IAEA Report on

Radiation Protection after the Fukushima Daiichi Accident: Promoting Confidence and Understanding

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FOREWORD

By Denis Flory
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In response to the accident at the Fukushima Daiichi nuclear power plant, IAEA Member States unanimously adopted the Action Plan on Nuclear Safety. Under this Action Plan, the IAEA Secretariat was asked to organize International Experts Meetings to analyse all relevant technical aspects and learn the lessons from the accident. The International Experts Meetings brought together leading experts from areas such as research, industry, regulatory control and safety assessment. These meetings have made it possible for experts to share the lessons learned from the accident and identify relevant best practices, and to ensure that both are widely disseminated.

This report on Radiation Protection after the Fukushima Daiichi Accident: Promoting Confidence and Understanding is part of a series of reports covering all the topics dealt with in the International Experts Meetings. The reports draw on information provided in the meetings as well as on insights from other relevant IAEA activities and missions. It is possible that additional information and analysis related to the accident may become available in the future.

I hope that this report will serve as a valuable reference for governments, technical experts, nuclear operators, the media and the general public, and that it will help strengthen nuclear safety.

EDITORIAL NOTE

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1. INTRODUCTION

Following the accident at TEPCO's Fukushima Daiichi nuclear power plant (the Fukushima Daiichi accident), the IAEA Director General convened the IAEA Ministerial Conference on Nuclear Safety in June 2011 to direct the process of learning and acting upon lessons to strengthen nuclear safety, emergency preparedness and radiation protection of people and the environment worldwide. The Conference adopted a Ministerial Declaration on Nuclear Safety, which, inter alia, requested the Director General to prepare a draft Action Plan.[1] The draft Action Plan on Nuclear Safety (the Action Plan) was approved by the Board of Governors at its September 2011 meeting,[2] and was subsequently unanimously endorsed at the 55th regular session of the IAEA General Conference on 22 September 2011. The purpose of the Action Plan is to define a programme of work to strengthen the global nuclear safety framework.

The Action Plan includes 12 main actions. One of the actions is focused on communication and information dissemination, and includes six sub-actions, one of which mandates the IAEA Secretariat to "organize international experts meetings to analyse all relevant technical aspects and learn the lessons from the Fukushima Daiichi nuclear power station accident".[3]

The International Experts Meeting (IEM) on Radiation Protection after the Fukushima Daiichi Accident: Promoting Confidence and Understanding was held from 17 to 22 February 2014 at IAEA Headquarters in Vienna. The IEM was convened to provide an opportunity for participants to discuss and assess the radiation protection challenges posed by the accident and the ways these challenges can be effectively addressed at the national and international levels.

The IEM was attended by over 220 experts from 68 Member States and 10 international organizations representing governmental, regulatory, operating, technical support, research and educational bodies. The IEM featured expert presentations from keynote speakers and panellists, and provided several opportunities for discussion, during which the participants shared their experience and identified lessons learned.

Each of the 15 technical sessions was summarized by the session Chair, and an IEM Chairperson's Summary was produced at the end of the IEM (see Annex A).

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[1] Declaration by the IAEA Ministerial Conference on Nuclear Safety in Vienna on 20 June 2011, INFCIRC/821, IAEA, Vienna (2011), para. 23.

[2] Draft IAEA Action Plan on Nuclear Safety, Report by the Director General, GOV/2011/59-GC(55)/14, IAEA, Vienna (2011).

[3] Ibid., p. 5.

1.1. BACKGROUND

The initiator of the Fukushima Daiichi accident was the Great East Japan Earthquake, a seismic event of extreme magnitude. The event was caused by a sequential rupture of successive fault segments and resulted in a massive release of seismic energy, generating a tsunami beyond the design basis of the Fukushima Daiichi nuclear power plant.

The defence in depth provisions at the Fukushima Daiichi nuclear power plant were insufficient to provide the appropriate levels of protection for critical safety systems. Consequently, there was a failure of the power supplies needed to provide ongoing support to key safety functions, including cooling of the reactor and spent fuel. This led to severe core damage and the release of significant quantities of radioactive material to the atmosphere and to the ocean. The released radioactive material exposed the local population to radiation in a number of ways, including external radiation exposure from radioactive material in the air and from radioactive material deposited on the ground, and internal radiation exposure from inhalation of radioactive material in the air and from ingestion of radioactive material in food or water. Immediate actions were taken by the Japanese authorities to reduce the population's exposure to radiation.

The Fukushima Daiichi accident raised a number of issues related to protecting people and the environment from ionizing radiation, in particular concerning the comprehensiveness and ease of implementation of the International System of Radiological Protection[4]. A number of specific issues were highlighted for further consideration, including the need to provide timely, factually correct, objective and easily understandable information to populations affected by a nuclear or radiological accident. This matter is addressed in a more specific manner in the IAEA Report on Enhancing Transparency and Communication Effectiveness in the Event of a Nuclear or Radiological Emergency[5].

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[4] The International System of Radiological Protection, developed, maintained and elaborated by the International Commission on Radiological Protection (ICRP), is used worldwide as the common basis for radiological protection standards, legislation, guidelines, programmes and practice.

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Report on Enhancing Transparency and Communication Effectiveness in the Event of a Nuclear or Radiological Emergency, IAEA, Vienna (2012), available at:
http://www.iaea.org/newscenter/focus/actionplan/reports/enhancetransparency180612.pdf

1.2. OBJECTIVE

The objective of this report is to highlight the lessons learned in the area of radiation protection in the light of the Fukushima Daiichi accident. The report highlights the views expressed by international experts during the IEM on Radiation Protection after the Fukushima Daiichi Accident: Promoting Confidence and Understanding. This is supplemented by experience from other relevant IAEA activities, such as the first fact finding mission to Japan[6] and the expert missions dealing with decommissioning[7] and remediation[8].

The report identifies key areas where the application of the International System of Radiological Protection can be strengthened as well as lessons learned for radiation protection specialists worldwide. The report is expected to contribute to the ongoing efforts to assist Member States in strengthening the protection of people and the environment from ionizing radiation worldwide and constitutes an integral part of the implementation of the Action Plan.

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[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Mission Report: The Great East Japan Earthquake and Tsunami Expert Mission — IAEA International Fact Finding Expert Mission of the Fukushima Dai-Ichi NPP Accident following the Great East Japan Earthquake and Tsunami, IAEA, Vienna (2011), available at:
http://www-pub.iaea.org/MTCD/Meetings/PDFplus/2011/cn200/documentation/cn200_Final-Fukushima-Mission_Report.pdf

[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Mission Report: IAEA International Peer Review Mission on Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 14, IAEA, Vienna (2013), available at:
http://www.iaea.org/newscenter/focus/fukushima/missionreport230513.pdf;
INTERNATIONAL ATOMIC ENERGY AGENCY, Preliminary Summary Report: IAEA International Peer Review Mission on Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 14 (Second Mission), IAEA, Vienna (2013), available at:
http://www.iaea.org/newscenter/focus/fukushima/missionreport041213.pdf

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, Final Report of the International Mission on Remediation of Large Contaminated Areas Off-site the Fukushima Dai-ichi NPP, IAEA Vienna (2011), available at:
http://www.iaea.org/newscenter/focus/fukushima/final_report151111.pdf;
INTERNATIONAL ATOMIC ENERGY AGENCY, Final Report: The Follow-up IAEA International Mission on Remediation of Large Contaminated Areas Off-Site the Fukushima Daiichi Nuclear Power Plant, IAEA, Vienna (2014), available at:
http://www.iaea.org/newscenter/focus/fukushima/final_report230114.pdf

2. RELEASE OF RADIOACTIVE MATERIAL TO THE ENVIRONMENT

The Fukushima Daiichi accident resulted in the release of large quantities of radioactive material to the atmosphere and the marine environment. In the context of an accident at a nuclear facility, such releases are often referred to as the source term. The radiological significance of the source term is defined by the characteristics of the radioactive material and its quantity. The most radiologically significant releases from the Fukushima Daiichi accident were isotopes of iodine and caesium, in particular, ^{131}I, ^{134}Cs and ^{137}Cs.

The releases to the atmosphere are currently estimated to be in the range of 100–500 petabecquerels (PBq)[9] for ^{131}I and 6–20 PBq for ^{137}Cs. The releases of ^{134}Cs were similar to those of ^{137}Cs. These quantities are about 10–20% of the releases that occurred during the Chernobyl accident and took place over a protracted period of many days. The main radionuclides released to the marine environment were ^{131}I, ^{134}Cs and ^{137}Cs. Smaller amounts of tritium (^{3}H) and other radionuclides were also released.

An understanding of the source term and of the distribution of radioactive material in the environment following an accident is important for decision making on actions to protect people from exposure to ionizing radiation. In Japan, protective actions were implemented, including evacuation and restrictions on consumption of certain foods. These protective actions, combined with the smaller source term, resulted in considerably lower radiation doses to the local population around the Fukushima Daiichi nuclear power plant than those incurred by the local population around the Chernobyl nuclear power plant.

2.1. AERIAL RADIOACTIVE RELEASES

Lessons Learned: In the absence of measurement results, predictions of the accident source term and of the dispersion in the atmosphere will have inherent uncertainties. However, the Fukushima Daiichi accident showed that appropriate public protection actions can be applied during the initial response to an accident, even in the absence of sophisticated source term and dispersion calculation tools.

The source term for the Fukushima Daiichi accident has been estimated by many institutions worldwide using computer based modelling techniques.

[9] 1 petabecquerel (PBq) = 10^{15} becquerels (Bq).

These estimates have been refined and updated as more information relating to the accident has become available. There is potential for further development of these computer based modelling techniques to enable prediction of the accident source term during the early stages of an accident. Efforts such as intercomparison exercises using these modelling techniques are one example of a potential area for improvement.

Following the Fukushima Daiichi accident, modelling techniques were also widely used by experts in many Member States to predict the movement of the radioactive release in the atmosphere. These techniques provided indications of the likely concentrations of radioactivity in air, both in Japan and elsewhere in the world, and were used by the relevant authorities to consider the implications of the radioactive release.

The atmospheric conditions prevailing at the time of the Fukushima Daiichi accident ensured that only very small amounts of radioactivity were deposited on the territories of Member States other than Japan. Consequently, the response in other Member States focused primarily on radiation monitoring activities to reassure and provide information to the public, including foreign nationals based in Japan at the time.

At the International Experts Meeting

During discussions at the IEM, it was noted that sophisticated computer based modelling and forecasts of the atmospheric transport of the radioactive releases proved to be effective and accurate. The experts highlighted the technical challenges of modelling atmospheric dispersion of radioactive releases from a multiple reactor source over a protracted period of time, with complex, rapidly changing weather patterns. In addition, the experts noted that performing these complex atmospheric dispersion modelling analyses requires scientific and technical staff with experience and a high level of skill. However, not all Member States possess the resources needed to perform such calculations, particularly in real time. Consequently international cooperation is needed to provide such forecasts in the event of a nuclear accident having transboundary radiological implications.

The experts also discussed the difficulties in explaining to a non-specialist audience the uncertainties associated with the results of the source term estimates and atmospheric dispersion analyses. The experts noted that these uncertainties are usually dealt with in a conservative manner and that the results used in decision making would ensure a high degree of protection of the public.

