Kyoto University
Research Reactor Institute

International Symposium on

Environmental monitoring and dose estimation of residents after accident of TEPCO's Fukushima Daiichi Nuclear Power Stations

14 December 2012
The Shiran Hall, Kyoto University

KURRI Research Program for Scientific Basis of Nuclear Safety

Programme
&
Abstracts

Preface

In March 2011, a massive earthquake and the resulting tsunami struck the Tohoku area in Japan, causing serious damages to TEPCO's Fukushima Daiichi nuclear plant and the release of a significant quantity of radionuclides into the surrounding environment. This accident underlined the necessity of establishing new and comprehensive scientific research for promoting safety in nuclear technology. With this aim, the Kyoto University Research Reactor Institute (KURRI) developed a new research program called the "KUR Research Program for Scientific Basis of Nuclear Safety" from this year. In this program, we are planning to hold an annual series of international symposiums along with many other research activities.

The first in this series of symposiums, entitled "The International Symposium on Environmental Monitoring and Dose Estimation of Residents after Accident of TEPCO's Fukushima Daiichi Nuclear Power Station," deals with the radiological effect of the March 2011 accident in Fukushima Daiichi NPP on the public. The purpose of this symposium is to collate data on environmental radioactivity and radiation dose in residents, discuss and verify these data, and clarify the actual situation of environmental contamination and resultant radiation exposed to the residents. We believe that an accurate estimation of the radiation dose is quite essential for planning for the healthy life and mental contentment of the residents, and we hope that many researchers who are studying the radiological effects of the accident will join us for these purposes. The environmental monitoring data are important for the dose assessment for residents. However, the monitoring data in the early stage are not sufficient for dose assessment, particularly near the NPP site, because of the confusion and blackout caused by the earthquake. However, many researchers and organizations in Japan and other countries have independently carried out radiation monitoring. We believe that the publication and reviewing of these data is not only essential but our duty toward future generations.

Approximately 10 invited lectures and 50 scientific papers will be presented in the symposium. Almost all the presentations have been written as original scientific papers, peer reviewed by specialists of the relevant research fields, and included in the proceedings booklet. On behalf of all the participants of the symposium, I sincerely hope that this symposium and its proceedings will contribute to the faster recovery of people who have encountered damages from the accident and will promote further progress in the research on nuclear safety.

Hirotake Moriyama
Director**,** Kyoto University Research Reactor Institute
Chair of the organizing committee

Host Organization

Kyoto University Research Reactor Institute (KURRI)

Support organization

・Japan Radiation Research Society
・ Atomic Energy Society of Japan
・Japan Health Physics Society
・ Japan Society of Nuclear and Radiochemical

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Program

9:00-10:00 Registration、Poster Reception

10:00-10:05 **Opening remarks** Prof. Hirotake Moriyama, Director of KURRI

10:05-11:05 **Accident of Fukushima Daiichi Nuclear Power Plant -Sequences, FP released, Lessons learned–**
Speaker: Prof. Jun Sugimoto (Kyoto University)
Chair: Prof. Ken Nakajima (KURRI)

11:05-11:50 **IAEA safety standards for radiological protection of the public in post-accident situations**
Speaker: Dr.Gerhard Proehl (IAEA)
Chair: Hirofumi Tsukada (Fukushima University)

11:50-13:20 Lunch and poster session

13:20-14:20 **UNSCEARs assessment of radiation levels/effects from Fukushima accident**
Speaker: Prof. Wolfgang Weiss
（Chair for the fifty-eighth and fifty-ninth sessions of UNSCEAR）
Chair: Prof. Hirotake Moriyama (Director of KURRI)

14:20-15:05 **Radiation monitoring and mapping around the Fukushima site**
Speaker: Dr. Kimiaki Saito (JAEA)
Chair: Prof. Hiromi Yamazawa (Nagoya University)

15:05-15:35 Coffee break and poster session

15:35-15:50 **Implication of the isotopic ratios of radionuclides observed in the contaminated areas surrounding Fukushima-Daiichi NPP**
Speaker: Prof. Hajimu Yamana (KURRI)
Chair: Prof. Itsumasa Urabe (Fukuyama University)

15:50-16:10 **Development of a car-borne survey system, KURAMA**
Speaker: Prof. Minoru Tanigaki (KURRI)
Chair: Prof. Itsumasa Urabe (Fukuyama University)

16:10-16:40 **NIRS's activities for the reconstruction of early internal exposure in the TEPCO Fukushima Daiichi Nuclear Power Station accident**
Speaker: Dr. Osamu Kurihara (NIRS)
Chair: Prof. Nobuhiko Ban (Tokyo Healthcare University)

