QST-P-11

QST-NIRS Dose Assessment Building
for Advanced Radiation Emergency Medicine

ABSTRACTS

The 5th QST INTERNATIONAL SYMPOSIUM

RADIATION EMERGENCY MONITORING and MEDICINE in NUCLEAR DISASTER

— Current Status of Each Country and Future Prospects —

Online+Onsite

21st–22nd September, 2021

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2-1, Nakase, Mihama-ku, Chiba-city, 261-8550 Japan

Hosted by National Institutes for Quantum and Radiological Science and Technology **(QST)**

In cooperation with: International Atomic Energy Agency **(IAEA)**

Sponsored by: Ministry of Education, Culture, Sports, Science and Technology **(MEXT)**, Nuclear Regulation Authority **(NRA)**, Hirosaki University, Fukushima Medical University, Hiroshima University, Nagasaki University

Preface

We are pleased to welcome you all to the 5th QST International Symposium.

Our institute, the National Institutes for Quantum and Radiological Science and Technology (QST), was established in 2016 through a merger of the National Institute of Radiological Sciences (NIRS) and a part of the Japan Atomic Energy Agency with the aim of becoming an international R&D platform covering broad areas related to Quantum. Since then, radiation emergency medicine and preparedness has remained one of the core missions of QST, which was succeeded from NIRS which was established in 1957 after the Daigo Fukuryu-maru accident where 23 Japanese fishermen were exposed to an H-bomb nuclear test at Bikini Atoll. In 2019, QST was designated as a Japan's National Core Center for leading and coordinating 4 Advanced Radiation Emergency Medical Support Centers (Hirosaki Univ., Fukushima Medical Univ., Hiroshima Univ. and Nagasaki Univ.) by the Nuclear Regulation Authority (NRA).

The QST International Symposium has been organized as an annual event of QST since 2017. This year is the 10th year since the Fukushima Daiichi Nuclear Power Plant accident. During that long period, considerable effort has been made by a number of people on the reconstruction and revitalization of Fukushima, "the land of fortune" in Japanese, with many struggling under difficult situations. Such experiences should be passed down to future generations and never forgotten. This symposium is focused on the current status of each country and future prospects regarding radiation emergency monitoring and medicine in nuclear disasters. Sharing the relevant information among countries with potential risks of radiological or nuclear accidents should be of great significance to strengthen their emergency preparedness and develop efficient collaboration and networking.

This symposium is organized in cooperation with the International Atomic Energy Agency (IAEA), Ministry of Education, Culture, Sports, Science and Technology (MEXT), NRA and 4 Advanced Radiation Emergency Medical Support Centers of Japan.

We believe this symposium will serve as a meaningful opportunity for all of us to share the latest information and future prospects, as well as exchange ideas for the future of this field.

Toshio Hirano, M.D., Ph.D.
President
National Institutes for Quantum and Radiological Science and Technology

The 5th QST International Symposium
on Radiation Emergency Monitoring and Medicine in Nuclear Disaster
–Current Status of Each Country and Future Prospects–

PROGRAMME AGENDA

Day 1 – Tuesday, 21 September 2021		
Online	**Registration**	
10:00-10:20	**Opening session**	
4’	Welcome address	Toshio Hirano, QST
16’	Greetings	
10:20-12:30	**Session 1. Current status and update of radiation emergency preparedness for radiological/nuclear disasters (moderators: H. Tatsuzaki, T. Tominaga, QST)**	
30’	Keynote lecture: Current status and update of the IAEA’s activities in nuclear or radiological emergency preparedness and response	Florian Baciu, IEC, IAEA
20’	Continuous improvement of the NRA Guide for emergency preparedness and response	Toshimitsu Homma, NRA
20’	Reorganization of a nuclear emergency system in Japan after the Fukushima Daiichi nuclear power plant accident	Tomohiko Makino, Cabinet Office
20’	Current status and update of radiation emergency preparedness for radiological/nuclear disasters in France	David Broggio, IRSN
20’	Radiation emergency preparedness for radiological/nuclear incidents: Current status and update for the United States	Carol J. Iddins, REAC/TS, ORISE
20’	QA, discussion and summary	
12:30-14:00	Lunch (the video on QST activities in the Fukushima nuclear disaster)	
14:00-16:50	**Session 2. Emergency monitoring for radiological/nuclear disasters (moderators: O. Kurihara, M. Kowatari, QST)**	
20’	Current situation of radiation monitoring and exposure doses evaluation around FDNPP	Yukihisa Sanada, JAEA
20’	Emergency monitoring system in Republic of Korea	Wi-Ho Ha, KAERI
20’	Emergency monitoring in Germany	Florian Gering, BfS
20’	Break	
30’	Keynote lecture: Outline of ICRU Report 92 on radiation monitoring for protection of the public after major releases of radionuclides to the environment	Volodymyr Berkovskyy, Ukrainian Rad Protect Inst, National Research Center for Rad Med
20’	Individual monitoring in Fukushima - Emergency phase -	Eunjoo Kim, QST
20’	Individual monitoring in Fukushima - Transition phase (emergency phase to existing phase) -	Masaharu Tsubokura, FMU
20’	QA, discussion and summary	

Day 2 – Wednesday, 22 September 2021		
10:30-12:10	**Session 3. Radiation emergency medicine - Health management and effective risk/crisis communication - (moderators: A. Kumagai, T. Nakajima, QST)**	
30’	Keynote lecture: ICRP’s new recommendations related to emergency and existing exposure situations	Michiaki Kai, Nippon Bunri Univ.
30’	Keynote lecture: Thyroid monitoring for the population after a major nuclear accident: Recommendations from an international expert group convened by IARC/WHO	Kayo Togawa, IARC, WHO
20’	Fukushima Health Management Survey - Summarizing a decade of survey results -	Kenji Kamiya, FMU/Hiroshima Univ.
20’	Crisis communications after the Fukushima nuclear disaster	Arifumi Hasegawa, FMU
12:10-13:30	Lunch (the video on QST activities in the Fukushima nuclear disaster)	
13:30-14:50	**Session 3. Radiation emergency medicine – Health management and effective risk/crisis communication (continued)**	
20’	Response to Fukushima and lessons learned (1) - Case study of Hirosaki University -	Masahiro Hosoda, Hirosaki Univ.
20’	Response to Fukushima and lessons learned (2)	Satoshi Tashiro, Hiroshima Univ.
20’	Response to Fukushima and lessons learned (3) Nagasaki University	Naoki Matsuda, Nagasaki Univ.
20’	QA, discussion and summary	
20’	Break	
15:10-16:50	**Session 4. International networking/collaboration (moderators: S. Yamashita, N. Matsufuji, QST)**	
30’	Keynote lecture: Overview of the SHAMISEN project	Takashi Ohba, FMU
30’	Keynote lecture: WHO global expert networks for strengthening global public health preparedness to radiation emergencies	Zhanat Carr, ECH, WHO
20’	ARADOS: Asian Radiation Dosimetry Group	Osamu Kurihara, QST
20’	QA, discussion and summary	
16:50-	**Concluding remark**	Takashi Nakano, QST

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Session 4. International networking/collaboration

Current status and update of the IAEA's activities in nuclear or radiological emergency preparedness and response

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Emergency Preparedness and Response (EPR) was addressed in the IAEA's program since its establishment in 1957. Currently, the IAEA Incident and Emergency Centre (IEC), formally established in 2005, is the global focal point for emergency preparedness and response for nuclear and radiological safety or security related emergencies, threats or events. It is also the world's centre for coordination of international emergency preparedness and response assistance. This vision is underlined by the IAEA Director General, Mr Rafael Mariano Grossi: "To protect the public and the environment in the event of a nuclear or radiological emergency, we must build effective national and international response arrangements. The IAEA's Incident and Emergency Centre is the global focal point for international preparedness and response to such an emergency, whether it arises from an accident, natural disaster, negligence or a security event."

Effective national and international EPR response arrangements are established on the basis of relevant international treaties (the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of a Nuclear or Radiological Emergency) and the relevant IAEA Safety Standards.