The IEM participants were provided with an overview of projects initiated in Japan relating to mapping the levels of radioactive material in the environment. This work includes studies of the levels of radionuclide transport in the atmosphere and deposition on land and will be used to predict changes in radioactivity levels and future radiation doses. Results of this work show that ^{137}Cs will be the most important radionuclide in terms of its contribution to radiation doses in the future. The measured deposition levels of ^{137}Cs have not changed significantly over the past three years, but the levels of ^{134}Cs have decreased as a result of radioactive decay.

The levels of radioactivity in the environment outside Japan were generally low and of minor radiological significance. However, the relevant authorities in many Member States were called upon to provide information and advice on the levels of radioactivity in the environment and in consumer products imported from Japan. The need for adequate preparation to respond to such requests for information and advice is discussed in Section 3.4 of this report.

2.2. MARINE RADIOACTIVE RELEASES

Lessons Learned: The generation of a large quantity of contaminated water, its storage on-site and discharges to the marine environment following the Fukushima Daiichi accident have presented new challenges to be addressed.

The Fukushima Daiichi accident represents the largest release of artificial radioactivity to the marine environment on a short timescale to date[10]. In the immediate aftermath of the Fukushima Daiichi accident, peak concentrations of radionuclides in the ocean 30 km offshore Fukushima Daiichi nuclear power plant were more than ten times higher than those observed in the Baltic and Black Seas following the Chernobyl accident.

In the first few weeks after the Fukushima Daiichi accident, radioactive material entered the marine environment directly from leaks from the damaged nuclear power plants and indirectly from dispersion in the atmosphere and deposition onto the ocean. There is large uncertainty regarding the quantities of radionuclides released to the ocean by these mechanisms; it is estimated that 3–6 PBq of ^{137}Cs, 10–20 PBq of ^{131}I and up to 1 PBq of ^{90}Sr reached the ocean. Currently, very large volumes of radioactively contaminated water are stored on the Fukushima Daiichi site. This water was used to cool the damaged reactor fuel and is being treated to remove the radionuclides of caesium; however, the ^{3}H, in the form of tritiated water, cannot be removed.

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[10] BAILLY DU BOIS, P., et al., "Estimation of marine source-term following Fukushima Daiichi accident", J. Env. Rad. **114** (2012) 2–9.

Leakage of radioactive water from storage tanks and from trenches has already occurred, and any further leakage brings the potential for direct discharge to the marine environment. In addition, groundwater flows from nearby areas are being contaminated on the site and subsequently entering the marine environment. There is also a possibility that some radioactively contaminated water is entering the marine environment from surface runoff following rainfall.

Management of contaminated water at the Fukushima Daiichi nuclear power plant remains a major challenge. A comprehensive policy has been formulated and is being implemented by the Japanese authorities to address all aspects related to this issue. This was one of the key areas addressed during the IAEA international peer review mission to Japan conducted in April 2013, which advised Japan on adequate measures for promptly detecting leaks and mitigating their consequences.[11] A second mission, conducted in November and December 2013, acknowledged the progress made in isolating and removing sources of contamination on the site and preventing leaks from it. The mission encouraged efforts to further improve the performance and capacity of the active liquid processing system on the site.

At the International Experts Meeting:

During the discussions at the IEM, it was emphasized that direct discharges to the marine environment did not occur during the Chernobyl accident and that the marine discharges following the Fukushima Daiichi accident present new challenges. The radionuclide levels observed in seawater offshore the Fukushima Daiichi nuclear power plant site have shown a wide variation over time, depending on the quantity and rate of releases to the ocean. It was noted in the presentations that the pre-accident concentrations of ^{137}Cs in surface waters off the coast of Japan were in the range of 1–2 Bq/m^3. A maximum ^{137}Cs concentration of 68 MBq/m^3 was observed in April 2011 at the point of discharge from the Fukushima Daiichi site. Substantial dilution in the ocean has taken place as a result of mixing processes from tidal forces, currents and winds. The caesium concentrations observed 30 km offshore were up to 50 times lower than the values measured at the discharge point. One month after peak releases, ^{137}Cs levels observed at the discharge point had decreased by a factor of 1000. It was noted that short-lived isotopes such as ^{131}I were no longer detectable in samples of seawater by the end of May 2011.

The experts described the outcome of global ocean circulation modelling showing that the radioactivity in the Pacific Ocean has been moving east, away

[11] Ibid. p. 5.

from the coast of Japan. Caesium-137 concentrations in the surface waters of the northwestern Pacific Ocean are predicted to reach a maximum of about 25 Bq/m^3. The experts noted that, after 3–4 years, very low levels of ^{137}Cs will reach the Pacific Coast of North America, with concentrations of about 3 Bq/m^3. The current ^{137}Cs background levels resulting from fallout from the testing of nuclear weapons in the 1950s and 1960s are around 1 Bq/m^3, highlighting the very large dilution capacity of the oceans. Radiation from the Fukushima Daiichi accident will be detectable in the marine environment in the longer term, albeit at extremely low concentrations. The experts reported on ocean modelling studies which forecast that, in the Pacific Ocean, concentrations of ^{137}Cs from the Fukushima Daiichi accident will be below 1 Bq/m^3 by 2021.

The fact that radionuclides continue to enter the marine environment underlines the importance of continuing to document the discharges, assess their impact and update global environmental models. Specifically, at the IEM it was noted that while the releases of ^{3}H and ^{90}Sr to the marine environment are not expected to contribute significantly to radiation doses to the public, their radiological impact should be documented and evaluated for the purposes of informing the public. Other radionuclides released to the marine environment are considered to be of much lower radiological significance.

2.3. IMPACT OF RADIOACTIVE RELEASES: RADIATION DOSE ASSESSMENTS

Lessons Learned: In the immediate aftermath of a nuclear or radiological accident, radiation dose assessments are primarily made using modelling techniques, as information available from radiation measurements may be limited. Conducting comprehensive radiation measurements following such accidents can provide important information to supplement the modelling techniques and further refine the radiation dose assessments.

In the immediate aftermath of a nuclear accident, mathematical models are used, for example, to estimate the dispersion of radionuclides in the atmosphere and their deposition on the ground, and the movement of radionuclides through food chains to humans. Models are also used to calculate radiation doses to people from radionuclides in the air and on the ground, and doses from radionuclides incorporated in the body from inhalation and ingestion.

Efforts to obtain measurements of radiation dose rates and levels of radionuclides in the terrestrial and marine environments and in food and drinking water were initiated in Japan soon after the accident. This included continuous monitoring of gamma radiation dose rates performed at certain fixed locations between 20 and 60 km from the site and mobile monitoring using vehicle- and aircraft-mounted radiation detection equipment.

A comprehensive radiation monitoring plan was developed for a more comprehensive assessment of the distribution and migration of radioactivity in the environment and in food and drinking water. This included a comprehensive assessment of the distribution of radionuclides deposited on the ground and the migration of radionuclides through different environmental media.

In July 2011, the relevant authorities in Japan began conducting whole body radiation measurements[12] of residents of Fukushima Prefecture to monitor levels of ^{134}Cs and ^{137}Cs. At the same time, an extensive measurement programme was established to ensure that radionuclide concentrations in food and drinking water were within the Government's guidelines for safe consumption.

At the International Experts Meeting:

The use of modelling techniques in radiation protection was discussed, and it was agreed that some form of modelling is always necessary in the assessment of radiation doses. There is uncertainty associated with the assumptions in the models and the data used. Consequently, there will be uncertainty associated with the model predictions, and some models will have greater uncertainty than others. The experts considered it an ongoing challenge to explain this uncertainty to a wider audience such as the public, the government and decision makers. The experts emphasized the importance of clearly explaining the uncertainty associated with the use of models, particularly as statements made in relation to possible health effects from exposure to radiation can be misinterpreted and given a significance that is not justified by the models and associated data.

The experts discussed the efforts in Japan to improve the assessment of radiation doses to the public. These efforts included obtaining a better understanding of the source term, further measurements of radioactivity in the environment and extensive whole body radiation measurements of the affected population. This information has been used to improve the dose assessments and has produced estimates lower than those predicted using modelling techniques alone.

During the IEM, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) summarized its assessment of the Fukushima Daiichi accident. This assessment was based on the use of models and the limited environmental radiation measurements available at the time to estimate doses to

[12] Whole body radiation measurement refers to the measurement, using appropriate radiation detectors, of radioactivity that has been incorporated into the human body.

the public. UNSCEAR reported that average effective doses for adult evacuees from Fukushima Prefecture are up to 10 mSv and are perhaps twice that level for infants. For the purpose of comparison, the annual average background dose to the Japanese population from naturally occurring sources of radiation is about 2.1 mSv.[13] Also for evacuees, the average absorbed dose to the thyroid is up to about 30 mGy for adults and up to 70 mGy for infants. In general, the dose estimates of UNSCEAR[13] are in good agreement with those previously published by the World Health Organization (WHO)[14]. UNSCEAR considers that the effect of the countermeasures taken by the Japanese authorities — such as evacuation, shelter-in-place orders and management of contaminated food — averted as much as 90% of the potential doses to individuals who were living in the affected areas.

The UNSCEAR estimates of the average effective dose received by 25 000 workers involved in mitigation and other activities at the Fukushima Daiichi nuclear power plant was approximately 12 mSv. About 35% of the workforce received doses of more than 10 mSv, while about 170 workers (0.7% of the workforce) received doses greater than 100 mSv. Twelve workers were estimated to have received thyroid doses in the range of 2–12 Gy. Health monitoring programmes have been put in place for those workers who received the highest doses.

Adults living in Fukushima City were estimated to have received an average effective dose of about 4 mSv in the first year following the accident. The estimated doses for one year old infants were about twice as high. The lifetime effective doses due to the accident that could be received by people who continue to live in Fukushima Prefecture were estimated to be just over 10 mSv, assuming no further remediation measures.

It was emphasized at the IEM that one of the aims the whole body measurements is to monitor individuals for the presence of radiocaesium. Follow-up investigation of the lifestyle of individuals with positive radiocaesium measurements may be used to identify behavioural habits that could be adjusted to assist in reducing the intake of ^{137}Cs — for example, by minimizing the consumption of wild boar and forest mushrooms that are found to be contaminated.

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[13] UNITED NATIONS, Sources, Effects and Risks of Ionizing Radiation: UNSCEAR 2013 Report to the General Assembly, Scientific Committee on Effects of Atomic Radiation (UNSCEAR), UN, New York (2014), Annex A, available at:
http://www.unscear.org/docs/reports/2013/13-85418_Report_2013_Annex_A.pdf

[14] WORLD HEALTH ORGANIZATION, Preliminary Dose Estimation from the Nuclear Accident after the 2011 Great East Japan Earthquake and Tsunami, WHO, Geneva (2012), available at: http://apps.who.int/iris/bitstream/10665/44877/1/9789241503662_eng.pdf?ua=1.

2.4. IMPACT OF RADIOACTIVE RELEASES: FOODSTUFFS AND MARINE BIOTA

Lessons Learned: The Fukushima Daiichi accident highlighted the need for radiation monitoring programmes in all Member States to measure radionuclide concentrations in environmental samples and foodstuffs in order to provide transparent and accurate information to members of the public.