16:40-17:10 **Release of plutonium isotopes from the Fukushima Daiichi Nuclear Power Plant accident**
Speaker: Dr.Jian Zheng (NIRS)
Chair: Prof. Nobuhiko Ban (Tokyo Healthcare University)

17:20-17:50 **Discussion** Chair: Dr.Kazuo Sakai (NIRS)
Co-chair: Prof. Sentaro Takahashi (KURRI)

17:50-17:55 **Closing remarks** Prof. Hajimu Yamana (KURRI)

18:00-19:30 Reception

Poster sessions

Topics 1 Radiation survey in environment

1 Kazuhiro Akimoto
Wind-Driven Transport of Resuspended Radioactive Dust in Fukushima Prefecture

2 Takao Ebisawa, Seiichi Hirose, Etsuko Furuta, Keiji Kusama, Takeshi Iimoto
Environmental radiation status in Bunkyo-ku, Tokyo, after the TEPCO Fukushima Dai-ichi NPP Nuclear Disaster

3 Seiichi Someya, Hirofumi Fujii, Takeshi Iimoto
Environmental radiation status in Kashiwa City (Chiba Prefecture) after the TEPCO Fukushima Dai-ichi NPP Nuclear Disaster

4 Sadao Iiizumi, Hirofumi Fujii, Takeshi Iimoto
Environmental radiation status in Nagareyama City (Chiba Prefecture) after the TEPCO Fukushima Dai-ichi NPP Nuclear Disaster

5 Takeshi Iimoto, Norio Nogawa, Hiroshi Mitani, Masao Kamiko, Takahiko Suzuki
Environmental radiation status in The University of Tokyo after the TEPCO Fukushima Dai-ichi NPP Nuclear Disaster

6 Takumi Kubota, Tomoko Ohta
Radiation measurement in the East Japan with a GM-tube detector after the Fukushima nuclear accident

7 Takumi Kubota, Jun-ichi Hori, Nobuhiro Sato, Koichi Takamiya
Measurement of radiation dose by car in Fukushima from 19 to 22 March 2011

8 Nobuhito Ohte, Masashi Murakami, Kohei Iseda, Keitaro Tanoi, Nobuyoshi Ishii
Diffusion and transportation dynamics of ^{137}Cs deposited on the forested area in Fukushima after the nuclear power plant accident in March 2011

9 Shinji Sugihara, Noriyuki Momoshima, Akihiro Maekawa, Ryohei Ichikawa, Hidehisa Kawamura
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10 Kazuaki Yajima, Kazuki Iwaoka, So Kamada, Masashi Takada, Hiroyuki Tabe, Hidenori Yonehara, Sin-ya Hohara, Genichiro Wakabayashi, Hirokuni Yamanishi, Tetsuo Itoh, Michio Furukawa
Dose rate survey inside and outside three types of public buildings located approximately 40 km northwest from the Fukushima Daiichi Nuclear Power Stations

11 Kazuaki Yajima, Kazuki Iwaoka, Hiroshi Yasuda
Radiation survey along two trails in Mt. Fuji to investigate the influence of the radioactive contamination due to the Fukushima nuclear accident

12 Tomoaki Yamamoto, Kenzo Muroi, Sumito Maruyama, Takahisa Koike, Marina Matsuda, Kenichiro Katsumata
Environmental radiation doses due to the accident at the Fukushima Daiichi Nuclear Power Plants

13 Tetsuo Itoh , Michio Furukawa, Nobuyuki Sugiura, Hirokuni Yamanishi, Genichiro Wakabayashi Tetsuo Horiguchi, Shin-ya Hohara, Masayo Inagaki, Hiroshi Noma, Kiyoshi Kojima
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14 Masahiro Yoshida
Environmental radiation measurements immediately after the accident and dose evaluations by soil deposition

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1 Tatsuo Aono, Satoshi Igarashi, Yukari Ito, Jyota Kanda, Takashi Ishimaru
Radioactivity Survey in Marine Environment in the Pacific off Fukushima after Accident of TEPCO's Fukushima Daiichi Nuclear Power Station

2 Satoru Endo, Tsuyoshi Kajimoto, Kiyoshi Shizuma
Dose rate estimation for northern Miyagi Prefecture area at the early stage of Fukushima accident

3 Naoto Fujinami, Naoto Miyajima, Tetsuya Watanabe, Yoshihiro Tanabe, Hajime Nishiuchi
Influence of the Fukushima Daiichi Nuclear Power Plant Accident observed from results of environmental radiation monitoring in Kyoto