In recent years, the IEC continued the development of the IAEA Safety Standards and Technical Guidance for EPR as well as Capacity Building in EPR. General Safety Guide 14 (Arrangements for Public Communication in Preparedness and Response for a Nuclear or Radiological Emergency) was published in 2020 and the SSG-65 (Safety Guide on EPR in Transport, revision of TS-G-1.2) is approved and is pending publication. DS504 (Safety Guide on EPR, revision of GS-G-2.1, Arrangements for Preparedness to Nuclear or Radiological Emergencies) was submitted to IAEA Member States (MSs) and International Organisations (IOs) for comments. For DS527 (Revision of GSG-2: Criteria for use in Preparedness and Response to Nuclear or Radiological Emergencies) the revision commenced and the DS532 (Safety Guide on Protection Strategy for a Nuclear or Radiological Emergency) is pending approval for development. On the development of the Technical Guidance, new EPR series publications were published in 2019 and 2020 such as the EPR Medical Physicist and Pocket Book (guidance for Medical Physicists in support of a response to nuclear or radiological emergencies), the EPR Combined Emergencies (challenges in Response to Nuclear or Radiological Emergencies combined with other emergencies) and the EPR Protection Strategy (considerations in the Development of a Protection Strategy for a Nuclear or Radiological Emergency). Other documents are approved to be published (Revised EPR First Responders, Revised EPR Medical, EPR Medical Follow Up, Revised EPR Method, Revised EPR Research Reactors,

Revised INES User's Manual) or are under development (Revised EPR Exercise, EPR Radiation Monitoring, EPR On-site Plan for NPP, EPR NPP Assessment). In Capacity Building, in 2020, the IEC conducted virtually about 40 webinars (with more than 12000 attendees) to raise awareness of selected EPR Safety Standards topics. Some 14 training events were conducted virtually in 2020 and about 20 events will be conducted in 2021, on the topics of Termination, Protection Strategy, First Responders, Actions to Protect the Public in case of Severe Conditions in an NPP, Development of National Emergency Response Plans and Effective Emergency Public Communications. E-learning materials are being developed for selected topics. Capacity Building in EPR is also conducted through the consolidation of the International Network on Education and Training in EPR (iNET-EPR), launched in July 2019 and which currently includes 173 institutions from 72 countries. In 2022, the IEC will resume the School of Radiation Emergency Management which is a 3-week training course, providing comprehensive training for MS officials involved in EPR at mid-managerial level. In terms of EPR review missions, since 1999, there were 48 EPREV missions conducted in 41 MSs and EPREV Guidelines were published in 2018. There were two EPREV missions implemented in 2019 (Canada and UAE) and three missions are planned for 2021-2022 (Hungary, Morocco, Slovenia). The IEC continued to operate and develop the Emergency Preparedness and Response Information Management System (EPRIMS) which allows self-assessment in EPR against IAEA safety standards and promotes information exchange and access to relevant information. There are currently 127 officially designated Country Coordinators in EPRIMS and 75 MSs have published one or more modules of their self-assessment on the EPR requirements stipulated in GSR Part 7.

In the recent years, the IEC strengthened the operational arrangements for notification and exchange of information in nuclear and radiological emergencies, for the provision of international assistance on request and for the conduct of the assessment and prognosis in nuclear and radiological emergencies. The EPR-IEComm 2019 (Operations Manual for Incident and Emergency Communications) was issued in 2020 together with the new Attachments (EPR-IEComm 2019 Attachment 2: International Radiation Monitoring Information System - IRMIS and EPR-IEComm 2019 Attachment 3: EPR International Radiological Information Exchange Format - IRIX). Workshops on Arrangements for Notification, Reporting and Assistance are conducted since 2010 to which all MSs are invited. Five such workshops with 177 participants from more than 92 Member States were conducted in 2019 - 2020. Based on the operational arrangements described in EPR-RANET 2018, RANET exercises and workshops were conducted. Ten editions of the Competent Authorities Meetings were conducted since 2001, the 10th edition was conducted virtually in 2020 and the 11th edition is planned for June 2022. The IEC extensively liaised with the Permanent Missions in Vienna and with the counterparts in MSs. In 2019 – 2020, five more MSs designated contact points under the Convention on Early Notification of a Nuclear Accident. There are 42 MSs which are regularly providing routine radiation monitoring data to IRMIS. The Unified System for Information Exchange in Incidents and Emergencies (USIE) has been developed to provide more functionality and a secure information exchange with encryption of data in transfer and in storage. Since 2019, the number of USIE users increased by 258 users bringing the total number of users to over 1700 users. The EPR- A&P 2019 manual (Operations Manual for IAEA Assessment during a Nuclear or Radiological Emergency) was published in February 2020 and is complemented with a supporting guide available on-line on the IAEA IEC Assessment Tools website. The Response and Assistance Network (RANET) registrations increased and there are currently (September 2021), 36 State Parties registered in RANET.

IEC continues the work of strengthening EPR globally. Key events on the calendar in 2021 - 2022 are: International Conference on the Development of Preparedness for National and International Emergency Response (EPR2021), 11 - 15 October 2021, Vienna/Virtual; the ConvEx-3 (2021) Exercise, 26 - 27 October 2021; the International Conference on A Decade of Progress after the Fukushima Daiichi NPP Accident; Building on the Lessons Learned to Further Strengthen Nuclear Safety, 8 - 12 November 2021, Vienna/Virtual; and the 11th Competent Authority Meeting (CAM) - Meeting of the Representatives of Competent Authorities identified under the Early Notification Convention and the Assistance Convention, 13 - 17 June 2022, Vienna.

Continuous improvement of the NRA Guide for emergency preparedness and response

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In order to develop a new nuclear emergency response system based on the experiences and lessons learned from the accident at the TEPCO's Fukushima Daiichi Nuclear Power Station, the Atomic Energy Basic Act, the Act on Special Measures Concerning Nuclear Emergency Preparedness (Nuclear Emergency Act), and other related laws and regulations were amended in conjunction with the establishment of the Nuclear Regulation Authority on September 2012, thereby establishing a new framework for the government's nuclear emergency preparedness and response. Under the provisions of the Nuclear Emergency Act, the NRA Guide for emergency preparedness and response (EPR Guide) was developed to ensure the effective implementation of protective actions by operators, designated administrative agencies, local governments and other parties, and have been revised successively since it came into effect on 31 October, 2012. The ultimate goal of the guide is to ensure that protective actions are taken to avoid or to minimize severe deterministic effects and to reduce the risk of stochastic effects as much as possible.

In light of the lessons learned from the rapid progress of the Fukushima Daiichi accident, the NRA has established a protection strategy according to the international standards in which precautionary urgent protective actions such as evacuation are taken based on the emergency class determined by observable facility conditions (EAL: Emergency Action Level) before the release of radioactive material, and further protective actions are promptly taken based on the measurements taken in the environment (OIL: Operational Intervention Level) when radioactive material is released. The EALs for commercial reactors have been reviewed successively, and also the EALs for nuclear fuel facilities were newly incorporated into the EPR Guide in 2017.

In order to provide appropriate medical procedures in a nuclear emergency, an effective system and chain of command should be established as a routine measure in institutions dealing with emergencies and disasters. In addition, it is important to ensure that medical institutions in the designated areas for emergency preparedness and response can cooperate with each other in a wide area in a nuclear emergency. The NRA has incorporated radiation medicine systems into the EPR Guide, together with education, training and drills for appropriate institutions, including the national and local governments. In 2018 the NRA established close coordination with the National Institutes for Quantum and Radiological Science and Technology designated as Core Center for coordinating and guiding four Advanced Radiation Emergency Medical Support Centers. With regard to provision of iodine thyroid blocking in the EPR Guide, the local governments should provide stable iodine tablets to residents in a precautionary action zone (PAZ) in preparation for an emergency. In the event of a general emergency, it requires the supply and intake of stable iodine tablets when evacuation is taken in an urgent protective action planning zone (UPZ), depending on the plant situation and the dose rates off the site. In 2019 the EPR Guide was revised to specify the efficacy or effectiveness of stable iodine tablets, adverse effects, appropriate timing of intake, and who should be given priority in taking stable iodine tablets.

Reorganization of a nuclear emergency system in Japan after the Fukushima Daiichi nuclear power plant accident

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Reflecting the lessons from Fukushima Daiichi Accident, the government revised the Atomic Energy Basic Act, the Act on Special Measures Concerning Nuclear Emergency Preparedness (Nuclear Emergency Act), etc. September 2012. The Atomic Energy Basic Act defines Nuclear Emergency Preparedness Council within the Cabinet during peacetime. The Nuclear Emergency strengthened the functions of the Nuclear Emergency Response Headquarters in any emergency. The Prime Minister leads these Council and Headquarters.

The Nuclear Regulation Authority (NRA) was established in September 2012. NRA holds the primary responsibility for technical issues of on-site safety. NRA also formulates and revises technical guidelines for off-site nuclear emergency preparedness and responses (NRA EPR Guide) since October 2012. The NRA EPR Guide defines the protection strategies and protective actions, including the Emergency Planning Zone (e.g. PAZ within approximately 5 km from the nuclear power stations, UPZ 30 km), the Emergency Class and the Emergency Action Level (EAL), Operational Intervention Level (OIL).

In accordance with the Basic Act on Disaster Management and the Nuclear Emergency Act, the Basic Disaster Management Plan includes sections on countermeasures related to nuclear emergencies. The Plan defines basic issues about emergency responses and assigned roles of the national government, local governments, and nuclear operators (licensees) under emergencies. The Nuclear Emergency Act requires licensees to develop the Nuclear Operator's Emergency Preparedness and Response Plan. Relevant local governments develop their own local disaster management plans and evacuation plans. Drills and exercises are conducted complying with these plans at licensee, local governments, and the national government levels.