Of particular concern to the Japanese public were the levels of radioactivity in food and whether or not locally produced food was fit for consumption. In response, the Japanese authorities initially set the limit for ^{134}Cs and ^{137}Cs in foodstuffs at 500 Bq/kg. Approximately one year later, this was reduced to 100 Bq/kg. At the same time, the limit for milk and infant food was reduced from 200 to 50 Bq/kg. The Japanese limit is about a factor of four to ten lower than the national standards applied in other Member States. These values were established to ensure that no individual received an annual dose above 1 mSv. Dose assessment studies in Japan showed that, one year after the accident, the highest annual doses were of the order of 0.02 mSv, compared with an average annual dose of 2.1 mSv from natural background radiation. This indicates that a highly conservative approach to protecting the public has been adopted.

Japan introduced a comprehensive food monitoring programme to ensure that levels of radionuclides in food destined for national consumption and/or export do not exceed the established maximum concentrations. The IAEA remediation mission team reviewed the large scale programme of food control and had the opportunity to visit a measurement facility for rice in Date City. The available evidence indicates that this monitoring programme is a highly effective tool in the process of protecting the public.

With regard to the impact on the non-human biota, the highest radiation exposures of wildlife appear to be associated with the aquatic environment from the caesium and iodine absorbed and retained by algae, fish, crustaceans, molluscs and plankton. The highest dose rates appear to have been below the UNSCEAR benchmark[15] of 0.4 mGy/h for the most exposed individuals of an aquatic population, below which observable effects in the associated populations are not expected. However, there is evidence that, close to the discharge point, some seaweed may have been exposed to dose rates of up to 25 mGy/h over a period of several days as a result of the uptake of ^{131}I, but these dose rates

[15] UNITED NATIONS, Sources, Effects and Risks of Ionizing Radiation: UNSCEAR 2013 Report to the General Assembly, Scientific Committee on Effects of Atomic Radiation (UNSCEAR), UN, New York (2014), Annex A, Attachment F-1: Methodology for Estimating Doses to Non-Human Biota.

fell rapidly in subsequent weeks as the level of discharge decreased. It is also considered unlikely that the elevated concentrations observed in individual fish specimens indicate prolonged exposure to whole populations and, consequently, the biota is not under threat at the population level.

At the International Experts Meeting:

The radionuclide concentrations in the marine biota were discussed at the IEM. The ^{137}Cs concentrations in fish caught offshore the Fukushima Daiichi nuclear power plant site varied by several orders of magnitude, from about 2 to about 5 000 Bq/kg, but the majority of the results were between 10 and 1000 Bq/kg.

The dose that could be incurred from consumption of ^{137}Cs and ^{134}Cs in seafood (fish, seaweed and shellfish) collected in the Pacific Ocean off the coast of Japan was estimated to be 0.7 mSv/a. In comparison, the estimated dose for consumption of seafood collected in open ocean waters was 0.002 mSv/a.

The effective dose for an individual who consumes a large amount of seafood (a ‘representative person’[16]) was also estimated. It was assumed that the ^{137}Cs content of the marine biota is 1000 Bq/kg (at the upper limit of the observed range) and that 100 kg of the biota is consumed per year (four times the average Japanese consumption rate). In this case, the annual dose from ^{137}Cs is approximately 1.3 mSv; including the contribution from ^{134}Cs and other radionuclides increases the total dose to about 2.9 mSv/a.

During the IEM, it was confirmed that radiation exposures of the non-human biota were generally too low to result in acute effects. Effects observed in the marine environment were confined to the immediate vicinity of radioactive release points. It was noted that radioactive discharges to the marine environment as a result of the accident are ongoing. The meeting also noted the importance of improving scientific knowledge by studying the impact of high radiation doses on individual fish, as opposed to studying impacts at the population level.

At the IEM, the importance of evaluating long term contamination in natural ecosystems was discussed. The ecological half-life[17] is a useful measure for studying the long term reduction of radionuclides in natural systems. It is desirable to analyse the ecological half-life in more marine biota populations in

[16] A representative person is an individual receiving a dose that is representative of the doses to the more highly exposed individuals in the population.

[17] The ecological half-life is the time required for a given contaminant concentration to decrease by 50% from combined physical, chemical and/or biological processes that remove it from an ecosystem or render it biologically unavailable.

order to better understand and predict the reductions in ^{137}Cs concentrations in this biota.

3. MANAGING THE IMPACT

The radiological issues arising from the Fukushima Daiichi accident continue to have an impact at the local, national and global levels, and the lessons to be learned from managing this impact are still evolving. Nevertheless, several general themes have emerged that appear to have broad consensus:

— It is important to monitor the health of workers and the public affected by a nuclear or radiological accident.
— Lessons learned from past accidents can assist in the efforts to remediate the contaminated areas off the site of the Fukushima Daiichi nuclear power plant.
— Understanding local conditions will enhance recovery of agriculture and help protect valuable forest ecosystems.
— Japan's experience supports the need for capacity building in radiation protection in other countries.

These themes are discussed in more detail in the following sections.

3.1. HEALTH MONITORING

Lessons Learned: It is important that health screening programmes for the exposed population be maintained to assist in early identification of any increased risk.

Although most long term health effects related to radiation exposure can only be inferred and not directly observed in a population, health monitoring of individuals can provide several important benefits. In the early phase following an accident, health monitoring can take the form of surveying for the presence of external and internal radioactivity. In the intermediate and late phases, health monitoring is carried out to screen for possible radiation related illness, such as excess thyroid cancer among those exposed as children.

From the studies carried out following the Chernobyl accident, it is known that exposure of the thyroid to radiation can increase the risk of thyroid cancer in those exposed as children (up to 18 years of age), with younger children (especially up to 5 years of age) being at greater risk than older children. These and other studies indicate that thyroid cancers begin to show an increase around 4–5 years after exposure to radiation, although the increased risk persists through to adulthood.

Because of these concerns, ultrasonographic screening of the thyroid for the presence of nodules[18] is being carried out in municipalities within Fukushima Prefecture, as well as in other prefectures affected by the accident. The ongoing screening programme includes those who were up to 18 years old at the time of the accident.

At the International Experts Meeting:

The experts discussed the higher than expected rate of precancerous thyroid nodules found during the thyroid screening programme introduced in Japan. An important distinction was made between prevalence and incidence of an observable health endpoint, such as cancer or precancerous nodules. Prevalence is the rate of a particular measurable endpoint in a population observed over time, and incidence refers to the rate of new cases of that endpoint.

The experts noted that experience from other exposed populations has shown that radiation exposure of the thyroid in childhood can contribute to increased incidence of thyroid cancer for a period ranging from 4–5 years after exposure up to 50 or more years after exposure. The experts considered that it is unlikely that the higher than expected incidence of thyroid nodules observed thus far from the ultrasonographic screening is due to radiation exposure from the accident. The Japanese authorities will continue to conduct follow-up checks of children exposed to radiation from the Fukushima Daiichi accident to determine whether there is any observable increase in the incidence of thyroid cancer in the affected population over time.

The experts also discussed the non-radiological consequences of the Fukushima Daiichi accident. They noted that, as was observed after the Chernobyl accident, the psychosocial impacts on the affected population can outweigh the direct radiological consequences, even though these effects are not always considered in radiation protection recommendations and international standards.

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[18] The term thyroid nodule refers to an abnormal growth of thyroid cells forming a lump within the thyroid gland. While the vast majority of thyroid nodules are benign, a small proportion of thyroid nodules are malignant.

Some experts questioned whether the non-radiological impacts associated with radiation exposure should be dealt with more explicitly in the International System of Radiological Protection. In addition, it was recommended that the national authorities develop easy to understand information and guidelines for responding to the complexity of factors that affect public health following a nuclear or radiological accident.

Long term health monitoring is especially important for the more highly exposed workers who responded to the accident. The experts highlighted the experience of more than 25 years of monitoring the health of emergency workers who responded to the Chernobyl accident. In these workers, an increase in non-cancer health effects such as cataracts and cardiovascular disease has been observed; however, the average doses received were higher and the number of emergency workers exposed to these higher doses was much larger than reported in Japan. The IEM concluded that while the available information suggests that no statistically significant increase in such health effects will be observable, it is nevertheless important that the health monitoring of these emergency workers continue.

Careful management of the radiation exposure of the group of workers involved in ongoing on-site recovery efforts at Fukushima Daiichi is also important and will help ensure that any long term health consequences in this group will be kept to a minimum.

3.2. LESSONS LEARNED FROM PAST NUCLEAR OR RADIOLOGICAL ACCIDENTS

Lessons Learned: Many of the lessons learned from previous nuclear or radiological accidents have still not been fully addressed; such lessons must be acted upon and not ignored.

The lessons learned from previous nuclear or radiological accidents include the need for improved risk communication strategies; ongoing public consultation and public involvement in decision making in relation to remediation; and better approaches to managing psychological health effects following radiation exposure.

A number of past nuclear accidents provide useful information relevant to remediation efforts in the areas off the site of the Fukushima Daiichi nuclear power plant to improve the living conditions of the people affected by the accident. Much of the technical information learned about remediation is covered in the IAEA Report on Decommissioning and Remediation after a Nuclear Accident[19].

A major lesson learned from past contamination events is that evacuation from contaminated territories is highly effective in reducing the radiation exposure of the affected population. For this reason, among others, the magnitude of the source term is not necessarily related to the dose received by the population. The countermeasures taken by the Japanese authorities, including evacuation, were successful in averting most of the potential dose to the residents within 20 km of the plant and in the other evacuated areas, thus reinforcing this valuable lesson. However, such countermeasures may also have negative impacts that need to be taken into account in decision making, such as the disruption of the lifestyles of those separated from their homes and familiar surroundings, and in some cases the dissolution of families and the loss of livelihoods.

Some lessons can be universally applied, while others may be influenced by site specific environmental issues and the custom and practice of the affected population. Examples of site specific factors that may need to be addressed include climate, soil type, dominant ecosystems and food chains. Factors involving local custom and practice may include dietary habits and special relationships to the land based on many generations of farming, or certain traditional practices such as fishing or hunting.

Another important lesson learned from past experience is the value of public involvement in the decision making process in the aftermath of a nuclear or radiological accident. Affected communities have a stake in the outcome of decisions regarding remediation and recovery efforts, and involving these communities in the decision making process will improve public confidence in these efforts. The IAEA remediation mission team that visited Japan in October 2013 saw many examples of good practice regarding stakeholder involvement, with demonstrable evidence that successful communication and engagement processes are being adopted at the national, prefectural and municipal levels. Improved communication with the public by decision makers, making use of both traditional sources of information and the newer forms of social media, will lead to better public acceptance of the decisions that affect their lives. This approach is fully consistent with the IAEA's International Basic Safety Standards[20].

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[19] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Report on Decommissioning and Remediation after a Nuclear Accident, IAEA, Vienna (2013), available at: http://www.iaea.org/newscenter/focus/actionplan/reports/decommissioning0913.pdf

[20] INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, IAEA Safety Standards Series No. GSR Part 3, IAEA, Vienna (2014).

At the International Experts Meeting:

The experts noted that experience gained from managing past nuclear or radiological events should continue to inform the approach to, and support the progress of, the remediation efforts in the areas off the site of the Fukushima Daiichi nuclear power plant to improve the living conditions of the people affected by the accident. The relevant lessons learned from the Chernobyl accident are important, as are those from other events such as the experience with the cleanup of the Marshall Islands and following the Goiânia accident in Brazil. Often, the societal impacts will be as significant as the technical challenges of cleanup and remediation; for example, the displacement of populations can last more than a generation and may result in significant lifestyle changes.