4 Ryuta Hazama, Akihito Matsushima
Comparison between fallout with rain from Fukushima, Chernobyl reactor accidents in Japan, and Hiroshima atomic bomb

5 Sin-ya Hohara, Masayo Inagaki, Hirokuni Yamanishi, Genichiro Wakabayashi, Wataru Sugiyama, Tetsuo Itoh
Survey of radioactive contamination distribution at Naka-Dori area, Tohoku Region, Japan

6 Nobuyoshi Ishii, Hiroyuki Koiso, Keiko Tagami, Shigeo Uchida
Elution of radiocesium from soil

7 Hidesuke Itadzu, Tetsuo Iguchi, Toshikazu Suzuki
Development of rapid self-absorption correction method used for HPGe detector

8 Tsuyoshi Kajimoto, Satoru Endo, Takeshi Naganuma, Kiyoshi Shizuma
Distribution of radioactive 137Cs and 134Cs in river water and bottom sand for major rivers at Minami-Souma City in Fukushima

9 Akihiro Maekawa, Noriyuki Momoshima, Shinji Sugihara, Toshiya Tamari
Determination of radiostrontium released from Fukushima Daiichi Nuclear Power Plant by extraction chromatography and liquid scintillation counting

10 N. Momoshima, S. Sugihara, R. Ichikawa, A. Maekawa, R. Ozawa, A. Nakama
Radioactivity in vegetation at Fukushima area contaminated with radionuclides released from TEPCO's Fukushima Daiichi Nuclear Power Stations

11 Kimihito Nakamura, Tetsuo Yasutaka
Characteristics of radiocesium concentration in stream water from a catchment in hilly and mountainous area at rainfall event

12 Tatsuya Shimazaki, Yoshioki Shiraishi, Kumiko Goto, Akihiro Kojima, Toru Urano, Seiji Okada
Specific activity and time dependence of radionuclides in soils affected by the accident of the Fukushima Dai-ichi nuclear power plant.

13 Kiyoshi Shizuma, Tsuyoshi Kajimoto, Satoru Endo
Early air sampling in Higashi-Hiroshima after the accident of the Fukushima daiichi nuclear power plant and subsequent sampling in Minami-Souma City during October 2011 to September 2012.

14 Keiko Tagami, Shigeo Uchida, Nobuyoshi Ishii, Jian Zheng
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15 Yoshito Watanabe, San'ei Ichikawa, Masahide Kubota, Masahiko Mizoguchi, Toshiyuki Takano,Yoshihisa Kubota, Shoichi Fuma, Satoshi Yoshida
Effects of radionuclide contamination on forest trees in 20 km exclusion zone around the Fukushima Daiichi Nuclear Power Plant

16 Masanobu Ishida, Ryota Nakagawa, Kohei Umetsu, Miyabi Sugimoto, Yuta Yamaguchi, Hideo Yamazaki
Geographical distribution of radioactive nuclides released from the Fukushima Daiichi Nuclear Power Station accident in the metropolitan area, Japan

17 Ryota Nakagawa, Masanobu Ishida, Daisuke Baba, Satomi Tanimoto, Yuichi Okamoto, Hideo Yamazaki
Spatial and temporal distribution of ^{134}Cs and ^{137}Cs derived from Fukushima Daiichi Nuclear Power Station in the sediment of Tokyo Bay, Japan

18 Tetsuo Yasutaka, Yoshishige Kawabe, Kimihito Nakamura, Akihiro Kurosawa, Takeshi Komai
Monitoring dissolved radioactive cesium in the Abukuma river water in Fukushima Prefecture

19 Wenting Bu, Jian Zheng, Tatsuo Aono, Keiko Tagami, Shigeo Uchida, Jing Zhang, Makio Honda, Masatoshi Yamada
Investigating plutonium contamination in marine sediments off Fukushima following the Fukushima Daiichi Nuclear Power Plant accident

Topics 3 Transfer model and/or parameters

1 Shigeto Fujimura, Takeshi Ohno, Yasuyuki Muramatsu, Hirofumi Tsukada, Kunio Yoshioka, Hiroshi Saito, Mutsuto Sato, Makoto Sato, Yuuki Sakuma
The use of rice seedlings to estimate the transfer of radiocaesium from soil to plants in Fukushima Prefecture

2 Jun Hirouchi, Tian Zhang, Yasuhiro Takamura, Shigekazu Hirao, Jun Moriizumi, Hiromi Yamazawa
Deduction of useful information from dose rate monitoring data in an emergency

3 Nao Ishikawa, Ayumi Ito, Teruyuki Umita
Possibility of removing radionuclides in landfill leachate using advanced wastewater treatment processes