In October 2014, the Cabinet Office appointed the Director-General for Nuclear Disaster Management to centrally take charge of comprehensive coordination regarding nuclear disaster prevention, and to accelerate strengthening national and local nuclear emergency preparedness. Cabinet Office supports local government through financial subsidies for infrastructures including sheltering facilities, medical equipment for radiation, iodine tablet stockpiling and distribution, public communication, etc.

Cabinet Office also leads drills and trainings. Nuclear Energy Disaster Prevention Drill (NEDPD) is the annual capstone to demonstrate the procedures of protective actions, involving high level of leaders such as the Prime Minister and Governors and Mayors of local and municipal governments, as well as thousands of residents as active participants and international partners as observers. Since Fukushima Daiichi accident, NEDPD are conducted based on the assumption of a complex disaster involving natural hazards.

The Regional Committee for Nuclear Emergency Preparedness in each region is in charge of developing Regional Emergency Response, which is the compiled plans of local governments' early protective actions including evacuation and relocation, screening and monitoring, medical responses. The Nuclear Emergency Preparedness Council has approved 9 Regional Emergency Responses out of 16 regions as of September 2021.

Responding to the global public health emergency of COVID-19 pandemic, Cabinet Office issued in June 2020 "Basic Concept of Protective Measures in Case of Nuclear Disasters during and Epidemic of Infectious Diseases Due to the Spread of the Novel Coronavirus", and in November 2020 its supplementary guidelines for local governments regarding IPC measures when taking protective actions under COVID-19 outbreaks. The guide explicates that the principle of shelter-in-place is not to ventilate after General Emergency, but also emphasizes infection control measures: advising local governments to make efforts to refresh air by fully opening windows of buses and evacuation centers for limited amount of time (e.g. every 30 min) with careful attention to radioactive release. Existing 9 Regional Emergency Responses has incorporated infection prevention control measures such as separating public into four groups (those infected with COVID-19, close contacts, symptomatic people, and others), and providing sufficient evacuation buses with respective groups, etc.

Current status and update of radiation emergency preparedness for radiological/nuclear disasters in France

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France is a highly nuclearized country with 18 Nuclear Power Plants (NPP) and 56 reactors. Nuclear safety and emergency preparedness are thus of mere importance. These topics cannot be extensively covered and we have selected a few items illustrating recent developments: safety of NPP, some new elements of policy for emergency and post-accidental management, recent developments in tools and methods and preparation for CBRN events.

The emergency response is described in a public guide [1] describing the role of the different actors and associated protection actions to be implemented in 8 typical situations. As a summary, the operator is in charge of restoring the NPP, the Prefect (i.e. the local state representative) is in charge of emergency response actions like evacuation. The Institute for Radiation protection and Nuclear Safety (IRSN) contributes in establishing diagnostic and prognostic of the nuclear facility, release prediction, provides the authorities with technical data, and deploys staff and resources on the field. The French Nuclear Safety Authority (ASN) provides the authorities with recommendations on the management of the situation.

Safety of nuclear power plants

In March 2011, following the Fukushima Daichi NPP accident, the European Council requested stress tests of NPP. Following these tests the ASN established an action plan for the safety improvement of NPP. The results of the action plan have been issued in December 2020 [2]. The construction of an autonomous 3 MW “ultimate” diesel generator, providing power for 72 h for each reactor, is illustrative of these actions.

New elements of doctrine

New policy elements for the management of the post-accidental phase have been validated. These new policy elements were constructed through the work of a steering committee (CODIRPA) including a broad range of stakeholders, among which a significant number of non-governmental organisations. As new elements of doctrine the active involvement, education and information of citizens have been validated. A practical guide for inhabitants of contaminated territories was published [3], inspired in part by Japanese guides.

The strategy for pre-distribution of stable iodine was modified, considering more severe accident scenarios and harmonization of European practices. As a result, the area of pre-distribution was extended to 20 km [4]. Two distribution campaigns were launched in 2019 and 2021, targeting 2.2 million people and 200 000 establishments.

The marketing authorization of stable iodine specifies that it cannot be taken more than two times. However, in case of repeated or long releases, multiple ingestion might be suitable. IRSN and the Army Pharmacy thus initiated a research program to study the side effects of multiple ingestion [5]. The results led to an official demand for modifying the posology: above 12 years-old the dosage could be 130 mg of KI/day during maximum 7 days [5, 6].

Development of new tools and methods

Three new developments will be discussed.

Recently, it was shown that inverse modelling can be useful in the early phase of an emergency: even a limited number of dose rate measurements can help in defining the source term in almost real time [7].

The IRSN fleet of mobile units enables internal contamination monitoring around the accident site. LaBr3 detectors are currently being tested to replace NaI probes. It is currently investigated if it's worth developing transportable equipment that would remain on the emergency site.

The CRIHOM software has been developed to handle internal monitoring results: it enables registration of monitored subjects, results' storage and dose assessment. Dose assessment can be corrected to take into account non measured radionuclides and external radiation. These additional exposures are calculated from the release spectrum and exposure conditions after measurement of a tracer radionuclide that is used to normalize the other exposures [8].

Preparation for CBRN events

A division of the Home Secretary is in charge of emergency training for CBRN events [9]. IRSN is increasing its participation to these trainings and organizes its own. CBRN events differ in some aspects from NPP accidents: new actors are involved, irradiated or contaminated victims could suffer from severe blast, the source term might be not identified quickly.

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Radiation emergency preparedness for radiological/nuclear incidents:

Current status and update for the United States

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This presentation will give an overview of the status of radiation emergency preparedness for radiological/nuclear (R/N) incidents in the United States (US). The US Government (USG) has a multi-faceted approach for preparedness for R/N incidents. The many different USG agencies, as well as, local; regional; state; territorial and tribal government and non-governmental (NGO) assets are in place for emergency preparedness and response. The Federal Emergency Management Agency (FEMA), part of the Department of Homeland Security (DHS) has a National Response Framework (NRF) for all types of emergencies in the US. The NRF has Emergency Support Functions (ESF) Annexes and Support Annexes for various incidents. The NRF for R/N incidents is in several ESFs. The U.S. Department of Energy (DOE) coordinates ESF # 12 Energy, along with DHS/FEMA coordination of ESF # 6 Mass Care; and The Department of Health and Human Services (HHS)/Assistant Secretary for Preparedness and Response (ASPR) coordinates ESF # 8 Public Health and Medical Services, will likely all be used for response to an R/N incident. Other ESFs will likely be involved, as well. Various departments will take lead depending on the type and scale of the incident (DHS, 2019) [1].

The Nuclear / Radiological Incident Annex (NRIA) designates response to accidental releases of radiological materials (nuclear facilities, lost material, nuclear weapon accident either domestic or foreign) or intended releases of radiological materials (radiological dispersal device, nuclear weapon, or improvised nuclear devices). The US DOE task is to assist with reestablishing the damaged energy infrastructure and provide technical expertise. The US DOE will supply the Federal Radiological Monitoring and Assessment Center (FRMAC) and other assets, such as the Nuclear Incident Response Team (NIRT), Advisory Team (a multi-agency team) and National Atmospheric Release Advisory Center (NARAC), Many assets such as the Radiation Emergency Assistance Center / Training Site (REAC/TS) fall within the NIRT (DHS, 2016, Kirk & Iddins 2015) [2,3]. These assets will be the initial response and will transition, with time, to the responsible agency or agencies.

Another aspect of the emergency preparedness and response is the US Strategic National Stockpile (SNS), managed by the Department of Health and Human Services (HHS). The SNS contains medications and equipment that may be used in large-scale incidents. Local authorities may request Federal assistance that can arrive within 24-72 hours. The individual state or states will distribute the supplies/equipment and medications. They also have the capability to set up temporary medical shelter through caches that contain beds, supplies and medications for up to 250 people per Federal Medical Station (FMS).

In addition to the named response agencies and assets, the U.S. currently funds radiological effects and countermeasures research in both government and private/university settings. The National Institute of Allergy and Infectious Diseases (NIAID) with their Radiation and Nuclear Countermeasures Program

(RNCP) (Rios, et al., 2014) [4] and the Biomedical Advanced Research and Development Authority (BARDA) under the Department of Health and Human Services (HHS) sponsor research in the development of countermeasures (CMs) and biodosimetry. In addition, many universities and companies develop pursue research in these areas either with grants or independently.

Once approved for use by the FDA, countermeasures developed through the above processes may be included in and requested from - the U.S. Strategic National Stockpile (SNS), managed by the Department of Health and Human Services (HHS). The SNS contains antibiotics, antivirals, chemical antidotes, antitoxins, life support pharmaceuticals, vaccines, intravenous (IV) administration supplies, airway maintenance supplies, masks, pandemic countermeasures, and medical/surgical items (Esbitt, 2003) [5]. These supplies are intended to supplement and resupply state and local agencies with these critical medical items in the event of a major natural or technical disaster, or an accident or incident involving the use of weapons of mass destruction within the United States or its territories. Upon request from a state or local agency, 12-Hour Push Packs and a Technical Advisory Unit can arrive on-scene within 12-hours of the decision to deploy (Singh, Romaine, and Seed, 2015) [6].