The experts emphasized that, in recovering from past contamination events, consideration of local custom and practice can play an important role in achieving public acceptance of cleanup decisions. Japan has taken many steps to preserve the traditional agricultural practices of Fukushima Prefecture, including monitoring and certifying that local produce is safe to eat.

The Fukushima Dialogue Initiative (FDI) was described at the IEM. The FDI is a collaborative effort between the International Commission on Radiological Protection (ICRP), local authorities and other sponsors, who have met to discuss issues of concern to the local population. The objectives of the FDI are to share ICRP recommendations directly with communities, to transfer the experience from communities affected by the Chernobyl accident to the communities in Fukushima Prefecture, and to facilitate discussions between local stakeholders. Several important lessons that were identified during the FDI meetings were shared with the participants of the IEM:

- Success depends on the combination of actions by authorities and actions by affected people and communities (self-help actions).
- Local communities should be engaged in developing improvement projects and in assessing progress.
- Expertise and support should be at the service of local citizens.
- Individual monitoring (internal and external) and self-measurement of radiation levels on land and in foodstuffs are essential and require outside support.
- Radiation protection culture is at least as important as remediation for improving safety and providing a feeling of security.

These lessons are discussed at length in Section 4 of this report.

It was also noted during the IEM that the IAEA safety standards can assist the Government of Japan in taking appropriate steps to best protect the public during remediation and recovery. Except where public safety considerations demand an immediate response, it is also clear that decisions on remediation and recovery should not be taken or implemented until there is adequate public consultation and acceptance.

3.3. UNDERSTANDING LOCAL CONDITIONS

Lessons Learned: Local conditions must be fully understood, as not all lessons from similar events can be universally applied.

Better understanding of both farming practices and radioecology will improve agricultural remediation and optimization while helping to protect valuable forest ecosystems. Knowing how the radionuclides of concern move in soil and how they are taken up and metabolized by plants and animals will improve management strategies for lessening their impact on humans. The measures that were effective for the agricultural sectors affected by the Chernobyl accident may be effective in Fukushima Prefecture, although the influence of local environmental conditions such as soil type, rainfall, topography and geology needs to be taken into account. Differences in crop types and their cultivation methods also need to be considered.

Good progress has been made in the remediation of farmland contaminated by radioactivity. Soil scientists have provided the results of research to help determine the most effective remediation techniques for contaminated soil depending on the soil type. There are examples where the technique known as phytoremediation[21] has been used to remove radionuclides from soil, taking advantage of the ability of certain plants to selectively absorb radionuclides of concern, such as caesium.

Soil amendments can be added to fix the radionuclides and reduce their bioavailability. Careful mapping of contamination and soil characteristics can help identify those areas that are the most vulnerable to high levels of soil-to-plant transfer and areas where treatment with agrochemicals or ploughing would be feasible and effective.

[21] Phytoremediation is a generic term for the group of technologies that use plants for remediating soils, sludges, sediments and water.

At the International Experts Meeting:

Experts from several Member States reported on experience with mitigating the effects of radionuclide contamination on farming and food production. Following the Chernobyl accident, reindeer in Norway began showing caesium levels above the regulatory limit for food consumption. Reindeer herding is an important part of the cultural heritage of the Sami people. The relevant authorities in Norway took steps to manage the food chain and reduce the levels of caesium in reindeer meat by providing clean food to reindeer and supplementing their diet with Prussian blue[22], which binds radiocaesium and significantly reduces its transfer to the flesh. The authorities in Norway also raised the acceptable level of caesium contamination for reindeer meat after determining that the activity concentration had been based on much higher annual per capita consumption of reindeer meat than is typical for most Norwegians. They also undertook other proactive remediation efforts, including selectively removing topsoil and contaminated vegetation in areas where livestock graze and vegetables are grown. Although these measures were expensive, they were found to be cost effective because they reduced the quantity of locally produced meat and produce that would otherwise have had to be destroyed.

In Japan, experiments showed that different plants take up caesium in different fractions among foliar, bark and soil pathways. Such data are being successfully used to establish crop specific remediation efforts. IEM presentations highlighted the importance of seasonal dependence on radionuclide uptake by plants. Removing contaminants before the growing season begins, such as in winter and early spring, can significantly reduce the amount of caesium in agricultural products.

In modelling the movement of radionuclides through the ecosystem and their bioaccumulation in various plants and animals, it is very important to use site specific parameters for factors dealing with, for example, the transfer from soil to plants. Research is often needed to establish these site specific parameters and will result in better predictions of the transport of radionuclides in the environment.

The experts noted that in Japan, where forests are an important economic and cultural resource, remediation activities involving extensive deforestation and topsoil removal should ideally be avoided because of the significant impact on the ecosystem. In areas of high radionuclide deposition, a more appropriate approach may be to restrict access until radiation levels have decreased through

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[22] Prussian blue (ferric hexacyanoferrate) is a biological decorporation agent for internal contamination of radiocaesium.

radioactive decay and weathering. Caesium-134 is disappearing as a result of radioactive decay, and studies show that the ^{137}Cs and ^{134}Cs are migrating vertically into the soil instead of horizontally. As the depth of soil migration increases over time, the shielding provided by the soil cover will reduce the radiation levels at the surface.

3.4. CAPACITY BUILDING

Lessons Learned: All Member States would benefit from a programme of capacity building in radiation protection. Member States need well trained people and adequate equipment to respond to a nuclear or radiological accident and its aftermath.

By the mid-1980s, radiation protection had already incorporated a substantial volume of fundamental scientific knowledge in radiobiology, biokinetics of radionuclides and dosimetry of ionizing radiation. In general, radiation protection was regarded as a well established field with an adequate capacity for all types of situations, including nuclear incidents. This assumption was critically challenged after the Chernobyl accident in 1986.

The experience of the Chernobyl accident contributed to the modernization of the International System of Radiological Protection and the upgrading of the IAEA safety standards and national regulations. The intensive work of the radiation protection community during the time between the Chernobyl and Fukushima Daiichi accidents substantially reinforced and expanded the capacity in the field of radiation protection. However, an accident of the scale of the Fukushima Daiichi accident would pose a significant challenge to the radiation protection capabilities in many Member States.

At the International Experts Meeting:

Capacity building for radiation protection is a process through which the government, regulatory body, operating organizations and other relevant stakeholders achieve an optimized and sustainable level of protection and safety. Capacity building can be defined as an overarching process that includes four essential elements:

- Education and training;
- Human resource development;

— Knowledge management;
— Knowledge networks.

Research and development is also an important component of this process.

As noted in the IAEA Report on Enhancing Transparency and Communication Effectiveness in the Event of a Nuclear or Radiological Emergency[23], the IAEA training programme on preparedness for and response to nuclear and radiological emergencies includes the requirements that all persons associated with performing functions during a nuclear or radiological emergency be suitably trained and qualified so that they understand their responsibilities and perform their duties safely, and that response organizations identify the knowledge, skills and abilities necessary to be able to perform the emergency response functions.

The experts at the IEM emphasized the importance of recruiting and training young professionals in all aspects of the International System of Radiological Protection to ensure that the knowledge gained from the Chernobyl and Fukushima Daiichi accidents is not lost to future generations. The current remediation and long term recovery operations in the affected areas of Japan are complex, as they include technical, societal, environmental and economic issues. Today's experts have much to teach the next generation of radiation protection professionals; and these young professionals have much useful experience — particularly in the effective use of social media and the Internet — that can be used to improve public communication and enhance public understanding of radiation science.

Despite the progress in capacity building since the Chernobyl accident, several important issues, such as the lack of evidence of health effects arising from exposure to low doses of radiation and the lack of appropriate guidance on the use of collective dose[24], had not been resolved at the time of the Fukushima Daiichi accident. It was suggested at the IEM that the IAEA, as well as other relevant international organizations, consider playing a more active role in the strategic planning, coordination and support of research programmes and scientific exchanges related to capacity building in radiation protection.

[23] See footnote 5.

[24] The collective dose is the total radiation dose incurred by a population.

4. INTERNATIONAL STANDARDS

Exposure to ionizing radiation may be detrimental to health. The International System of Radiological Protection that has evolved to provide for the protection of human health is based on three principles:

- Justification, the process of determining whether exposure to radiation from any human activity is overall beneficial, that is, the exposure should do more good than harm;
- Optimization of protection, where doses should be kept as low as reasonably achievable, taking into account economic and societal factors;
- The application of dose limits, where the total dose to an individual from regulated sources in planned situations should not exceed appropriate limits.

In the event of a nuclear or radiological accident, measures may need to be introduced to prevent the exposure of people to radiation. One important potential radiation exposure pathway is through the ingestion of contaminated food. Consequently, appropriate management of the food chain following an accident is important.

A nuclear or radiological accident can affect many States. For example, it can have an impact on the accident State as well as other States over whose territory any airborne radioactive material passes or whose waters receive liquid radioactive releases. There may also be issues in distant States that import food and other commodities from States directly affected by an accident.

International standards for controlling contaminated foodstuffs, drinking water and non-food commodities should, among other things, maintain public trust in the safety of food and commodities. The Fukushima Daiichi accident has demonstrated that further internationally harmonized guidance needs to be developed to support the more effective application of these standards.

The Fukushima Daiichi accident underlines the need for clarity in the practical implementation of the international recommendations and standards, to allow experts and the public to fully understand the application of the system of protection.

4.1. STANDARDS FOR THE CONTROL OF CONTAMINATED FOODSTUFFS, DRINKING WATER AND COMMODITIES

Lessons learned: There is a need for greater transparency in the derivation of standards for levels of radioactivity in food and drinking water to facilitate their application by national experts and their understanding by the public.

The standards for levels of radioactivity in food and drinking water need to be easily applied in the Member State in which an accident occurs and in other Member States that could be affected. Similarly, clear guidance is required on the monitoring of non-food commodities, on the decontamination measures that might need to be considered and on how any waste materials generated as a result of decontamination should be managed.

In the aftermath of the Fukushima Daiichi accident, considerable attention was focused on the radionuclide contamination of food produced in Japan and sold on national and international markets. There are several international standards dealing with radionuclides in food and drinking water which are applicable both in an emergency and under 'normal' conditions. However, the numbers given in these standards, often expressed either as reference levels or as activity concentrations, differ owing to various considerations related to protecting consumers in different circumstances.

The reasons for having these different activity concentration values, the criteria on the basis of which they have been derived and the circumstances under which they are intended to be applied are not always clearly understood. Several important issues have been raised with respect to the control of foodstuffs and drinking water contaminated as a result of a radiological or nuclear accident. Currently, many national and international standards are not consistent in terms of the recommended maximum concentrations, the terminology used and the circumstances under which they apply. This causes confusion for national authorities and for the public.

To address these concerns, in 2013 the IAEA convened a Working Group of International Organizations to develop a publication that summarizes all relevant international standards, identifies any inconsistencies that may exist and proposes a resolution of these inconsistencies.

Since the Fukushima Daiichi accident, several countries have raised concerns about which values to apply in the control of imported commodities such as automobiles or furniture with surface contamination. Similar concerns have arisen with respect to ships and shipping containers that could become contaminated in transit.