4 Kayoko Iwata, Keiko Tagami, Shigeo Uchida
Estimation of ecological half-lives of radiocesium in marine biota at the offshore of Fukushima, Japan

5 Masanori Kimura, Kazumasa Shimada, Shogo Takahara, Fumihisa Nagase, Toshimitsu Homma
Estimation of accident source terms for the Fukushima Daiichi Nuclear Power Plant using RAMS/HYPACT

6 Hi-Rocky Ohtani , Xiaoguang Lu, Akira Tsuchiya, Shinichiro Yoshida, Takahiro Hirayama
Sedimentation diffusion of radioactive cesium in a paddy field.

7 Takashi Saito, Satoru Ohkoshi, Shigeto Fujimura, Koji Iwabuchi, Masaaki Saito, Tomoaki Nemoto, Mutsuto Sato, Makoto Sato, Kunio Yoshioka, Hirofumi Tsukada
Distribution of radiocesium on cultivated field and suppressive effect of radiocesium uptake in brown rice by potassium

8 Yasukazu Suzuki, Takasi Saito, Hirofumi Tsukada
Phytoremediation of radiocesium in different soil using cultivated plant

9 Guosheng Yang, Jian Zheng, Keiko Tagami, Shigeo Uchida
Direct determination of tellurium in soil and plant samples by sector-field inductively coupled plasma mass spectrometry for the study of soil-plant transfer of radioactive tellurium following the Fukushima Daiichi Nuclear Power Plant accident

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1 Shigekazu Hirao, Hironori Hibino, Takuya Nagae, Jun Moriizumi, Hiromi Yamazawa,
Source term estimation using environmental monitoring data

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1 Hikaru Amano, Yuji Ohta, Shigeru Banba, Takeshi Maeyama, Yoshihiro Ikeuchi, Takao Morimoto
Radiation doses from external and internal by inhalation of atmosphere and ingestion of drinking water contaminated by the Fukushima Daiichi Nuclear Power Plants Accident for the people living in the Chiba district**.**

2 Sakae Kinase, Masanori Kimura, Shinji Hato
Internal dosimetry for continuous chronic intake of caesium-137 in cedar pollen after the Fukushima Daiichi Nuclear Power Plant accident

3 Kouta Kurihara, Yuko Kinashi, Kenichi Okamoto, Eiko Kakihana, Tomohiro Miyake, Tomoyuki Takahashi, Keiko Fujiwara, Hiroshi Yashima, Hidehito Nakamura, Sentaro Takahashi
Internal radiation dose of KURRI volunteers working at evacuation shelters after TEPCO`s Fukushima Daiichi nuclear Power Plant accident

4 Shigeru Kumazawa
Distribution of doses to residents evacuated after Fukushima Nuclear Power Station accident

5 Yoshiyasu Nagakawa, Takashi Suzuki, Yasuhito Kinjo, Noboru Sakurai, Takahiro Sotodate, Hiroaki Ise

Measurement of radioactivity in air-borne dust and estimation of public dose in Tokyo after the Fukushima Daiichi Nuclear Power Plant Accident

6 Shogo Takahara, Masashi Iijima, Kazumasa Shimada, Masanori Kimura, Sakae KINASE, Toshimitsu HOMMA

Assessment of doses to the public in the contaminated areas resulting from the Fukushima Daiichi Nuclear Power Station accident

7 Hiroko Yoshida, Noriyasu Hirasawa, Ikuo Kobayashi

Initial substantial reduction in air dose rate of Cs-origin and personal dose to residents due to the Fukushima nuclear accident

Abstracts

Accident of Fukushima Daiichi Nuclear Power Plant -Sequences, FP released, Lessons learned–

Jun Sugimoto

Dep. of Nuclear Engineering, Graduate School of Engineering, Kyoto University

The nuclear accident occurred at the Fukushima Daiichi Nuclear Power Plant on March 11, 2011 was caused by the extremely massive earthquake, *Great East Japan Earthquake*, and gigantic tsunami rarely seen in the history and resulted in the severe accident that extended over multiple reactors simultaneously. Within an hour of the earthquake tsunami disabled the emergency diesel generators (EDGs), due to flooding of the switchgear, or flooding of the EDG rooms. This resulted in a station blackout event for Units 1 through 4. All station batteries were also lost at Units 1, 2, and 4 due to the tsunami. Although some details of the accident are still not known well, the sequences, causes and consequences of the accidents have been basically clarified by the efforts of several investigation committees. According to these investigations, no serious damage was identified for safety important components and systems before the attack of the tsunami. Loss of containment function of reactor pressure vessel (RPV) and containment vessel (CV) was primarily caused by the loss of isolation condenser (IC) for Unit 1, reactor core isolation cooling (RCIC) system for Unit 2, and RCIC and high pressure coolant injection (HPCI) systems for Unit 3, causing loss of core cooling for several or more hours. Especially, CV of Unit 2 is estimated to be breeched and most fission products (FPs) released to the environment will be from Unit 2. Hydrogen generated with zirconium-water reaction is estimated to be leaked through flanges, hatches or penetrations, and hydrogen explosion occurred at the highest floor of the reactor building of Unit 1, 3 and 4.