The current status of the U.S. FDA approved CMs for Acute Radiation Syndrome all support bone marrow recovery with three cytokine growth factors and one thrombopoietin agonist. Research for CMs for other organ system damage seen with radiation injuries is ongoing. The use of Emergency Use Authorizations (EUA) during the SARS CoV-2 pandemic has been encouraging. This may allow many CMs in later stages of research and development, to be options under EUA. Currently, no biodosimetry techniques, including the dicentric chromosome assay (DCA) known as the "gold standard", are FDA approved (Waselenko, et al., 2004) [7]. Research in biodosimetry, as well as physical dosimetry techniques is ongoing.

The current status of CMs for internalized radionuclides include two prescription medications and one over the counter (OTC) medication that are FDA approved and available for three common radionuclides present in fresh fission products, longer term radionuclides, and neutron activation products (Cassatt, et al., 2008) [8]. One of these, the calcium or zinc DTPA, may be considered for some other radionuclides, however, these are not FDA approved.

Bioassay labs for bio-excreta assessment of internalized radionuclides are not plentiful in the US. The Centers for Disease Control and Prevention (CDC) has the capability to perform urine bioassays and several commercial labs may do both urine and fecal bioassays (Whitcomb, et al., 2018) [9]. These results will take time for results and may not be practical in a large-scale incident for immediate guidance, though will assist in population monitoring (Li, et al., 2017) [10]. When appropriate, hand held Geiger-Mueller Counters or other portable instrumentation may be used for "spot check" of urine (Kramer, Hauck, & Capello, 2008) [11].

Many agencies are now addressing the need for subject matter experts (SME) and technical experts to support responders in an R/N incident (Miller, 2012) [12]. This has been done on a smaller scale, though at expert level, over the years within the supporting agencies. Examples of this support include the US DOE assessment scientists who help gather and analyze measurements of radionuclides in air samples or US EPA for soil/water samples; US DOE National Atomospheric Release Advisory Center (NARAC), which takes the atmospheric release data and provides plume models; and US DOE REAC/TS that provides SMEs for the injuries and illnesses resulting from R/N incidents (as well as educating healthcare providers and other emergency personnel). Many agencies are collaborating to establish more individuals throughout the country with various levels of training to broaden the response capabilities (Irwin, 2018) [13].

The US has worked with global emergency and preparedness response with individual nations; through the International Atomic Energy Agency (IAEA) and their Radiation Assistance Network (RANET); and through the World Health Organization's Radiation Emergency Medical Preparedness and Assistance Network (REMPAN).

There are areas of focus in our emergency preparedness and response for R/N incidents involving the broadening of our CMs, dose assessment techniques, and responder base knowledge.

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Current situation of radiation monitoring and exposure doses evaluation around FDNPP

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The radionuclides released by the Fukushima Dai-ichi Nuclear Power Plant (FDNPP) accident ten years ago are still being monitored by various research teams and the Japanese government. Various surveys have been conducted to evaluate the ambient dose equivalent rate (air dose rate), including airborne radiation survey using manned or unmanned helicopters [1] as shown in Fig.1, carborne survey, and ground-based survey, and their results have been used as key data, such as for the demarcation of evacuation or decontamination areas. In addition, comparison of different survey tool's results could help evaluate the exposure doses and the mechanism of radiocesium behavior in the urban environment in the area. In this presentation, the large-scale radiation monitoring will be summarized for environmental restoration.

The Japanese government is beginning to consider radiation protection in the "specific reconstruction reproduction base area" of the FDNPP, the evacuation order of which will be lifted by 2023 [2]. It is essential to grasp the present situation of radiation contamination and evaluate exposure dose in the area to realize the lifting of this evacuation order zone. Many surveys on the evaluation of the distributions of air dose rate have been carried out, and exposure dose has been estimated using the results since the FDNPP accident. Nevertheless, more detailed information on exposure is needed for the area because the radiation level is relatively high. This will also be helpful in preparing a prudent evaluation plan. This study is aimed at evaluating the detailed contamination situation in the area and estimating exposure dose with consideration of areal circumstances. Packaging technology was constituted for (1) an airborne survey of the air dose rate using an unmanned helicopter and ground-based measurement (walk-survey), (2) the evaluation of airborne radiocesium and (3) the estimation of external/internal effective doses for the typical life patterns assumed. Our study resulted in a detailed map of the air dose rate and clarified the distribution pattern in the area. Moreover, the exposure dose of residents was evaluated by considering some life patterns based on this map.

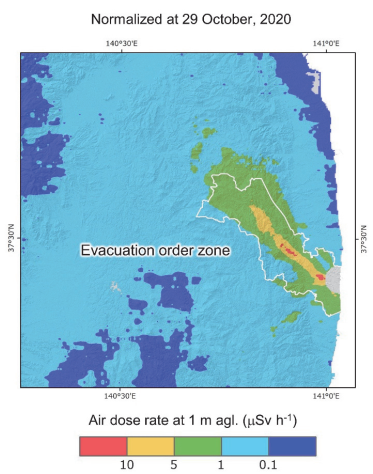

Fig.1 Dose rate map by airborne radiation survey at 29 October, 2020.

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Emergency monitoring system in Republic of Korea

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In Korea, national radiation emergency preparedness and response system has been established by NSSC (Nuclear Safety and Security Commission), a governmental authority, according to the act on "Physical Protection of Nuclear Facilities and Countermeasures against Nuclear Emergencies." Emergency monitoring is crucial for decision making of protective actions and other response actions in emergency exposure situations after large-scale nuclear or radiological events. In general, emergency monitoring is composed of source monitoring, environmental monitoring and individual monitoring. In this presentation, national system for environmental monitoring and individual monitoring is mainly introduced since source monitoring is primarily performed by nuclear licensees which have operated nuclear facilities.

Figure 1 represents nuclear emergency response organizations established following a nuclear emergency. According to the relevant regulations, an off-site emergency management center, local government's emergency management center and nuclear licensee's emergency operating facility will be activated under the command of a central headquarter of nuclear emergency management when a nuclear emergency occur. In addition, for the purpose of technical support, joint radiation monitoring center under the headquarter of technical support for radiation protection and joint radiation emergency medical service center under the headquarter of radiation emergency medical assistance for radiation injuries will be set up by KINS (Korea Institute of Nuclear Safety) and KIRAMS (Korea Institute of Radiological and Medical Sciences), respectively. Environmental monitoring will be implemented by the joint radiation monitoring center composed of technical experts of KINS, environmental radiation analysts from nuclear licensees and local governments. For environmental monitoring under normal operation of nuclear facilities, KINS has operated IERNet (Integrated Environmental Radiation Monitoring Network) composed of 194 monitoring stations throughout the country as shown in Fig 2. After large-scale nuclear accident occurs, the joint radiation monitoring center will play key roles for environmental monitoring in the affected area. Airborne, foodstuff, commodities, and drinking water will be sampled and monitored at monitoring stations appointed by national nuclear emergency response plan. Individual monitoring will be implemented by several organizations including nuclear licensees, local governments, KIRAMS and local radiation emergency medical centers. KIRAMS has provided technical assistance for individual monitoring of external and internal contamination for emergency workers as well as members of the public.

Emergency monitoring criteria should be predetermined for effective and timely response to a nuclear emergency. NSSC adopted generic intervention levels and operational intervention levels on the basis of

IAEA safety guides. And KINS, KIRAMS and KAERI (Korea Atomic Energy Research Institute) have carried out research projects to update the emergency monitoring criteria. And rapid and accurate radiation monitoring techniques using mobile vehicles and unmanned devices have been developed to be applied for emergency monitoring by several research groups in Korea. The current status of the research and development projects for emergency monitoring will also be introduced in the presentation.

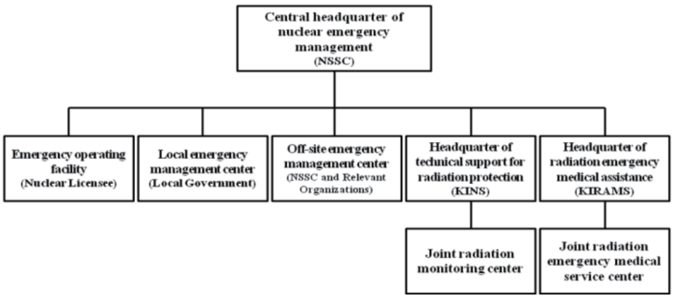

Fig 1. Nuclear Emergency Response Organizations

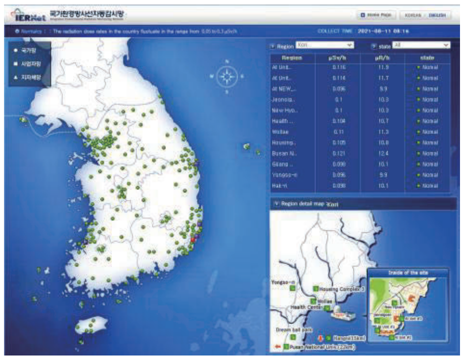

Fig 2. Integrated Environmental Radiation Monitoring Network (IERNet) established by KINS

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Emergency monitoring in Germany

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The German Federal Office for Radiation Protection (BfS) operates the German Integrated Measuring and Information System for the Surveillance of Environmental Radioactivity (IMIS). The task of IMIS is to continuously monitor the environment and thus to be able to detect small changes in environmental radioactivity over a large area in a fast and reliable manner, as well as to recognize long-ranging trends. More than 50 German Federal and Länder laboratories participate in this environmental monitoring programme.

