructure (non-cross committee)	CNRA	A	L		
8. Radiological protection (non-cross committee)	CRPPH	A		L	
9. Radiological protection aspects of decontamination and recovery (onsite and offsite, non-cross committee)	CRPPH	A		L	

P: planned, A: active, L: lead committee, S: supporting committee.

Onsite accident management

Regarding onsite accident management, the STG-FUKU recommended to the CNRA that an experts' meeting be held to better define the activities in this area that the NEA could support in addressing lessons learnt from the Fukushima Daiichi accident. The meeting was held on 20-22 March 2012 and included a pre-meeting survey to collect information on national approaches to onsite accident management. Responses were received from 12 countries; experts from 10 countries participated in the meeting.

During the meeting, the experts identified four broad areas (transitional procedures, onsite and offsite interactions, design and equipment, and human and organisational factors) under which ten proposals were developed and prioritised. Work that experts considered important to start immediately include issues related to the ability of people responding to the accident to be able to handle beyond-design-basis situations and conditions; how and when to engage external help; approaches to decision making with guiding principles during emergency situations; and ensuring that instrumentation and equipment for addressing long-term aspects of onsite accident management are available. Other important issues that, for various reasons might be taken up at a later stage, include developing and maintaining the competencies of the people responding to beyond-design-basis events, and enhancements to onsite accident management procedures and guidance based on lessons being learnt from the accident.


TEPCO, Japan

Emergency Response Headquarters for the Fukushima accident (April 2011).

Reassessment of defence-in-depth

Following the issues and priorities outlined in its Concept Paper on Fukushima as well as the key priorities raised by the STG-FUKU, the CSNI and its working groups are currently considering tasks related to improving robustness and decreasing vulnerabilities of current and new reactor designs. Foremost in this area is further study of the means by which to improve a plant's ability to withstand the loss of basic safety functions such as residual heat removal, and coupled events such as the loss of power and the loss or degradation of critical instrumentation and control (I&C) systems. These vulnerabilities will be grouped into two broad categories. The first involves the loss of electrical systems, including how to better design electrical power generation and distribution systems within and outside the plant to maintain critical safety functions (core cooling, containment integrity, spent fuel cooling and confinement of radioactivity) and to effectively monitor them during prolonged loss of power events. The concept of better optimising current battery loads and sustaining critical power for extended periods of time is another key issue to be examined.

The second broad area concerns loss of ultimate heat sink, including a review of how safety functions for core cooling and spent fuel pool cooling can be maintained in the case of prolonged loss of heat sink. Design and other provisions to cope with loss of ultimate heat sink is a key aspect of increasing the defence-in-depth and robustness of plants. At its 6-7 June 2012 meeting, the CSNI further considered these two technical areas as well as discrete technical studies to address them.

Radiological protection and public health

With respect to radiological protection and public health issues, the CRPPH has been providing technical assistance to the Japanese authorities and international community via initiatives such as the Expert Group on Radiological Protection Aspects of the Fukushima Accident (EGRPF), the assessment and sharing of national lessons learnt, the co-sponsorship of an International Symposium on Decontamination organised by the Japanese government in October 2011, and the co-sponsorship of the Fukushima Dialogue Initiative symposia being organised by the International Commission on Radiological Protection (ICRP).

In addition, the CRPPH agreed that it would be important to quickly collect the experience and lessons of its membership with regard to the evolution of national emergency response plans as a result of the Fukushima accident. A short list of framework areas has therefore been prepared to facilitate the identification of commonalities in national assessments, so that the committee may most effectively identify relevant areas for further CRPPH work. Below are the categories of issues identified for the collection of member country views and approaches with regard to their self-assessment of pre-Fukushima emergency response plans:

Relative to an accident in your own country:

- preparations for communications with other countries: preparations for translation, preparations to address overseas issues, preparations to advise other countries on decisions taken (or to be taken);
- preparedness and response plans for long-term releases: management of sheltering, of evacuated populations, of livestock and of civil protection (including medical support);
- preparedness and response plans for protection strategy optimisation (as in ICRP Publication 109): assessment of short-term countermeasure effects, projection of circumstances and exposure pathways over the longer term (i.e. up to one year), setting reference levels, establishing triggers, assessment and decision support tools;
- preparedness plans for recovery (as in ICRP Publication 111): radiation monitoring arrangements, introduction of health surveillance programmes, stakeholder involvement in emergency management planning, management of contaminated foodstuffs, mechanisms/processes for recovery planning.

Relative to an accident in another country:

- preparations for communication with other countries: understanding of facilities (such as type, location, surroundings, and citizens at or near the facility), approaches to collecting information (i.e. from the IAEA, the EC, the regulator or other institutions in the accident country);
- preparedness plans for assessment of overseas accidents: source-term assessment, access to local/regional meteorological data;
- preparedness plans for providing advice: to citizens in the accident country, to support embassy needs, to airlines and shipping companies, to national industry in the accident country, for importing food and goods from the accident country.

The initial results of the survey have been evaluated. However, in order to facilitate a more in-depth analysis, a new joint survey of the CRPPH and Working Party on Nuclear Emergency Management (WPNEM) members is being developed.

Safety research

One of the key areas of the integrated NEA response to the Fukushima Daiichi accident involves the review of past and ongoing safety research to determine whether there are gaps in research revealed by the accident that need to be addressed. The CSNI is currently considering a fundamental review of its past experimental work carried out as part of the OECD/NEA joint international research projects in order to apprise what has been done to date, to identify key technical gaps where safety research may be required and to provide recommendations regarding priority safety research topics in the future. Results would then be presented to the member countries for their consideration.

Next steps

Based on the decisions taken by the CNRA, the CSNI and the CRPPH during the first half of 2012, certain high-importance and high-urgency tasks will be launched. Current tasks undertaken in response to the Fukushima Daiichi accident will continue as per their original schedule. The goal is to produce results in a timely manner for the benefit of the member countries and to provide them with information and data that will complement their work on Fukushima follow-up initiatives. The three committees have been clear in their expectations: that highly important, urgent tasks produce draft results within one year. Lower-importance and/or lower-urgency tasks are to be completed within a one- to three-year time period. The tasks which form part of the Integrated NEA Fukushima Actions for Safety Enhancements will be monitored and reported on through the NEA website and via the standing technical committee meetings on a regular basis.

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