The fission products released to the environment were estimated by the severe accident analysis code, MELCOR, from inside the reactor core, and also by atmospheric dispersion simulations code, SPEEDI, by coupling with environmental monitoring data in the reverse estimation method from outside of the plant. The estimated release amount of I-131 is in the order of 120 – 160 PBq, and that of Cs-137 is in the order of 6 – 15 PBq for both estimations.

Lessons learned from the accident identified by investigation committees cover wide spectrum of insufficient measures, such as for earthquake and tsunami, station blackout, severe accident management, common cause accident at multiple unit site, education and training, chain of command at the accident, disaster prevention and safety regulation system. These lessons should be shared all over the world for the higher level of safety assurance of current reactors, and advanced reactors without the need of evacuation in principle should be developed for future.

IAEA safety standards for radiological protection of the public in post-accident situations

Gerhard Proehl

International Atomic Energy Agency Division of Transport, Environment and Waste Safety

Introduction

Radioactivity is a natural phenomenon and natural sources of radiation are features of the environment. Radiation and radioactive material may also be of human origin and have many beneficial applications, including uses in medicine, industry, agriculture and research as well as for nuclear power generation. The radiation risks to people and the environment from radionuclides released to, or existing in, the environment have to be assessed and controlled through the application of standards of safety.

Development of Safety Standards

The development of Safety Standards is a key activity of the IAEA. The Safety Standards provide a system of fundamental safety principles, safety requirements and guidance on its implementation. The key document for radiation protection is the recently published International Basis Safety Standards (BSS) (IAEA, 2011). Regarding exposures of the public, the BSS clearly distinguish between planned, existing and emergency exposure situations.

A planned exposure situation arises from the deliberate operation of a source or from the conduct of activities that result in, or could result in, exposure. Provision for protection and safety can be made before embarking on the activity concerned, the associated exposures and their likelihood of occurrence can thereby be restricted from the outset. An emergency exposure situation can arise as a result of an accident, a malicious act or another unexpected event; it requires prompt action in order to avoid or to reduce adverse consequences.

Usually, post-accident situations are considered as existing exposure situations, i.e. this being a situation that already exists when a decision has to be taken on the need for remedial actions for controlling exposures. In implementing remedial actions, the three radiation protection principles of “justification”, “optimization” and ”limitation” apply. Justification ensures that any facility and activity that gives rise to radiation risks must yield an overall benefit; i.e. it must do more good than harm. Optimization of protection and safety is to ensure that all exposures are controlled to levels that are as low as reasonably achievable, economic, societal and environmental factors being taken into account. For exposures in post-accident situations, BSS recommends reference levels for the effective dose to the representative person in the range of 1–20 mSv/year. The actual value chosen for the reference level will depend upon the prevailing circumstances for the exposures under consideration. The optimized protection strategies are intended to keep doses below the reference level. Reference levels are not limits, but all reasonable steps shall be taken to prevent doses remaining above the reference levels.

Assessment of exposures, optimization and environmental monitoring

For the implementation of these Safety Standards, the radiological assessment of exposures to the public is a fundamental element. Exposures arising from environmental radioactivity are the result of the complex interaction of radionuclide properties, environmental conditions, agricultural practices, living habits as well as the spatial distribution of radionuclides in the environment and their time-dependence. The paper will illustrate and discuss these dependencies exemplarily, taking into account the dose assessments for population groups affected by the Chernobyl accident (UNSCEAR, 2011) and by the Fukushima accident (WHO, 2012).

Optimization is a complex process that has to consider public perception of exposures, side-effects of remedial actions, the life style of the population in the affected areas. To highlight important input factors, remediation strategies implemented in areas by the Chernobyl accident are discussed with regard to the reduction of exposures, environmental conditions, costs and acceptance by the public.
For the remediation planning, the characterization of the contamination situation is a key element. The paper summarizes the most important radiological and radioecological quantities to ensure reliable dose assessments for potentially affected population groups. Monitoring approaches will be discussed that facilitate dose assessment, enable transparency and that help to achieve credibility of the results.