The possible contamination of travellers, either with surface contamination on their skin or clothing, or with radionuclides within their body, has also caused concern. In the immediate aftermath of the Fukushima Daiichi accident, some airline flights to and from Japan were also cancelled, although the reason for such decisions was not always clear.

At the International Experts Meeting:

It was emphasized that, while radiation protection and safety is a national responsibility, international standards in this area are needed to promote consistency, to help provide assurance that nuclear and radiation related technologies are used safely, and to facilitate international cooperation and trade. The experts recognized that the development of guidance in this area is a complex issue that requires the involvement of a number of relevant international organizations.

Regarding the control of foodstuffs, drinking water and non-food commodities, some international intergovernmental standards exist — such as the Codex Alimentarius[25], and World Health Organization (WHO)[26] and IAEA[27] standards — but they contain different numerical values that apply for different products in different situations. As a result, the standards may appear to be inconsistent.

The experts highlighted that food and drinking water are considered jointly in emergency exposure situations[28] but separately in existing exposure situations[29]. Furthermore, the stage of food production and the period of time after an accident to which the Codex Alimentarius guideline levels apply need to be clarified.

The experts also noted that, ethically, it may be difficult for a Member State to use one criterion for the protection of its own population during an emergency exposure situation and another criterion for trade with other Member States as covered by the Codex Alimentarius.

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[25] JOINT FAO/WHO FOOD STANDARDS PROGRAMME, CODEX ALIMENTARIUS COMMISSION, Codex General Standard for Contaminants and Toxins in Food and Feed, CODEX STAN 193-1995, CAC, Rome (2013).

[26] WORLD HEALTH ORGANIZATION, Guidelines for Drinking-Water Quality, 4th Edn, WHO, Geneva (2011).

[27] INTERNATIONAL ATOMIC ENERGY AGENCY, Application of the Concepts of Exclusion, Exemption and Clearance, IAEA Safety Standards Series No. RS-G-1.7, IAEA, Vienna (2004).

INTERNATIONAL ATOMIC ENERGY AGENCY, Arrangements for Preparedness for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GS-G-2.1, IAEA, Vienna (2007).

[28] An emergency exposure situation is a situation of exposure that arises as a result of an accident, a malicious act or any other unexpected event that requires prompt action in order to avoid or reduce adverse consequences.

[29] An existing exposure situation is a situation of exposure that already exists when a decision on the need for control needs to be taken.

The experts also emphasized that standards should not be so restrictive that food which could be deemed fit for consumption is destroyed. Overly restrictive standards may also have significant economic costs that need to be fully taken into account in the decision making process.

4.2. REVIEW AND REVISION OF THE INTERNATIONAL SYSTEM OF RADIOLOGICAL PROTECTION

Lessons learned: Although the International System of Radiological Protection has been shown to be robust, it is considered to be overly complex.

The ICRP has published recommendations for the protection of people in emergency exposure situations and guidance on the protection of people living in long term contaminated areas after a nuclear accident or a radiation emergency.[30] These recommendations were published shortly before the Fukushima Daiichi accident, and thus there was little practical experience in their application at the time of the accident.

The ICRP recommends that a reference level to guide optimization in existing exposure situations be selected within a range of annual doses of 1–20 mSv to members of the public, to be amended as necessary during the course of remediation. The International Basic Safety Standards[31] also provide criteria for guiding remediation operations and state that the value adopted for the reference level will depend on the prevailing circumstances from the exposures under consideration, including the feasibility of controlling the exposure situation and experience in managing similar situations in the past.

In choosing the optimized remediation option, the radiological impacts on people and the environment are to be considered together with non-radiological impacts. It is important not only to consider the likely reduction in radiation doses but also to give proper attention and weight to societal factors as part of the decision making process. The costs of the transport and management of radioactive waste, the radiation exposure of, and health risks to, the workers managing the waste, and any subsequent public exposure associated with its disposal should also be taken into account.

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[30] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Application of the Commission's Recommendations to the Protection of People Living in Long-term Contaminated Areas after a Nuclear Accident or a Radiation Emergency, Publication 111, Ann. ICRP **39** 3 (2009).

[31] See footnote 20.

Environmental remediation has been necessary as a result of the Fukushima Daiichi accident, and the work carried out has followed the ICRP recommendations. The IAEA international mission to Japan in October 2013[32] reviewed the remediation strategies, plans and work being carried out. The mission highlighted the important progress made since the first mission in October 2011. The mission team provided advice on several points where current practices used in Japan could be further improved, taking into account both IAEA safety standards and the experience of remediation programmes in other Member States. One piece of advice related to remediation situations; any level of individual radiation dose in the range of 1–20 mSv/a is acceptable for use as a target for remediation. These levels are in line with the international standards and with the recommendations of the relevant international organizations (e.g. ICRP, IAEA, UNSCEAR, WHO).

At the International Experts Meeting:

One issue identified by the experts at the IEM related to the complexity of the International System of Radiological Protection. There was a widespread view that the system is overly complex, to the extent that even some radiation protection professionals have difficulty in fully understanding all the components of the current system. The experts considered that there may well be too much focus on the numerical values assigned to limits and reference levels within the system and not enough attention given to the philosophy underpinning these values. The application of the system cannot be effective unless it involves sound judgement based on strong ethical considerations and accepted societal values. The experts noted that this poses a particular difficulty for regulatory bodies, which often prefer the straightforward numerical approach and are less comfortable when having to make value judgements as part of their decision making process.

The experts also emphasized the importance of reaching international consensus on the approach to managing the transition from an emergency exposure situation to an existing exposure situation; namely, agreeing when the emergency phase ends and ‘normality’ returns, although this may be different from the normality that applied prior to an accident. The absence of quantitative recommendations for when and under which circumstances emergency protective measures can be lifted is an issue that needs to be addressed.

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[32] INTERNATIONAL ATOMIC ENERGY AGENCY, Final Report: The Follow-up IAEA International Mission on Remediation of Large Contaminated Areas Off-Site the Fukushima Daiichi Nuclear Power Plant, IAEA, Vienna (2014), available at: http://www.iaea.org/newscenter/focus/fukushima/final_report230114.pdf

During the IEM, the experts considered that further guidance on application of the justification principle is needed, particularly on how to reach decisions in the demanding situations that may follow a nuclear or radiological accident. The experts highlighted the example of decision making on remediation actions that could have a significant social impact. In some cases, it may be questionable whether such actions do more good than harm and whether they can be justified. In this light, the experts noted that the application of the International System of Radiological Protection cannot be completely effective unless strong ethical considerations and accepted societal values serve as the basis of the judgements involved.

The experts considered that the ultimate success of remediation programmes depends on the combined actions taken by the local authorities, affected communities and individual citizens. Different cultural characteristics have to be taken into account; for this reason, different approaches will apply in different Member States. It was also noted at the IEM that the affected population needs to be involved in setting remediation priorities and in assessing the progress and effectiveness of remediation activities. The experience of previous remediation activities has shown that decisions are more readily accepted if they are made following consultation between the responsible authorities and the affected population.

International standards for remediation[33] exist; however, the experts considered that there is a need for clear, quantitative international guidance on remediating contaminated territories, including disposal of contaminated debris and rubble. The guidance ideally will be based on existing radiological protection principles, taking into account objective issues such as radiation exposure and the costs of remediation, but also societal issues such as public perception, anxiety and political considerations. The availability of clear, detailed guidance will also facilitate communication with the public.

The experts recognized the difficulties associated with returning people to their homes in areas that had been evacuated, particularly in the application of ICRP recommendations. The ICRP considers this as an existing exposure situation where the dose reference levels of between 1 and 20 mSv/a may apply. However, the public in Japan interpreted it as a planned exposure situation, which is associated with a dose limit of 1 mSv/a. The International Basic Safety Standards state that the additional radiation dose due to the remediation actions themselves should not exceed 1 mSv/a for a member of the public; that is, the remediation work is a planned action for which the public dose limit applies,

[33] INTERNATIONAL ATOMIC ENERGY AGENCY, Remediation Process for Areas Affected by Past Activities and Accidents, IAEA Safety Standards Series No. WS-G-3.1, IAEA, Vienna (2007).

except for the remediation workers themselves. Greater clarity is required concerning the application of these numerical values.

Finally, it was noted that the content of international standards, including the underlying science and philosophy, needs to be adequately communicated to decision makers and to the public, and that this poses many challenges. Because of its importance, communication is discussed separately in Section 5 of this report.

5. COMMUNICATION

One component of the Action Plan relates to communication and information dissemination, with the objective of enhancing the transparency and effectiveness of communication. Communication is a two way process: one party needs to provide information of interest to the other party, and the other party needs to understand it. If the information is not provided in an appropriate form, if it is not in clear, understandable language, it will not be understood. This is particularly important where one party is trying to encourage action by the other party, for example, encouraging them to stay indoors or to avoid consumption of certain foods. Trust is another important component of a successful communication process.

5.1. RISK COMMUNICATION IS ESSENTIAL FOR PUBLIC UNDERSTANDING AND ACCEPTANCE

Lessons learned: Provision of clear, objective and understandable information to the public during and after a nuclear or radiological accident can help to reduce public concern and contribute to an effective response to an accident. Experience from past nuclear and radiological accidents highlights effective public communication as one of the most important challenges.

As has been the case with most previous accidents involving radiation exposure, communication between the radiological protection experts and the authorities, and between the authorities and the public, has presented difficulties.

Member States need to develop emergency communication plans that clearly define the roles and responsibilities of the national stakeholders involved in communication and ensure that the communication plans are maintained and regularly tested. The requirements for both domestic and international communication, as well as those for the different information needs of the general public and of technical experts, should be addressed in these communication plans.

All stakeholders, and in particular the public, have to be properly informed about radiation risks. This should be done in advance of any nuclear or radiological emergency, although it is recognized that this is the time when there is likely to be less public interest. Most of the concerns and questions that are likely to arise can be predicted in advance. It is essential to identify key messages, with supporting information, and to develop and implement a wide-ranging communication strategy with stakeholders.

At the International Experts Meeting:

Throughout the IEM, the importance of communication, and specifically risk communication, was discussed by the experts. While risk communication is an accepted science based discipline, it is nevertheless a discipline in which the radiation protection community is not particularly adept. There is a strong need to provide a firm basis for communicating and promoting a better understanding of radiation and radiation risks.

The public confusion that can arise concerning radiation safety issues was discussed at the IEM. Some examples of these issues are: the different numerical criteria applied in different radiation exposure situations; the different radiation dose terms and units used; the potential effects of low radiation doses; the basis of calculations to infer possible health effects in exposed populations; and the different numerical values used for the control of food and drinking water. As a further example, following the Fukushima Daiichi accident, the public in Japan did not understand why they were permitted to receive higher levels of radiation doses during the emergency situation — a time when they were expecting to be better protected — than the level they were informed was a dose ‘limit’ before the accident. As a result, some members of the public believed they were not being properly protected by the relevant authorities.

During the IEM, presentations by risk communication specialists focused on ways to communicate to help the public understand the science associated with radiation protection. Best practices and challenges for crisis communication were also presented and discussed.