IMIS is primarily designed for the quick assessment of the radiological situation in an emergency situation. In order to enable the authorities to initiate appropriate protective actions for the public, IMIS has been designed to provide mainly three types of information in a fast and reliable manner:

- Which areas are affected, and what level of contamination has to be assumed?
- What radionuclides are involved?
- What is the current and anticipated level of exposure to the public in the affected areas?

IMIS integrates the data from several continuously operating monitoring networks that have been set up for monitoring radioactivity on the ground, in the atmosphere, in the federal waterways and in the North and Baltic Seas. The largest monitoring network is an early warning network with roughly 1800 automatic ambient dose equivalent rate (ADER) stations equally distributed over the German territory. This dose-rate monitoring network is being operated by the German Federal Office for Radiation Protection (BfS), the network was established during the cold war period and was improved after the Chernobyl accident in 1986.

Moreover, IMIS collects data from a large number of laboratories: in routine operation of the IMIS system, more than 10,000 measurements of environmental radioactivity are performed each year all over Germany on samples from air, water, soil, feed- and foodstuffs and other parts of the environment. These measurements of environmental samples are carried out by more than 40 specialized laboratories distributed across Germany and the results are collected and evaluated within the IMIS system.

Several hundreds of users of the IMIS system have access to all relevant data on a 24/7 basis, thus assuring that all parties involved in the management of an emergency situation have instantly access to the same information and are thus capable of deciding about appropriate protective actions. This is being supported by radiological situation reports distributed via IMIS, that provide an overview of the radiological situation and its expected development over time, integrating both all relevant monitoring data and also prognostic data provided by specialized numerical models for predicting e.g. the atmospheric transport of radionuclides and assessing the resulting doses to the public.

Outline of ICRU Report 92
on radiation monitoring for protection of the public after major releases of radionuclides to the environment

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Nuclear installations may contain a large inventory of radioactive material, and an emergency may cause uncontrolled releases of radionuclides to the environment. Malevolent acts may also cause such releases. The international safety standards require that the operators of nuclear installations and the governments have adequate radiation monitoring capabilities to collect and process data quickly and accurately to inform decision-makers who manage protective actions in the course of the emergency and during the following weeks, months, and possibly, years.

The core mission of the International Commission on Radiation Units and Measurements (ICRU) is to develop a coherent system of quantities and units in the field of ionizing radiation and provide recommendations on how to measure these quantities. A new report Radiation Monitoring for Protection of the Public After Major Releases of Radionuclides to the Environment [1] has been prepared by the ICRU Report Committee 28. The report provides detailed practical information on radiation monitoring to protect people and the environment after significant environmental releases. The report deals with the design and operation of off-site monitoring programs and systems. It is based on the experience from responding to prior accidents combined with analyses of various policies and procedures used by countries worldwide. The report includes five chapters.

The first chapter introduces the objective of the report and outlines its structure. The second chapter provides an overview of processes that lead to releases of radioactive material to the environment, compositions of releases (source terms), mechanisms of the radionuclide transfer in environmental media and food chains, the relative importance of radionuclides and pathways of exposure, objectives, and main principles of radiological protection in a nuclear or radiological emergency, and the role of monitoring data in emergency preparedness and response. Summary information about significant environmental releases in the past concludes the chapter.

The third chapter of the report describes the design and operation of radiation monitoring programs at the national and facility levels. It covers preoperational monitoring, monitoring during normal operations, at various phases of the emergency and during post-emergency existing exposure situations. Radiation monitoring programs are essential components for the safe operation of a nuclear installation and the country's emergency management system. A monitoring program specifies media to be sampled, spatial locations and frequencies of sampling or measurements, radionuclides to be quantified, and monitoring systems to be used. In the preoperational phase, the monitoring programs focus on collecting data for reliable assessments of the radiological impact of releases. During normal operation, monitoring programs serve as a warning system to alert the operator and government of a radioactive release. Should a release occur, dedicated monitoring programs provide vital information to guide immediate actions at the installation and mitigate the consequences of the release. Monitoring programs continue to contribute to health and safety when the emergency phase has ended, and long-term remedial actions need to be managed.

The fourth chapter includes a review of monitoring equipment, systems, and methods employed to gather radiological and supporting information within monitoring programs discussed in the third chapter. The selection of equipment and techniques will change with the evolvement of the emergency and post-emergency existing exposure situation. The measurement methods used and the amount of data to be collected depend on the urgency of the decisions and the availability of resources. Other considerations are which media pose the most significant risk and which radionuclides are of greatest concern at that phase. In the early phase of an emergency, decisions may need to be made to avoid immediate danger to life or health. Often these initial decisions will be made with information from limited radiological measurements because of the quantity, sensitivity, or positioning of the equipment that was readily available. After the emergency has passed, the management of long-term protective actions will require precise and extensive measurements, and more personnel and equipment can be involved.

The fifth chapter includes gives a summary of quantities and units for emergency radiation monitoring. Consistent use of terminology and units is critical when health and safety decisions based on measurements are to be made. Experts who analyze the radiation monitoring data and provide them to decision-makers shall ensure the data are accurate, homogeneous in terms of units, and appropriately communicated.

Six appendices provide additional related details and discuss specific radiation accidents. The experience accumulated after accidents at the Chernobyl Nuclear Power Plant (former USSR, 1986) and the Fukushima Daiichi Nuclear Power Station (Japan, 2011) is summarised in comprehensive appendices.

The target users of the report are managers responsible for the planning, design, and operation of off-site radiation monitoring at the national, regional, and local levels. The report may also be helpful for national authorities and organizations regulating and implementing emergency preparedness and response and the environmental remediation of areas affected by an emergency.

Acknowledgements

The author expresses his deepest appreciation to all colleagues and institutions involved in preparing the ICRU Report 92.

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Individual monitoring in Fukushima - Emergency phase -

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Much effort has been made on the dose reconstruction for residents involved in the 2011 Fukushima Daiichi Nuclear Power Plant (FDNPP) accident. The results demonstrated that the radiation exposure dose levels to the residents by this accident were low in general, indicating that their future health risk would be trivial or undetectable. However, one remaining issue is the uncertainty in the assessment of individual thyroid doses due to the intake of short-lived radioiodine (mainly, ^{131}I) that existed only in the early period of time after the accident. The number of direct human measurements for ^{131}I totaled only about 1,300 regarding members of the public. These data should have been used as the base for the dose reconstruction; however, they were far less than the populations in the affected areas. Most of the data were obtained from screening campaigns to examine internal thyroid doses to young children about two weeks after the accident. The results revealed that the individual thyroid doses were mostly less than 20–30 mSv; however, these campaigns were conducted only in three municipalities outside the 30 km radius of the FDNPP. Thus, other data were necessary to perform the dose assessment for individuals from neighboring municipalities where prompt evacuation orders were issued by authorities. We used data of whole-body counter (WBC) measurements for Cs, atmospheric transport and dispersion model (ATDM) simulations and personal evacuation behaviors in the dose reconstruction. Our recent studies indicated that some residents living near the FDNPP might be significantly exposed during their evacuation.

On the other hand, it should be noted that there were many difficulties in the screening campaigns, e.g., selecting target areas with sparse environmental monitoring data, finding suitable measurement places under elevated background radiation levels, recruiting subjects during the accident, measuring young children including infants, and a limited time period available for measuring ^{131}I. It is thus vital to establish a feasible and robust population monitoring method in case of a future nuclear accident that would be likely to be caused by an unprecedented natural disaster in Japan as experienced in the FDNPP accident. The presentation will address our proposed method to cope with the above difficulties along with the experiences of population monitoring at the early phase of the FDNPP accident.

Individual monitoring in Fukushima
- Transition phase (emergency phase to existing phase) -

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Individual monitoring in the transition phase to the existing phase is one of the most important tools for identifying individuals who exceed the reference level and analyze the causes of their life behavior in detail. However, when the results of individual monitoring are required for use in estimating the mean, median, and maximum values in a population, many uncertainties are involved. They include, the relationship between the values indicated by personal dosimeters and the effective dose, inappropriate use, changes over time, effects of lifestyle behaviors, ensuring the representativeness of the subjects monitored, and comparability with other dosimetries. While it is necessary to ensure privacy and take into account rumors caused by monitoring itself, individual monitoring after the transition phase is more meaningful as risk communication with residents in addition to individual dose assessment.

In this presentation, the status of individual dosimetry conducted mainly by local governments, after the Fukushima nuclear power plant accident, will be introduced in terms of external and internal exposure. Lessons learned and future issues will be introduced.