IAEA activities

Finally, the paper gives an overview on objectives and aims of main IAEA activities initiated after the Fukushima accident.
In order to provide support to monitoring, by mid-March 2011 the IAEA agreed to send teams of IAEA experts to support Japan in the fields of environmental monitoring. Four teams were active from 18 March – 18 April 2011 providing support to assist in the extensive monitoring programme setup by the Japanese authorities.

On the request of the Government of Japan, the IAEA organized a Mission to support the remediation of large contaminated areas off-site of the Fukushima Dai-ichi Nuclear Power Plant. The mission was organized in order to: (i) provide assistance related to Japan's plans to remediate large areas contaminated by the accident; (ii) discuss the identification of the appropriate set of remedial actions to reduce exposures to the public after contamination of inhabited and agricultural areas; (iii) review ongoing remediation strategies, plans and activities; and (iv) disseminate Japanese experience gained during the remediation activities to the international community.
Within the Action Plan on Nuclear Safety – set up by the IAEA – protection of people and the environment from ionizing radiation following a nuclear accident is an important point. Focus is given to facilitate the use of available information, expertise and techniques, assessment decontamination and remediation both on and off nuclear sites, including monitoring of radionuclides in the environment.

INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards; IAEA Safety Standards Series No. GSR Part 3 (Interim), IAEA, Vienna (2011). (http://www-pub.iaea.org/MTCD/Publications/PDF/p1531interim_web.pdf)
United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR): *Sources and effects of ionizing radiation, Volume II, Annex D:* Health effects due to radiation from the Chernobyl accident, United Nations, New York, 2011.
World Health Organization (WHO): Preliminary dose estimation from the nuclear accident after the 2011 Great East Japan Earthquake and tsunami, Geneva, 2012

UNSCEARs assessment of radiation levels/effects from Fukushima accident

Wolfgang Weiss

Chair of UNSCEAR

1. Aims and objective:

The aim of the assessment is to develop a comprehensive report with scientific annexes for the General Assembly, the scientific community and the public that evaluates information on the levels of radiation exposure due to the nuclear accident following the Great East-Japan earthquake and tsunami, and the associated effects and risks.

Specific objectives are to address the following questions:

Source term:

- What is the amount and nature of radioactive material released to the environment? How much to air? How much to sea?
- What radionuclides were released?
- What was the time profile? What events led to releases and the dispersion patterns?
- What are the uncertainties on the source term estimates?

Environmental dispersion and deposition:

- What was the dispersion pattern (air and sea)? What were the atmospheric concentrations of radionuclides with respect to time and location? What are the deposition patterns and modes? What radionuclides were deposited?
- Where are the hotspots and how can they be explained?
- How did the accident compare with those at Chernobyl, TMI, and Windscale?

Doses to members of the public:

- What effects due to radiation were observed to date, if any?
- Which are the key exposure pathways?
- What were the levels and time profiles of contamination in various foodstuffs (farmed and natural), and expectations of future development based on past experience?
- What were the protective actions taken, who was affected and when?
- What were the key organ and effective doses to adults, children, infants, and foetus for each prefecture (and some specific settlements/districts) and in other countries and/or regions of the world?
- What were the doses for the first year based on measurements?
- What is the effect on these dose estimates from the on-going remediation and protective measures?
- What doses are projected for beyond the first year?
- What are the uncertainties associated with the dose estimates?
- What were the populations most at risk?

Doses to occupationally exposed persons:

- What effects were observed to date, if any?
- What were the exposures of operational staff and emergency response personnel (levels, at what times)? Key organ and effective doses?
- What are the uncertainties associated with estimates of their doses?
- What were the working conditions that affected exposure?
- What groups of workers were most at risk? How can they be characterized?
- What medical monitoring was implemented in groups of workers most at risk?

Effects on the natural environment

- What effects were observed to date, if any?
- In what components of the natural terrestrial and aquatic environments and in which species are there significant accumulation of radionuclides?
- What in general terms were the doses and dose rates to plants and animals

- What are the uncertainties associated with those dose estimates?
- How do they compare with normal exposures?
- Did any plants or animals receive doses at levels that UNSCEAR would expect effects?