The experts considered that the radiation protection community needs to dedicate sufficient resources to ensure that stakeholders are adequately informed about radiation, radiation risks, and the underlying philosophy and ethics of the International System of Radiological Protection. To date, public understanding of these issues is not adequate, resulting, in some cases, in unnecessary concerns about possible health effects following radiation exposure and in a failure to fully accept and implement advice from the relevant authorities in the aftermath of an accident.

5.2. SOCIAL MEDIA BRING NEW CHALLENGES

Lessons learned: The development of social media has resulted in an increase in the number of sources and the amount of information available, including contradictory information.

One of the significant differences in the aftermath of the Fukushima Daiichi accident compared with the Chernobyl accident was the availability of, and access to, information. At the time of the Chernobyl accident, there was often a lack of publicly available information. The increased availability of information from social media can make it difficult for the public to identify credible information sources and can be a significant challenge for national authorities. However, social media can also be used to the benefit of the national authorities, as they provide a very efficient vehicle for the dissemination of information to a wide and varied audience.

At the International Experts Meeting:

The experts discussed the challenges posed and opportunities provided by social media for governments, regulatory bodies and other national authorities. The information made available through social media may be based on emotion and may vary widely in quality. It is not always clear how the user can identify quality sources of information, and timeliness is an important consideration — information from official sources often requires internal clearances before it can be published, whereas other information, such as media reports, can appear immediately.

In the four months after the Fukushima Daiichi accident, there was a high level of related activity on blogs and social networking sites such as Twitter and Facebook, while Google returned approximately 75 million results for the term ‘Fukushima’. These new social media also provide the radiation protection community with opportunities to provide information in a more interactive way.

The concept of ‘crowdsourcing’ was discussed in detail during the IEM. Crowdsourcing is a term describing the practice of obtaining needed services, ideas or content by soliciting contributions from a large group of people, especially an on-line community. Crowdsourcing of information on radiation and radiation doses occurred in response to the perceived lack of publicly available official information. During the IEM, the experts noted that social media also allowed third party environmental radiation monitoring services to present their results.

The experts considered that crowdsourcing, if used in the collection and dissemination of radiation data, might also help to instil confidence in information provided by official sources. National authorities could adapt their operations to take this technology into account. These new groups should maintain their independent approach to performing measurements and focus on the quality assurance aspects involved in their technical procedures. The discussions at the IEM revealed that, in the area of radiological protection, these new social media place greater responsibility on the relevant authorities to provide information in a timely manner and to disseminate it as widely as possible. These authorities also need to ensure they are a trusted source of information in advance of any incident or accident so that their views are sought and valued after an incident or accident has taken place.

6. CONCLUSIONS

The discussions at the IEM covered a very wide range of issues, many of which are interlinked. The following are some of the major conclusions that were drawn:

— The International System of Radiological Protection stood up well to the ‘test’ of the Fukushima Daiichi accident. The application of the system ensured that there were no immediate health effects. Based on the currently available information, increases in the incidence of health effects such as cancers are not expected to be discernible against background rates and natural variability. Nevertheless, the current system is considered to be overly complex and difficult to understand, particularly for the public. A system that is better understood and easier to implement would be more effective.
— It is important that programmes for health screening of the exposed population be maintained. There is still some uncertainty regarding the actual doses received by individuals, and ongoing health screening will assist in early identification of any increased risk.
— When making decisions on actions to reduce radiation exposure, it is important to take into account all associated impacts, many of which are economic, societal or environmental in nature. Such decisions are not always easy and invariably involve a degree of judgement. Experience has shown that such decisions are more readily accepted if they are made following consultation between the responsible authorities and the affected population.

- Fear of radiation can sometimes cause more harm that the radiation itself. While no direct health effects may be discernible, there can be an indirect impact on the social and mental well-being of the affected population.
- In the aftermath of a nuclear or radiological accident, there is always concern about radioactive contamination of the food chain. This concern is particularly acute in the accident State, but it is also relevant for other affected States and for States importing food from regions directly affected by the accident. There is a clear need for a more harmonized approach to the control of contaminated foodstuffs and drinking water. The relevant international organizations need to use the opportunity that is currently available to produce clearer and more effective guidance on these issues.
- Similar issues arise in relation to commodities that may have surface contamination following a radiological or nuclear accident. While surface contamination standards have been developed for such items in transport, more generic guidance that considers a wider range of exposure scenarios needs to be developed. Internationally harmonized guidance is also required on the approach to decontamination and management of transborder travellers.
- Following the Chernobyl accident, there was often a lack of information available to the public. Following the Fukushima Daiichi accident, because of social media and ready access to the Internet, there was an overload of information. In a world where anyone can claim to be an expert, it is a challenge for governments and national authorities to establish themselves as credible sources of information on which the public can depend. However, in an interconnected world, all organizations have the opportunity to disseminate information to a wider audience.
- Nuclear and radiological accidents have a worldwide impact. Every country needs to have in place adequate monitoring capabilities to identify any arrival of radioactivity on its territory and to evaluate the associated impact, even when the radiological and environmental impact is expected to be minimal. Such monitoring is essential for public reassurance, and all countries need to invest in such programmes.
- Many of the lessons learned from previous nuclear or radiological accidents have not been fully implemented, and similar issues and concerns have been raised since the Fukushima Daiichi accident. Lessons identified from previous accidents must be addressed, not ignored.

— Radiation protection is a core scientific discipline in both nuclear and non-nuclear countries. The young professionals of today hold the key to addressing many of the challenges posed by the Fukushima Daiichi accident and must be provided with the necessary information and skills to carry out this work effectively. The IAEA needs to work with its Member States to ensure the intergenerational transfer of the relevant knowledge, experience and skills.

Annex A

CHAIRPERSON'S SUMMARY[1]

International Experts Meeting on Radiation Protection after the Fukushima Daiichi Accident: Promoting Confidence and Understanding 17–21 February 2014, Vienna

INTRODUCTION

This is the sixth International Experts Meeting organized under the IAEA Action Plan on Nuclear Safety. The purpose of the meeting is to provide an opportunity for experts to discuss the various radiation protection issues that have been highlighted by the Fukushima Daiichi accident and to consider how these should be addressed at both the national and the international levels.

The importance of the subject matter, which addresses both technical issues and societal concerns, is underlined by the fact that the IEM has attracted over 200 participants from 69 Member States and 10 international organizations. In addition, the organizers have used the meeting as an opportunity to involve as many young professionals as possible as part of the IAEA's programme of capacity building.

It is important at the outset to put the scale of the Fukushima Daiichi accident into context. We know that, as a result of the earthquake and tsunami that preceded the accident, up to 16 000 people lost their lives, over 6 000 were injured and close to 3 000 are still missing.[2] In addition, approximately 400 000 people were evacuated and a similar number of homes were destroyed. As reported during the meeting this week, some 113 000 people from 11 municipalities were evacuated by government order and a further 50 000 subsequently evacuated voluntarily. While in this meeting we are focusing specifically on the nuclear accident and its consequences, we must never forget that the accident was only one component of a much larger disaster that needed to be addressed by the Japanese authorities at the same time.

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[1] The opinions expressed in this Summary — and any recommendations made — are those of the Chairperson and do not necessarily represent the views of the IAEA, its Member States or other cooperating organizations.

[2] National Police Agency of Japan, http://www.npa.go.jp/archive/keibi/biki/index_e.htm

Release of radionuclides to the environment

There is still some uncertainty about the source term from the Fukushima Daiichi accident, but more accurate estimates have become available in the time that has elapsed since the accident. The current estimates of the atmospheric releases of ^{131}I are of the order of 100–500 petabecquerels (PBq), while estimates of the releases of ^{137}Cs are in the range of 6–20 PBq. The amount of ^{134}Cs released to the atmosphere was similar to that of ^{137}Cs. Unlike the situation that followed the Chernobyl accident, there have also been large discharges to the marine environment, of the order of 10% and 50% of the atmospheric discharges of ^{131}I and ^{137}Cs, respectively. Marine discharges continue, but they are not large in terms of radioactivity levels.

As of February 2014, the total discharges are of the order of 10% of the discharges that took place following the Chernobyl accident. This figure may increase, depending on the scale and duration of future discharges to the marine environment.

The committed effective dose over 50 years has been estimated using maximum deposition densities. This calculation shows that ^{137}Cs is the radionuclide of most radiological significance, representing about 73% of the committed effective dose, while ^{134}Cs represents an additional 26%. Because of its much shorter half-life, the significance of ^{134}Cs as a contributor to radiation dose diminishes relatively quickly over time, and ^{137}Cs assumes a greater importance in percentage terms. Because of its short half-life, ^{131}I represents much less than 1% of the committed effective dose.

Conclusion: Early real time sampling and personnel monitoring is important to improve the source term estimation and reduce the uncertainty in estimated values.

Transfer of radionuclides in the environment

Studies have been undertaken in several different environments, and different behaviour of the deposited radiocaesium has been observed.

In undisturbed areas, physical decay is the predominant mechanism in reducing external gamma dose rate. Some vertical migration also takes place, but horizontal migration of radiocaesium is generally not observed. In forest areas, the radiocaesium is generally retained and recycled within the ecosystem. However, vertical migration down into the soil profile is also observed, and horizontal migration can take place due to water movement and landslides, depending on the topography and the extent to which the area is disturbed. In urban areas and on surfaces such as roads, the radiocaesium is easily removed and accumulates on nearby land. In such cases, the 'decontamination factor' is considerably higher than that attributable only to physical decay.

Regarding the marine environment, large volumes of contaminated groundwater with low levels of radioactivity continue to be released from the reactor site into the sea. The principal radionuclides in the releases are tritium, ^{90}Sr and ^{137}Cs.

Recommendation: While the releases of tritium and ^{90}Sr to the marine environment are not expected to account for a large percentage of the collective dose or significant individual doses, their radiological impact should be documented and evaluated for public reassurance.

Health effects

In addition to the studies carried out in Japan, both WHO and UNSCEAR have undertaken international assessments of the possible health consequences of the Fukushima Daiichi accident. The estimates of doses received by the public in these studies and assessments are in good agreement, with the average individual effective dose typically being 1 mSv or less, and with a range up to about 25 mSv.

The majority of workers at the Fukushima Daiichi nuclear power plant received individual doses below the national limit of 250 mSv for radiation workers engaging in emergency work, although six workers received higher doses. For these six workers, internal exposure was the dominant exposure pathway. Around 170 workers may have received doses above 100 mSv, and 12 workers have been assessed with thyroid doses in the range of 2–12 Gy, primarily from ^{131}I.

Three years after the accident, there have been no deaths caused directly by exposure to radiation due to the accident. As the system of radiation protection is based on the linear no-threshold model, any radiation exposure, no matter how small, is considered to carry with it some degree of risk. For this reason, existing models attribute an increased risk of late effects (i.e. cancers) among the exposed populations. Because of the limitations of epidemiological studies in terms of the population size required to demonstrate an increased incidence of late effects, and on the basis of the available data, radiation doses received by residents and workers seem to be too low to detect any increase of late effects directly related to radiation exposure.

Following the Fukushima Daiichi accident, exposures due to ^{131}I were minimized as a result of restrictions on the sale and consumption of milk and other food products likely to be contaminated. Consequently, most of the thyroid doses in Fukushima Prefecture were a result of inhalation. However, there is considerable variability of ^{131}I uptake among individual members of the public and considerable uncertainty in the estimated thyroid doses.