Monitoring of external exposure was mainly carried out by local governments through the distribution of personal dosimeters.[1,2] Monitoring began in the latter half of 2011 and early 2012, although the availability, implementation period, and target of monitoring differed by municipality. The monitoring system has gradually shifted from an opt-out system to an opt-in system, and the number of inspectors has been decreasing. Many municipalities compile their own data and present it in different ways, which often makes comparisons difficult. Although the reference level of intervention differs among the municipalities, there are limited examples of intervention tools used for risk communication. In addition, there are many cases in which individual dosimetry are used for dose assessment in areas where evacuation orders have been lifted, or before people return to their homes, but the values are known to be much lower than the typical estimates from environmental monitoring.[3] In the future, it will be necessary to discuss how individual dosimetry can contribute to dose assessment for populations in such areas.

Internal exposure monitoring using whole body counters (WBCs) have been conducted by the national government, JAEA, local governments, and citizen groups since the early post-accident period. Currently, it is mainly conducted by Fukushima Prefecture and its local governments. As in the case of external exposure, the existence of monitoring, period of implementation, and the target differ. Many residents are below the detection limit, showing a decisive difference from the Chernobyl nuclear accident. Although there have been reports of interventions with a certain reference level, it has been difficult to continue dietary interventions for internal contamination.[4] A good example of a risk communication tool used is the Babyscan, a WBC specifically for infants.[5] In both cases, the number of testers have decreased, and it is time to discuss the purpose and direction of future monitoring.[6]

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ICRP’s new recommendations related to emergency and existing exposure situations

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The International Commission on Radiological Protection (ICRP) continues to develop recommendations to strengthen the radiation protection system based on the latest scientific information, societal experience and values. Following the accident at the Fukushima Daiichi Nuclear Power Plant, several lessons have been learned on radiation protection and related issues, and the ICRP has published Publication 146, which describes radiation protection of humans and the environment in the event of a major nuclear accident. The ICRP 2007 recommendations defined three exposure situations in Publication 103. It has considered how to apply the three principles of radiation protection in each exposure situation, and Publication 146 provides recommendations on radiation protection for emergency exposure situations during a major nuclear accident and for existing exposure situations after an accident. Although adverse health effects following radiation exposure are a major concern, a large-scale nuclear accident will present complex situations for individuals and society, and the social, environmental, and economic consequences can be significant. Conventional radiation protection is essential, but radiation protection is only one of the contributions that can be made during an accident. The objective of radiation protection is to reduce the radiological impact on humans and the environment, to maintain a sustainable living environment, an appropriate working environment for responders, as well as the quality of the environment. The objectives of radiation protection are achieved using the principles of justification and optimization. The justification principle states that the decision to change the exposure situation should result in more benefits than harms because the implementation of protective measures can cause significant disruptions. Lessons learned from the Fukushima accident suggested that the unplanned evacuation of the elderly and people under medical supervision from nursing homes and medical facilities may have resulted in more harm than benefit. ICRP has recommended that rapid post-accident evacuation should be prepared with stakeholder involvement in pre-planning and training. Optimization is a step-by-step process that takes into account a variety of factors in order to select the best protective measures based on special circumstances. The process of optimization should reflect ethical values such as stakeholder involvement. In optimization, reference levels are used as a tool to control inequities in the distribution of individual exposures and to maintain or reduce them as much as reasonably achievable. Reference levels do not represent predetermined regulatory limits that should not be exceeded, such as dose limits. If the situation evolves and the dose distribution changes, it may be appropriate to reevaluate the reference level. The ICRP defined the timeline for post-accident management into three categories, early, intermediate, and long-term phases.

and further divided the target into onsite and offsite to consider protective measures. The ICRP recommended reference levels and approaches to protective measures along these timelines. People engaged in responding to the accident, emergency teams including firefighters, police officers, medical personnel, etc., workers, professional occupations, and volunteer citizens are all referred to as responders. The "responders" in post-accident situations can replace the "occupational workers" in planned exposure situations. Protective actions in emergency and existing exposure situations should be treated by distinguishing between responders and the public. This recommendation emphasizes the importance of optimizing protection for the recovery of living and working conditions in the affected areas even in the intermediate and long-term phases. The recommendation emphasizes the role of cooperation in the collaborative research process to facilitate informed decisions by authorities, experts, and exposed persons about their own protection, which is called as the co-expertise process.

Thyroid monitoring for the population after a major nuclear accident: Recommendations from an international expert group convened by IARC/WHO

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Issues related to overdiagnosis of thyroid cancer raised a question of whether and how to implement health surveillance of thyroid cancer in case of a nuclear accident that involves the release of radioiodine. In 2017, the International Agency for Research on Cancer (IARC) convened an international, multidisciplinary Expert Group to address the question and develop recommendations on long-term strategies for thyroid health monitoring after a nuclear accident [1,2]. Based on the current scientific evidence and previous experiences, the Expert Group recommends 1) against population thyroid screening after a nuclear accident, and 2) that consideration be given to offering a long-term thyroid monitoring programme for higher-risk individuals (defined as those exposed in utero or during childhood or adolescence with a thyroid dose of 100–500 mGy or more) after a nuclear accident. Thyroid monitoring programme is defined by the Expert Group as including education to improve health literacy, registration of participants, centralized data collection from thyroid examinations, and clinical management. A thyroid monitoring is an elective activity offered to higher-risk individuals, who may choose how and whether to undergo thyroid examinations and follow-ups. The choice of a thyroid dose range, 100–500 mGy, for an actionable level reflects the option to be more inclusive (lower actionable levels) or to be more efficient (higher actionable levels) in monitoring and identifying radiation-associated thyroid disease. Those recommendations were developed in the context of considerations relevant to exposure to any toxic substances, and preparedness and response to nuclear accidents, such as the establishment of a health surveillance programme (e.g. cancer registration), a risk communication programme, dosimetry monitoring and protective actions. The Expert Group emphasized the importance of additional considerations for decision–making about thyroid monitoring after a nuclear accident, such as socioeconomic implications, health-care resources, and social values.

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Fukushima Health Management Survey - Summarizing a decade of survey results -

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In response to the 2011 nuclear power plant accident in Fukushima, its prefectural government commissioned the Fukushima Health Management Survey to Fukushima Medical University, at which the Radiation Medical Science Center for the Fukushima Health Management Survey was established. The initial purpose of this survey was to estimate external exposure doses of Fukushima residents and assess their health conditions, in order to promote their long-term wellbeing through prevention, early detection, and early treatment of disease. In conjunction with the 10th anniversary of the nuclear accident, the Center compiled and published a report on survey results thus far, summarized emerging issues regarding the survey, and prepared updated information materials for residents, so that the survey will be better utilized to support the health of Fukushima's people (1). This presentation will provide an overview of our decade-long accumulation of survey results.

This multifaceted survey includes a Basic Survey, which aims to estimate external exposure doses, and four detailed surveys to assess specific aspects of residents' health: 1) Thyroid Ultrasound Examination (TUE), 2) Comprehensive Health Checkup (CHC), 3) Mental Health and Lifestyle Survey, and 4) Pregnancy and Birth Survey (2).

In the Basic Survey, external exposure doses for more than 466,000 people during the first four months after the accident were estimated, showing that 99.8% of the residents were exposed to less than 5 mSv (3).

TUE has been performed for approximately 380,000 residents who were under 18 at the time of the accident. The fourth round of TUE is in its final stage, and periodic 5-year follow-up examinations for those who have reached age 25 have begun. The numbers of those diagnosed with thyroid cancer or nodules suspected to be malignant in the first through fourth rounds of TUE are 116, 71, 31, and 33, respectively (3). The Prefectural Oversight Committee for the Fukushima Health Management Survey evaluated the results of the first and the second rounds of TUE and concluded that no correlation can be found between thyroid cancers detected through TUE and radiation exposure in Fukushima (4,5).

Efforts are being strengthened to ensure that the advantages and disadvantages of TUE are fully understood and accepted by examinees, and that informed consent is properly documented for those who wish to participate. Concurrently, the Prefectural Oversight Committee is now discussing future directions of TUE, taking into account the advantages and disadvantages of receiving the examination and other ethical perspectives.

In the CHC, which has been provided to approximately 210,000 residents from nationally designated evacuation zones, increases were observed in the number of those with obesity, hypertension, diabetes, lipid disorders, chronic kidney disease, liver dysfunction, and polycythemia vera (6). The survey results, which show increases in risk factors for cardiovascular diseases, such as obesity, hypertension, diabetes, and dyslipidemia, indicate the importance of implementing health management practices to control these factors.

In the Mental Health and Lifestyle Survey, which also covers residents from the evacuation zones, the proportions of people with low general mental health, such as depressive tendencies, people with strong trauma-related symptoms, and children who needed support due to problematic behavior, were higher than those of Japan's overall population immediately after the accident, with a decline over time (3). Regarding lifestyle habits, there was a trend toward improvement, with temporal increases in sleep satisfaction and frequency of regular exercise, and decreases in the proportions of smokers and problem drinkers (3).