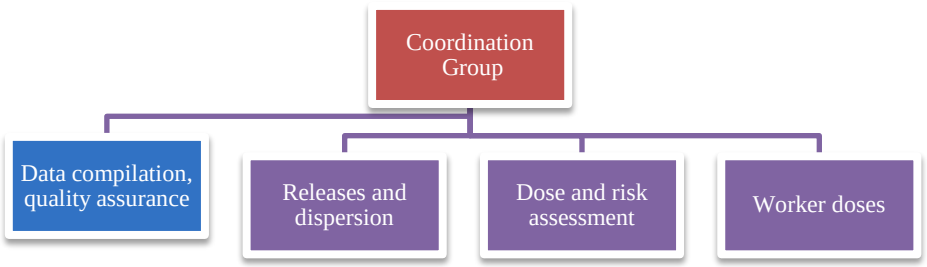
General aspects:

- How confident is UNSCEAR in the representativeness and quality of the information, and of their assessment?
- What is the likely impact on human health and environment? For what time period are effects expected and of what type?
- What are the unknowns and needs for future research or follow-up?

2. Timescale

The plan to assess the levels, effects and risks of exposure was decided on 58th session of UNSCEAR in May 2011. The final report/Report to Assembly and publication is due for the 60th session of UNSCEAR in May 2013.

3. Organization of Work



- Over 80 experts offered as contributions-in-kind
- Attendance at meetings and work – cost-free to UN
- Project Manager and Coordinating Lead Writer engaged
- Channels to Japanese experts
- Trust Fund contributions provide buffer
- International Organizations contributing: CTBTO, FAO, IAEA, WHO, WMO.

4. The preliminary findings of 59th session of UNSCEAR (May 2012) are included in the Report to the General Assembly (approved November 2012)

The key findings at this stage oft he assessment are:

- No radiation health effects observed among public or workers
- Six workers received doses above 250 mSv; 170 received doses above 100 mSv; thyroid doses being estimated
- Six workers died in first year – not due to radiation
- Thyroid monitoring of 1,080 children: maximum dose reported was 35 mSv
- Highest exposures of wildlife in marine environment.

5. Work in progress

- An all expert meeting will be convened end of November 2012 to discuss the status of the work and the way forward to complete the report. Key achievements so far are:
- The data management procedures have been established and shared with all experts
- Gross checks with date from NGOs are under way
- The source term analyses have been completed
- Atmospheric dispersion simulations have been performed in close co-operation with WMO
- The development oft he methodology and marine dispersion simulations are ongoing
- Inhalation and ingestion dose evaluations fort he public are ongoing
- Progress has been made with the analyses of non-human biota
- Date analyses für worker exposures are underway after all relevant data have been provided.
- A Health Implication Task (HIT) Group has been established to assess health risks to workers and the public.

The presentation will describe in detail the achievement made in December 2012 as well as the way forward toward completing the assessment.

Radiation monitoring and mapping around the Fukushima site

Kimiaki Saito

JAEA

Soon after the Fukushima Daiichi Nuclear Power Plant Accident, in order to assess the impact and take appropriate measures, accurate and precise information was necessary on contamination conditions around the Fukushima site. Though a large number of environmental monitoring was performed after the accident, the methods, locations, time, accuracy were diverse, and it was difficult to integrate the results and construct contamination maps. Thus, the Ministry of Education, Sports, Science and Technology (MEXT) commissioned JAEA to construct detailed contamination maps around the Fukushima site, and the first mapping project started. So far, three series of mapping projects have been implemented in collaboration with a number of organizations.

In the first project, the region up to 100 km from the Fukushima site and the rest of Fukushima prefecture were divided into about 22,000 small areas, and five soil samples were collected at one selected location in each area. By analyzing the collected soil samples, radionuclide deposition maps were constructed for Cs-137, Cs-134, I-131, Te-129m, Ag-110m, Pu-238, Pu-239+240, Sr-89, Sr-90. Further, maps on dose rates in air was constructed according to monitoring data at soil sampling locations and to car-borne survey data using the KURAMA systems developed at Kyoto University. From these maps, detailed contamination conditions around the site were clarified.

Accumulated effective doses for 50 years due to external exposures and inhalation due to re-suspension were evaluated from the observed radioactivity, and it was confirmed that radiocesium is most important among the observed radionuclides from a viewpoint of exposures in future. The doses from plutonium and strontium were found much smaller than other nuclides.

In the second and third campaigns, radionuclides deposited on ground were quantified utilizing in-situ measurements instead collecting soil samples; while, dose rate measurements were carried out using the same methods. Temporal change of contamination conditions was analyzed based on several different kinds of monitoring data. Both deposited-radionuclide activity and dose rates in air have certainly reduced in 14 month after the first campaign. Generally, car-borne survey data showed large dose-rate reduction as elapsed time. Further, decreasing tendency was found to be different according to land use: in urban and water areas, decreasing tendency was large; in ever-green forest it was small. In a comparison of air dose rates at 1 m height between measurements in June 2011 and August 2012, there were locations where dose rate reduction was much higher than other locations, which is considered due to decontamination.