Thyroid screening studies in Japan using ultrasonography have shown that the incidence of thyroid nodules and cysts is broadly similar across the country and no increased incidence is evident in the exposed populations. One estimate presented at the meeting indicated that a small increase in thyroid cancer of the order of 0.1% over the next 50 years has been predicted, assuming an average dose to the thyroid of 20 mGy. The majority of these would be expected to be observed in future years but may not be distinguishable from the background incidence.

While no direct health effects may be discernible, impacts on mental and social well-being such as depression and post-traumatic stress have been observed in the affected Japanese population. The fact that the psychosocial impact can outweigh direct radiological consequences was also observed after the Chernobyl accident.

Conclusion: Because of the uncertainty in the currently available dose estimates, it is important that work continue, both to better establish the range of individual doses received and to determine if there are any identifiable health consequences in terms of late effects, including non-cancer effects, in the exposed populations. The Fukushima Health Management Survey will be an important contributor to this work.

Foodstuffs and drinking water

Several important issues have been raised in respect of the control of foodstuffs and drinking water contaminated as a result of a radiological or nuclear accident. Currently, many national and international standards exist in terms of activity concentration in specific foodstuffs, but these are not always consistent in terms of the permitted maximum concentrations, the terminology used and the circumstances in which the standards apply. This causes confusion for both national authorities and the public. This is a particular issue for developing States, which may not have the necessary infrastructure to both establish and monitor compliance with national standards for radioactivity in foodstuffs.

The existence of different national standards has a direct impact on trade in that it may be difficult for States to export foodstuffs that exceed the values they apply nationally. If importing countries reduce activity concentrations in existing national standards to comply with the levels established by the exporting country, the public may feel that in the past they were not adequately protected. In areas which are seriously affected by radioactive contamination, the optimized strategy is normally to apply countermeasures. Continuing to grow food which cannot be sold generates large amounts of waste that needs to be managed, while discontinuing farming has a negative impact on the ecosystem. Both these options also have significant economic and societal costs, and so it is preferable to maintain the lifestyle of farmers, fishermen and hunters. The production of bio-fuel and fibre crops is an option, provided that there is a market for such products and that they are acceptable to the public.

Conclusion: The relevant international organizations need to prioritize work to develop a harmonized approach to the control of foodstuffs and drinking water contaminated as a result of a nuclear or radiological accident. This needs to be simple to implement and take fully into account the issues that apply in the accident State, other affected States and States that are not affected. Similarly, guidance needs to be developed on the international trade in and the control of contaminated non-food commodities.

Remediation

Remediation of urban and rural environments has been necessary, even though internal and external doses as a result of the Fukushima Daiichi accident have been lower than expected. The various remediation technologies that were developed following the Chernobyl accident have, in general, been shown to be effective in responding to the Fukushima Daiichi accident, although the degree of effectiveness has been influenced by local conditions.

However, the technical aspects are only one consideration. For remediation to be successful, proper attention needs to be given to societal factors affecting decision making, including local priorities and knowledge. The affected populations need to be involved in the setting of remediation priorities and in assessing progress and effectiveness. Information, expertise and resources should be available to support local communities.

Remediation involves not only the cleanup of land and structures, but also the reduction of doses by acting on pathways of exposure. In the recovery phase, both agricultural measures and well informed individual behaviours play a key role in this.

Self-help actions by communities and individuals should be encouraged and supported through the promotion of radiation protection culture. Individuals and communities having the knowledge and skills to enable them to make informed choices and to behave wisely will result in reduced individual doses, as these depend heavily on individual behaviour. In addition, understanding of the situation and a sense of control will enhance confidence and therefore overall well-being.

Dose reduction is one of many factors influencing decision making in remediation. This is particularly true when individual doses are in the range of 1–20 mSv. Societal, environmental and economic considerations must be taken seriously. Available resources must be spent wisely, and actions taken to reduce doses may have negative environmental or other impacts. For this reason, all factors must be taken into account to ensure optimal decision making.

In addition, many of the remediation programmes that have been implemented have high associated costs.

Conclusion: The ultimate success of remediation programmes depends on the combined efforts of actions by the local authorities, affected communities and individual citizens.

Social media

When we compare the Chernobyl and Fukushima accidents, one very noticeable difference on the societal level is the availability of and access to information. We now have the Internet; social media have become one of the main sources of information exchange, especially among young people; and even crowdsourcing, defined as the practice of obtaining needed services, ideas, or content by soliciting contributions from a large group of people, and especially from an on-line community, is a fact of life in some countries. As we have heard during this meeting, the right to know and the right to understand have evolved into the right to participate. The public is no longer prepared to sit idly by if their needs are not being met — they simply go out and organize things themselves.

In the area of radiological protection, this brings new challenges, but also opportunities. In a world where there is no longer any limit on the number of 'instant experts' who can convey very different and even contradictory messages to large groups of people over a very short time period, and where everybody can create news, there is a responsibility on government authorities and agencies to provide information in a timely manner and to disseminate it as widely as possible. The authorities also need to make themselves a trusted information source in advance of any incident or accident so that their views are sought and valued after an incident or accident has taken place.

But crowdsourcing — for example, in the collection and dissemination of radiation data — can also help to instil confidence in information from official sources. But to continue to be effective, these public groups need to maintain their independence; to be seen to work too closely with the authorities will diminish their effectiveness, and consequently also their credibility, making them redundant. For government authorities and agencies, crowdsourcing certainly is the 'genie that will not go back in the bottle'. It is necessary to accept that this technology is here to stay and that empowerment of the public is not necessarily a negative development.

Conclusion: The development of social media brings challenges in terms of the increase in the sources and the amount of information, even contradictory information, that is available and the difficulty in identifying credible sources. This is a challenge for national authorities, but can also be used to their benefit, as social media provide a much more efficient outlet for dissemination.

Risk communication

Throughout the meeting, we discussed the importance of communication, and specifically risk communication. Communication is necessary between experts, between government agencies, between experts and government agencies, and with the public. While risk communication is an accepted, science based discipline, it is nevertheless a discipline in which the radiation protection community is not particularly adept.

It is important to communicate with the public in their own terms using terminology they understand. In the case of emergencies, messages need to be clear and simple, supported with facts and figures, and should be placed in context to explain the data more clearly to the recipient audience. These messages need to be prepared in advance, and practiced. There is a large amount of work involved, but as a profession this is work that we need to prioritize. We need to understand that people need to know that we care before they care what we know. Very often, technical issues have a low priority in public decision making, and proper communication that takes societal concerns and values fully into account is important.

We need to provide a firm basis for communicating and promoting a better understanding of radiation risks and the International System of Radiation Protection to all stakeholders, in particular the members of the public. In this respect we may well look to the International Radiation Protection Association (IRPA) and the IRPA Associated Societies as the voice of the more than 18 000 radiation protection professionals in more than 60 countries. They are close to their communities and are therefore very well placed to become a trusted source of expertise for the wider community.

Conclusion: The need for better communication falls on the radiation protection community as a whole. We need to dedicate resources to ensure that we adequately inform decision makers and the general public about radiation, radiation risks and the underlying philosophy and ethics of the International System of Radiation Protection. If people do not understand our advice, it is unreasonable to expect them to implement it.

International System of Radiation Protection

We heard at the start of the meeting that the International System of Radiation Protection stood up well to the very demanding 'test' of Fukushima: No contradictory information was brought forward at the meeting, and this confirms that the system has shown itself to be robust and tailored to the demand presented by such a major accident. However, areas for improvement of the system have been identified and are currently being addressed by the ICRP.

One area for improvement relates to complexity. There is a widespread feeling that in recent years the International System of Radiation Protection has become overly complicated, so that even the professionals have difficulty in fully understanding it. Furthermore, we have reached the stage where there may well be too much focus on the numbers and not enough on the philosophy underpinning those numbers. The application of the International System of Radiation Protection cannot be effective unless it involves sound judgement based on strong ethical considerations and accepted societal values.

A lot of effort has been put into application of the principle of justification to planned exposure situations; there is now a need for the ICRP to further develop thinking on justification in emergency exposure situations and in existing exposure situations. The ICRP also needs to address the transition from an emergency exposure situation to an existing exposure situation.

Recommendation: While the International System of Radiation Protection is, generally, fit for purpose, it should be modified and improved in line with the lessons learned from the Fukushima Daiichi accident.

Capacity building

The IAEA has an important role to play in capacity building, and this International Experts Meeting provided an ideal opportunity to contribute to the knowledge and skills of young professionals. It is important to remember that the response to the Fukushima Daiichi accident will last over several years, even decades, and that radiation protection expertise is one of the key skills required — the young experts of today will have to bear that responsibility, and we in turn have a responsibility to help develop them as best we can. This is not just an issue for Japan, as we need to learn and spread all the lessons learned in Fukushima across the profession and reflect them in international and national policies.

IRPA, as the voice of the radiation protection professionals, plays an important role in capacity building for young scientists. It is a priority for IRPA to support young practitioners and scientists in their work in radiation protection, in their education and training, and in their efforts to become members of the radiation protection community.

Recommendation: All States should develop and implement a national strategy in relation to building and maintaining competence in radiation protection.

For the summary of the meeting, the following recommendations for future activities were identified.

(1) There are many examples of good coordination and cooperation between international organizations in responding to radiation protection issues from the Fukushima Daiichi accident. The IAEA should take the lead to firmly establish and build on these relationships at the organizational level.
(2) The IAEA should work with other international organizations to develop a harmonized approach to the control of foodstuffs and drinking water contaminated as a result of a nuclear or radiological emergency that addresses the needs of all States.
(3) The IAEA should work with other international organizations to develop guidance on the control of non-food commodities contaminated as a result of a nuclear or radiological emergency.
(4) Any nuclear or radiological emergency can impact even distant States; thus the authorities are expected to undertake reassurance monitoring, as a minimum. The IAEA should continue to support the development of radiation monitoring and measurement infrastructure in developing countries.

Sigurður M. Magnússon
21 February 2014

Annex B

CONTENTS OF THE ATTACHED CD-ROM

The following papers and presentations from the International Experts Meeting on Radiation Protection after the Fukushima Daiichi Accident: Promoting Confidence and Understanding are available on the attached CD-ROM.