The Pregnancy and Birth Survey was offered to pregnant women who received maternal and child health handbooks from their municipalities in Fukushima Prefecture and those who had delivered in the prefecture. The survey showed that rates of preterm births, low birth weight babies, and incidences of congenital malformations did not differ from Japanese national averages (6). On the other hand, the percentage of pregnant and nursing women with depressive tendencies was higher after the accident, but declining over time.

The Fukushima Health Management Survey is not just for assessing Fukushima residents' health status, but also for providing various types of support directly to residents with health issues found through the survey, and promoting a diverse range of activities implemented in cooperation with each municipality to help residents maintain and enhance their health.

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Crisis communications after the Fukushima nuclear disaster

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Crisis communication is a measure that helps organizations respond to sudden and serious events. In a crisis situation such as a nuclear disaster, crisis communication plays an important role in helping medical professionals in the frontline to build consensus and recognize risks during disaster response. Ideally, it should be provided by an authoritative organization such as the government, but in the case of the Fukushima Daiichi nuclear power plant (FDNPP) accident, crisis communication was provided only by private citizens who were aware of the crisis at the hospital [1].

During the acute phase of the FDNPP accident, Japan's first severe nuclear accident, the information necessary for disaster management was not provided to front-line medical staff. Fukushima Medical University (FMU) Hospital lacked information, and we had no idea what was happening at the nuclear power plant, what was happening around the nuclear power plant, what the effects of radiation exposure would be, or what would happen in the future. The anxiety stemming from the above overwhelmed the general public and medical professionals, and as a result, the hospital was faced with the crisis of continuing its operations, even if only temporarily [2,3].

Actually, the hospital's crisis communication in response to the nuclear accident took place in three steps. In the first step, experts in the FMU hospital provided basic knowledge about radiation risks to the hospital staff. In the second step, the Radiation Emergency Medical Support Team was stationed at the hospital day and night, carefully building dialogue and trust. In the third step, outside experts were invited to discuss what the FMU hospital could and should do. More than 200 medical staff gathered in the auditorium and shared time to think about countermeasures with the experts. Afterwards, our perception of the nuclear accident changed because we realized that it was not something that others could solve for us, but something that we had to solve ourselves. It was similar to the process of a patient who has been informed of cancer, overcoming despair, anguish and anxiety, and adapting to reality[4]. The experience of the Fukushima accident suggests the need for an effective plan for crisis communication.

The experience of FDNPP accident suggests that effective planning for crisis management and crisis communication with those at immediate risk is absolutely necessary. However, there is no consensus on when, who, and how to conduct crisis communication. There is also no framework that organizes the knowledge and skills related to crisis management. At the very least, there needs to be a communication route for organizations to request crisis communication when they are faced with a crisis situation. The above is one of the future challenges revealed by the FDNPP accident[5].

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Response to Fukushima and lessons learned (1) - Case study of Hirosaki University -

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On 13 March, the members of Radiation Safety Council of Hirosaki University were convened, and they discussed a policy against the Fukushima nuclear accident. Based on the request of the Japanese government, the council concluded that university staff members would be dispatched to Fukushima for support residents there. The first team of our university was dispatched to Fukushima on March 15. At that time, main activity in Fukushima was screening test for radioactive contamination to the public. Additionally, we conducted radiation measurements and environmental sampling for dose assessments. We conducted a car-borne survey along the express way from Aomori Prefecture to Fukushima Prefecture repeatedly using a gamma-ray spectrometer to evaluate the temporal variation of ambient dose rates. Through this experience, we learned importance of continuous measurements by car-borne surveys to know the behavior of radioactive plumes that might be released in a nuclear accident. In mid-April 2011, we measured I-131 activity in thyroid for 62 residents and evacuees using a 3-in × 3-in NaI(Tl) scintillation spectrometer, and estimate the thyroid equivalent doses for them. A few research groups have been conducted the thyroid dose assessments using a different methodology. Thyroid doses estimated by the several groups have been reported as a similar level. However, the doses from I-132 and I-133, which are short-lived radionuclides, were not taken into account in the thyroid dose estimation due to lack of information. After a nuclear accident, prompt thyroid measurements are very important to evaluate the contribution of short-lived radionuclides. However, in this period, various photon peaks from nuclear fission products are observed in gamma-ray spectra immediately after a nuclear accident. Therefore, it is difficult to distinguish the peaks from I-132 and I-133 in the gamma-ray spectra obtained by NaI(Tl) scintillation spectrometers. It is essential that a standardized technique independent of measurement geometry should be developed for improved accuracy of thyroid monitoring. Throughout our several activities at Namie Town, Hirosaki University entered into a partnership agreement with Namie Town, Fukushima Prefecture in September 2011. We conducted research project on the dose estimation from natural and artificial radionuclides for the residents of Namie Town (FY2017-2019). The doses from natural and artificial sources will be compared to enable residents in the area judge the influence of the Fukushima nuclear accident on overall dose. We will also introduce about overview of this research project based on our published literature.

Response to Fukushima and lessons learned (2)

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After the Fukushima Daichi Nuclear Power Plant accident, the human health effects of low dose radiation exposure by nuclear disasters and also by radiation medicine have been attracting public attention. Since the low dose irradiation has limited human health effects, development of the high sensitivity system is required for biological and medical studies. To date, the most established methods for the biological estimation of radiation dose in the field of emergency medical care is chromosome analysis. Chromosome analysis, however, is technically very demanding. Moreover, analysis of a large number of cells is necessary to detect a small amount of abnormal chromosomes induced by low-dose radiation exposure. Therefore, the development of high sensitivity/throughput chromosome analysis is required to detect the effects of low dose radiation. We have established the PNA-FISH analysis, as a high-throughput chromosome analysis technique. Using this technique, we could detect the increase of abnormal chromosomes in peripheral blood lymphocytes after low dose irradiation by CT examination [1]. We noticed that the increase in chromosome aberrations due to low-dose radiation exposure vary among individuals [2]. The new biological dosimetry techniques may contribute to the management of radiological diagnosis based on the individual differences in radiation sensitivity. Recently, we also reported the possible association of acute toxicities of cancer chemoradiotherapy with the induction of chromosome aberrations [3]. The clinical application of these new biological dosimetry techniques will be discussed.

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Response to Fukushima and lessons learned (3) Nagasaki University

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The first dispatch of the radiation emergency medical assistance team from Nagasaki University landed at Fukushima city on March 14, 2011, 48h after the hydrogen explosion at Unit-1 of Fukushima Daiichi Nuclear Power Plant (FDNPP). This team consisted of five members with different specialties: Medicine, nursing, radiological technology, and protection. During a succession of explosion at Unit-3, 2 and 4, they were involved in various activities for six days, such as setting the base for radiological triage at the Fukushima Medical University (FMU) and considerations for administration of stable iodine. Especially, after the fallout of rain and snow containing radionuclides late in the afternoon on March 15, accurate radiation monitoring, appropriate radiological protection measures, and risk communications with health care workers became more crucial. The first team left FMU on March 19, however, the long-term support from Nagasaki continued. The effective dose of five members in Fukushima for six days ranged from 31 to 52μSv by external and from 20 to 54μSv by internal exposure.[1)]

The whole-body counter (WBC) examination for internal exposure dose evaluation was also began on March 15 in Nagasaki University. In 173 persons, mainly evacuees and first responders who stayed in the Fukushima prefecture between March 11 and April 10, 2011, ^{131}I, ^{134}Cs and ^{137}Cs were detected in more than 30% of them. Notably, higher detection rate and internal radioactivity were found in the first week after the accident. The maximum committed effective dose and thyroid equivalent dose was 1 mSv and 20 mSv, respectively.[2)] Although the body burden ^{131}I was only found in April, ^{134}Cs and ^{137}Cs remained detectable until November 2021.[3)]

After the FDNPP accident, fear of health risk due to radiation exposure was spread in entire population of Japan. This was partly attributable to the overflow of irresponsible radiation monitoring data via internet and social media networks, and inconsistency of health risk evaluation by radiation specialists. In fact, no exact monitoring data was available in FMU which were to be sent from the Emergency Response Center (ERC) because the emergency monitoring system of Japan did not work due to widespread destruction of monitoring stations. The only trustworthy way was to measure by oneself and share the results in members of the society of radiation safety and protection through the mailing lists. In this way, not a few radiation facilities belonging to university voluntarily contributed to emergency monitoring and communicated accurate information. As emergency monitoring is like a wheel of a cart as well as emergency medicine, education of radiation monitoring in emergency settings shall be effective in development of future human resource. In contrast, the inconsistency of evaluation on health risk of radiation by specialists was not unexpected, because the specialists are composed of miscellaneous scientists and technologists and their perception of risk varied widely.[4] To avoid any messy situations in future, the importance of radiation health risk education to students, especially medical and related schools, was emphasized after the FDNPP accident. The common points from these lessons learned indicates education in younger generation as one of the key factors to make radiation emergency responses effective and substantial. [5]

In Japan, we have still undergone radiological accidents and unnecessary personal exposure for several times since 2011. The same would be true in next 10 years. Continuous education and training are essential; however, those are not all. Creativity, imagination, and strong will to improve are required for all the people involved in radiation emergency preparedness.

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Overview of the SHAMISEN project

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Preparedness and response to nuclear accidents were led by experts and governments based on the recommendations of the ICRP (International Commission on Radiological Protection) and the IAEA (International Atomic Energy Agency). These recommendations were mainly focused on the minimising the somatic health effects of radiation exposure in humans. However, the experience from previous nuclear accidents shows that such accidents also had a major impact on the mental health of the populations affected, a finding not taken into account formally in the recommendations of the ICRP and IAEA for preparedness and response. The SHAMISEN (Nuclear Emergency Situations - Improvement of Medical And Health Surveillance) project therefore aimed to provide comprehensive recommendations for preparedness and response to nuclear and radiological accidents, based not only the direct somatic health effects of radiation but also the indirect health (including psychological), social and economic effects of such accidents and of the response and remediation actions taken to reduce exposure of the populations.

The SHAMISEN project reviewed the lessons learned from previous nuclear accidents, specifically those at the Three Mile Island, Chernobyl, and Fukushima nuclear power plants, in terms of evacuation, dosimetry, health surveillance, and epidemiological studies. This project also investigated ongoing nuclear accidents initiatives, including radiation protection methods, return policies, and training for human resources. This project was an international collaboration of 18 partners, including European countries, countries involved in the Chernobyl accident, and Japan.

The SHAMISEN project reported 28 recommendations in May 2017. This includes 7 general recommendations and 21 specific to the different phases of a nuclear accident: preparedness, emergency and recovery [1]. The recommendations were classified into 5 areas: evacuation, dosimetry, communication and training, epidemiological studies, and health surveillance, and cross-sectional recommendations (mainly related to ethics) were also produced. Evacuation was divided into two aspects (evacuation of residents and evacuation of medical facilities) with recommendations related to preparedness, evacuation such as temporary relocation and long-term evacuation, and return after lifting of evacuation. The recommendations related to dosimetry again focused on characterised by assessment doses methods the 3 different phases of a nuclear accident. Under the topic of communication and training, we recommended to have training in radiation protection for stakeholders in advance and interactive communication before, during and after the accident. The recommendations on health surveillance and on epidemiological studies included creation of core protocols in peace time to be tailored to the specific emergency, establishment of rosters of affected populations in the emergency phase and the importance of establishing, harmonising and linking appropriate databases, and of following ethical principles, in particular respecting the autonomy and dignity of affected persons and ensuring the protection of their personal data. Health surveillance, moreover, should be conducted to improve the health and well-being of affected populations and any specific health screening should be set-up only when it will do more good than harm.

Overall, these recommendations stress the importance of a participatory approach, engaging all appropriate stakeholders in communication, decisions, dosimetric monitoring and surveillance. Stakeholder engagement is essential to build trust in the response, compliance with the measures taken, reduce stress in affected populations and enable them to take control of their own lives. An infographics aimed at translating the recommendations of the SHAMISEN project for the general public has been prepared in 4 languages (Figure 1) [1], and the detailed recommendations (including the background and justification for each, the way they should be implemented and by whom) are available in the SHAMISEN recommendation booklet in English, French, Russian, and Japanese [1]. The SHAMISEN project was supported by the EURATOM (European Atomic Energy Community) programme of the European Commission in the framework of the OPERRA (Open Project for the European Radiation Research Area) project (FP7 grant agreement No. 604984).

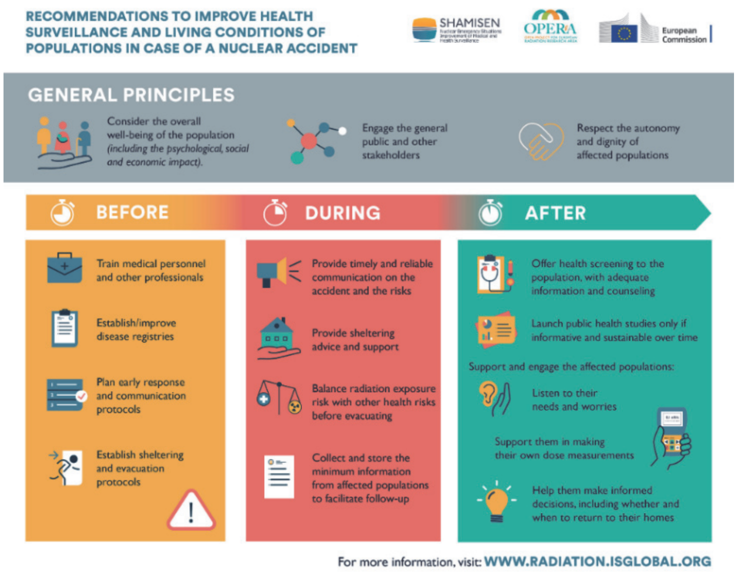

Figure 1 Information sheet of the SHAMISEN project for the general public [1]

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WHO global expert networks for strengthening global public health preparedness to radiation emergencies

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In line with the mandate of a global health leader, World Health Organization provides legal instruments, polices, norms and regulations to ensure member states compliance with the International Health Regulations (IHR) [1]. The 2005 revision of IHR ensured that health emergencies are addressed in a harmonious all-hazard fashion, including emergency preparedness and response (EPR) to radiological accidents and nuclear disasters. According to IHR (2005), countries are required to put in place all necessary components for a coordinated, timely, and efficient response to health emergencies. These requirements include cross-cutting elements that apply to all types of health emergencies, such as legislation, financing, cross-sector coordination, etc. as well as hazard specific requirements, which will vary depending on country's risk profile specifics.

Most countries using nuclear technologies for industrial, medical and research purposes, have put in place adequate tools, mechanisms and resources needed to address the EPR to radiological and nuclear emergencies, in line with international standards and requirements [2]. However, the vast majority of WHO's 196 member states do not use nuclear technologies and many of them still lack regulatory and radiation protection frameworks, and do not meet the requirements for radiation emergency EPR, including plans and protocols, resources, manpower, expertise, etc [3]. Moreover, non-nuclear and lesser developed states often may have other public health priorities to address in terms of types of health emergencies (e.g. outbreaks, natural disasters, or situations involving displaced populations and refugees). WHO supports its members states to ensure that for strengthening national preparedness and for response to health emergency the required technical support and assistance can be accessed through WHO and its global expert networks.

To support capacity building, research and cooperation in the field of medical response to radiation emergencies, WHO has set up two global networks: (i) Radiation Emergency Medical Preparedness and Assistance Network (REMPAN) established in 1987 [4] (ii); BioDoseNet, a network of biodosimetry laboratories to support response to radiation emergencies, established in 2008 [5].

The report will describe both of these networks and their activities towards strengthening global public health preparedness to radiological and nuclear emergencies.

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ARADOS: Asian Radiation Dosimetry Group

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The Asian Radiation Dosimetry Group (ARADOS) is a voluntary network on radiation dosimetry among Asian countries and have been active since 2015. The motivation for founding ARADOS is similar to that of European Radiation Dosimetry Group (EURADOS), namely to establish a platform for promoting the research and development and Asian cooperation in the field of the dosimetry of ionizing radiation. The main activity of ARADOS is an annual meeting (AM) to share information on the participants' recent research and discuss collaboration projects. Although ARADOS was started by organizations in China, the Republic of Korea and Japan, other Asian countries have been interested in the activities of ARADOS and the number of participants in the AMs has been increasing. Currently, about 20 institutes of Asian countries have participated in the past AMs.

The main missions of ARADOS were determined as follows: (1) to enhance and harmonize the radiation dosimetry capabilities in Asian countries; (2) to share information on research activities on radiation dosimetry in each country and (3) to prepare a joint response for radiation dosimetry services in the event of a large-scale radiological/nuclear (RN) accident. The last mission, which has not been addressed by EURADOS, came from the delegates' common understanding of the importance of radiation emergency preparedness for such an event after the 2011 Fukushima Daiichi nuclear power plant accident in Japan.

In order to conduct the above missions effectively, four working groups (WGs) were formed in ARADOS: internal dosimetry (WG1), external dosimetry (WG2), biological dosimetry (WG3) and computational dosimetry (WG4). Study items are proposed by members of each WG. To the present, two inter-laboratory comparison exercises were organized by WG1 (direct thyroid measurement) and WG3 (chromosome analysis). These exercises were found to be effective to harmonize and improve the relevant techniques of the participants; however, also revealed difficulties to implement collaborative studies. The next step for ARADOS is to further activate collaborations among the members and also to expand the network. In that sense, the role of the founder institutes of ARADOS will thus become more important in the next decade, and some issues encountered in the past should also be solved through discussion among ARADOS members. This presentation will give an outline of ARADOS and describe its future plans.

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ABSTRACTS

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