RELATED DOCUMENTS

Programme of the International Experts Meeting on Radiation Protection after the Fukushima Daiichi Accident: Promoting Confidence and Understanding

Opening Remarks
D. Flory
Deputy Director General and Head of Department of Nuclear Safety and Security, International Atomic Energy Agency (IAEA)

Introductory Comments
P.S. Hahn
Director, Division of Radiation, Transport and Waste Safety, International Atomic Energy Agency (IAEA)

Introductory Comments
T. Fukui
Director for Monitoring, Nuclear Regulatory Authority of Japan, JAPAN

Chairperson’s Summary
S. Magnússon
IEM Chairperson, Icelandic Radiation Safety Authority, ICELAND

PRESENTATIONS

Session 1 (Monday): Setting the Scene

(Keynote) IAEA Activities under the Nuclear Safety Action Plan
G. Caruso
International Atomic Energy Agency (IAEA)

(Keynote) The IAEA Safety Standards: From Science to Regulation
M. Pinak
International Atomic Energy Agency (IAEA)

(Keynote) An Overview of the Current Distribution of Radionuclides Released to the Environment following the Fukushima Accident
K. Saito
Japan Atomic Energy Agency, JAPAN

Session 2 (Monday): Response of International Organizations

Session Chairperson's Introductory Comments
A. González
Nuclear Regulatory Authority, ARGENTINA

WHO's Response to the Fukushima Daiichi NPP Accident
E. Van Deventer
World Health Organization (WHO)

Activities in Food and Agriculture following the Fukushima Daiichi Accident
C. Blackburn and G. Dercon
International Atomic Energy Agency (IAEA)

Science, Values and Stakeholder Dialogue: NEA Experience in Fukushima
E. Lazo
OECD Nuclear Energy Agency (OECD/NEA)

Session 3 (Tuesday): Exposures and Exposure Pathways (1)

(Keynote) Assessment of Radiation Exposures — Modelling versus Measurement and Associated Uncertainties
L. Anspaugh
University of Utah, USA

Experience, Lessons Learned and Improvements from the Use of the National Atmospheric Release Advisory Centre (NARAC) in Dealing with the Fukushima Daiichi Accident
G. Sugiyama
Lawrence Livermore National Laboratory, USA

Characteristics of Spherical Cs-Bearing Particles Collected during the Early Stage of FDNPP Accident
Y. Igarashi
Meteorological Research Institute, JAPAN

Evaluation of Radiation Dose by Wild Fires in the Evacuation Zone after the Fukushima Accident
T. Ichiki
Japan Nuclear Energy Safety Organization (JNES), JAPAN

Session 4 (Tuesday): Exposures and Exposure Pathways (2)

Marine Radioactivity after the Fukushima Accident: Distribution of Radionuclides, Modelling and Assessment of Radiation Doses
P. Povinec
Comenius University, SLOVAKIA

Short and Long Term Ecological Half-lives of Radiocaesium in Marine Populations
K. Iwata
National Institute of Radiological Sciences (NIRS), JAPAN

Session 5 (Tuesday): Radiation Protection Issues (1)

(Keynote) Managing the Food Chain: Radiation Protection and Societal Aspects
A. Liland
Norwegian Radiation Protection Authority (NRPA), NORWAY

Radiocaesium Concentration Change in Persimmon Fruits with Time: Do We Need Remediation Action on the Fruit Trees Now?
K. Tagami
National Institute of Radiological Sciences (NIRS), JAPAN

Result of Whole Body Counting for JAEA Staff Members Engaged in Emergency Radiological Monitoring for the Fukushima Daiichi Accident
C. Takada
Japan Atomic Energy Agency (JAEA), JAPAN

Weakness of Emergency Monitoring Networks and Innovations
J. Hůlka
National Radiation Protection Institute (SURO), CZECH REPUBLIC

Session 6 (Tuesday): Radiation Protection Issues (2)

Safecast: Effective Use of Internet and Social Media in Third Party Environmental Radiation Monitoring after the Fukushima Daiichi NPP Disaster
A. Brown
SAFECAST

Why Site Specific Parameterization Is Vital for Dose Assessment
J. Napier
Oregon State University, USA

The Experience of Long Term Medical and Biophysical Control of Personnel Participating in Execution of Reconstruction Works at Object 'Shelter' of Chernobyl NPP
D. Bazyka
National Academy of Medical Sciences of Ukraine, UKRAINE

Radiation Protection Framework and Implementation Models in Public and Industrial Applications Outside Emergency Zones: Case Studies from Japan after the Fukushima Accident and Lessons Learned
J.-U. Schmollack
TÜV Rheinland Industrie Service, GERMANY

Session 7 (Wednesday): Health Aspects in Affected Communities

(Keynote) Societal Issues following Disaster Evacuation
G. Baumont
Institute for Radiological Protection and Nuclear Safety (IRSN), FRANCE

(Keynote) A Review of Health Effects Following the Chernobyl Accident: What Can We Expect from Fukushima?
D. Bazyka
National Academy of Medical Sciences of Ukraine, UKRAINE

Ultrasonography Survey and Thyroid Cancer in the Fukushima Prefecture
P. Jacob
Helmholtz Zentrum München, GERMANY

Session 8 (Wednesday): Remediation

(Keynote) Lessons from ICRP Activities with Fukushima
C. Clement
International Commission on Radiological Protection (ICRP)

Agricultural Land Management Options Following Large Scale Environmental Contamination: Evaluation for Fukushima Evacuated Territories
H. Vandenhove
Belgian Nuclear Research Centre, BELGIUM

Radioactivity Decontamination in and around School Facilities in Fukushima
J. Saegusa
Japan Atomic Energy Agency (JAEA), JAPAN

Session 9 (Wednesday): Risk Communication (1)

(Keynote) Risk Communication — Linking Science with Society
V. Covello
Center for Risk Communication, USA

Risk Communication Activities of JAEA after the Fukushima Daiichi Accident
H. Takashita
Japan Atomic Energy Agency (JAEA), JAPAN

Communicating Uncertainty in Health Risk: An Analysis of Media Discourses on Low Level Radiation after the Fukushima Accident in South Korea
C.W. Lee
Korea Institute of Radiological and Medical Sciences (KIRAMS), REPUBLIC OF KOREA

Session 10 (Wednesday): Risk Communication (2)

Action in Nagasaki University/Kawauchi Village Reconstruction Promotion Base
M. Orita
Nagasaki University, JAPAN

Post Fukushima Environmental Survey and Public Acceptance on Nuclear Power in Malaysia
Teng Iyu Lin
Atomic Energy Licensing Board (AELB), MALAYSIA

Communication Aspects after the Fukushima Daiichi Accident: View and Experience of the Regulator
B. Havránková
State Office for Nuclear Safety (SUJB), CZECH REPUBLIC

Fukushima Disaster Response: The States' Perspective in the United States and Future Activities from Lessons Learned
P. Mulligan
New Jersey Department of Environmental Protection, USA

Communication with the Public after Fukushima — Social Media and Conventional Media
C. Stieghorst
University of Mainz, GERMANY

Session 11 (Thursday): Oral Presentation of Posters

Exposures and Exposure Pathways (EX)

EX4PO: Minimum Detection Limit of Portable NaI Gamma Detector for Thyroid Radioactivity Intake Field Measurements of the Public
K. Romallosa
PHILIPPINES

EX6PO: Development of Gamma Camera for Localization of Radiation Hotspots Using Timepix
O. Ploc
CZECH REPUBLIC

EX2PO: Fission Product Screening Using a Portal Monitor
N. Hertel
USA

Radiation Protection Issues (RP)

RP9PO: EURADOS Survey on In-vivo Monitoring Data of Exposed Foreigners in Japan, Obtained in their Respective Countries at an Early Stage after the Nuclear Accident of Fukushima Daiichi Nuclear Power Plant
M.A. Lopez
SPAIN

RP4PO: Elements to Be Taken into Account for an Appropriate Assessment of the Effective Dose to Public in Case of Release of Bulk Amount of Contaminated Water into the Sea
R. Paci
ALBANIA

RP8PO: Assessment of Dose to the Nursing Infant from Radionuclides in Breast Milk
K.F. Eckerman
USA

Health Aspects in Affected Communities (MS)

MS2P0: Training of Health Professionals in Managing Contaminated Exposed Individuals — Experiences and Challenges Faced in Pakistan
R.A. Khan
PAKISTAN

Remediation (RE)

RE4PO: Toward Safe Disposal of Radioactively Contaminated Municipal Solid Waste Incinerator Fly Ash: Moisture Absorption and Cs Immobilization
K. Yamada
JAPAN

RE7PO: Method for Estimating the Dose Distribution of People to Be Returned in Long Term Contaminated Area
S. Takahara
JAPAN

RE3PO: Relevant Radionuclide Concept in Radioactive Waste Management
M. Medici
ARGENTINA

Session 12 (Thursday): Capacity Building in Radiation Protection

(Keynote) From Chernobyl to Fukushima: Experiences of a Young Scientist
V. Berkovskyy
Radiation Protection Institute, UKRAINE

Establishing Sustainable Infrastructures for Education and Training in Radiation, Transport and Waste Safety: IAEA's Approach to Support Member States
A. Luciani
International Atomic Energy Agency (IAEA)

Capacity Building in Japan: The Role of Young Professionals
H. Ogino
Central Research Institute of Electric Power Industry (CRIEPI), JAPAN

Capacity Building in Radiation Protection in the United Arab Emirates
A. Al Shehhi
Federal Authority for Nuclear Regulation (FANR), UNITED ARAB EMIRATES

Session 13 (Thursday): Historical Perspectives from Past Accidents

(Keynote) Overview of Public Exposures from Major Radiological Events
A. Bouville
USA

The Goiânia Accident — Public Risk Perception after Twenty-Five Years
M.M. Oliveira Ramos
National Commission of Nuclear Energy (CNEN), BRAZIL

The Management of Contaminated Land: Challenges in Belarus following the Chernobyl Accident
I.M. Bogdevitch
Research Institute for Soil Science and Agrochemistry, BELARUS

Radiation Exposures in the Marshall Islands: Still Learning after Sixty Years
S. Simon
National Cancer Institute, USA

Session 14 (Thursday): Sharing Experiences

(Keynote) Communication after the Fukushima Accident: An Eyewitness Account
J. Ring
Gighouse Films, UK

The Impact of the Fukushima Accident on Date City
S. Nishida
Mayor of Date City, JAPAN

The Experience of the Sami People in Norway following the Chernobyl Accident
A. Liland for I.M. Eira-Åhrén
Norwegian Radiation Protection Agency, NORWAY

Session 15 (Friday): Global Responses to the Fukushima Accident

(Keynote) The Role and Priorities of the International Radiation Protection Association (IRPA) in the Development of the System of Protection
R. Coates
International Radiation Protection Association (IRPA)

National Presentations (Oral Posters)

GR1P: Bulgarian Experience with the Fukushima Event in March 2011: Lessons Learned
J. Djounova
BULGARIA

GR3P: Development of Post-accident Strategy in Slovenia
H. Janžekovič
SLOVENIA

GR5P: Communication and Public Information System in the Republic of Macedonia
G. Angelovski
THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA

GR6P: Fukushima Daiichi Nuclear Power Plant Accident: Radiation Exposure Concern in Nepal
B. Shah
NEPAL

GR7P: Taking into Account the Fukushima Accident National Radiation Protection Programme
A. Simo
CAMEROON

GR8P: An Assessment on the Transportation of Artificial Radionuclides Arising from the Fukushima Nuclear Accident to Hong Kong
W. Ma
CHINA

GR10P: Long Range Transport of Radioactivity from Fukushima — Modelling of Air Mass Trajectories
A. Ioannidou
GREECE

GR11P: Effects of the Fukushima Daiichi Accident in Hungary — Measurements, Results and Public Acceptance
A. Strádi
HUNGARY

GR12P: Assessment of Radioactivity Levels of Foodstuffs Entering Mombasa Port, Kenya
M. Atogo
KENYA

GR13P: The Moroccan Environmental Signature of the Fukushima Accident
T. El Khoukhi
MOROCCO

GR14P: Monitoring Radioactivity in the Philippine Environment Immediately after the Fukushima Daiichi Nuclear Power Plant Accident
T. Garcia
PHILIPPINES

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