In the projects, migration of radionuclides in various environmental conditions has been investigated by field studies, and the features have come to be clarified. In soil, most cesium existed in top 5 cm even in December 2011. In cedar forests, cesium existed both at canopies and litter layers in June 2011; while, in broad-leaved forests, cesium existed mostly at litter layers. Cesium has come down gradually by throughfalls in the forests; and the distribution of cesium in forests is changing slowly. Migration of cesium associated with suspended sediments in water was found to be important both in lands and in rivers. Cesium concentrations in air are not high, though they change according to conditions.

A data base was constructed, and all accumulated data have been recorded in the data base. The data are now open to the public by pictures and by numerical data through the web site of MEXT, so that various people can easily utilize the data. By analyzing the accumulated data, models to predict contamination conditions in future are now under developing to provide fundamental information for countermeasures from now on.

Implication of the isotopic ratios of radionuclides observed in the contaminated areas surrounding Fukushima-Daiichi NPP

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Enormous amount of analysis data have been reported for the radionuclide concentrations in the soil samples taken in the areas contaminated by the Fukushima-Daiichi NPP accident. Since the accident, the concentrations of ^{137}Cs, ^{134}Cs and ^{131}I have been sufficiently reported by enormous monitoring activities, and those of ^{90}Sr and alpha-nuclides have been reported even with limited frequency. The observed ratio of these nuclides, such as ^{137}Cs/^{134}Cs, ^{131}I/^{137}Cs, ^{90}Sr/^{137}Cs, as well as ^{238}Pu/$^{239+240}$Pu gives various implications about the origin and the progress of the contamination. The ratio ^{137}Cs/^{134}Cs, which generally represents the burn-up of the reactor core fuel, is expected to give information about the source-term of the release. The variation of the ratio between ^{90}Sr and Cs nuclides, which were observed in the limited period after the accident, is expected to give a hint on the different progress of the severe accident, as well as of the different history of the transport in the environment after the release. In particular, reported wide variety of the Sr/Cs ratio depending on the places along different direction from NPP deserves elaborate consideration.

In this paper, by using the fuel burn-up calculation results, the implication that are extractable from the observed isotopic ratios of radionuclides will be discussed. In addition, the possible application of the accumulated carborne monitoring data by KURAMA(Kyoto University Radiation Mapping System) for this purpose will be also discussed.

Keywords: Fukushima-Daiichi NPP accident, ^{137}Cs, ^{134}Cs, ^{90}Sr, Isotopic ratio, KURAMA

Development of a car-borne survey system, KURAMA

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We have developed a car-borne survey system named as KURAMA (Kyoto University RAdiation MApping system) and KURAMA-II for the establishment of air dose rate map in Fukushima and surrounding area as a response to the nuclear accident at TEPCO Fukushima Daiichi Nuclear Power Plant on March 11, 2011.

KURAMA is a γ-ray survey system with GPS and up-to-date network technologies developed for a primary use of car-borne surveys. An in-vehicle part of KURAMA consists of a commercial air dose rate survey meter, an interface box, a GPS unit, a PC, and a 3G mobile Wi-Fi router. The monitoring data tagged by GPS location data are simultaneously shared with remote servers over a cloud-based network, and then processed by servers for a real time plot on Google Earth and other various purposes. KURAMA has served for several measurement projects for establishing radiation dose maps by Fukushima prefectural government or by the Ministry of Education, Culture, Sports, Science and Technology, Japan (MEXT). Fukushima prefectural government now uses KURAMA for precise surveys in residential areas to find possible hot spots, which are to be authorized for evacuations after additional precise surveys. MEXT conducted car-borne surveys twice, one in June 2011 for Fukushima prefecture and the surrounding area, and the other in December 2011 for a wider region in Eastern Japan.

Based on successful applications of KURAMA for the establishment of air dose rate maps, KURAMA-II is developed for the continuous monitoring on public vehicles moving around in living areas, such as local buses and delivery trucks. NI CompactRIO is chosen as the platform of the in-vehicle part in KURAMA-II because of its compactness, ruggedness and the native support of LabVIEW. KURAMA-II achieves to obtain energy spectra of radiations by introducing C12137, a CsI detector series manufactured by Hamamatsu. The system was developed in less than 2 months, to dramatically improve the handling and ease-of-use, and achieve better ruggedness for long-hour invehicle logging purposes. Now KURAMA-II extends its applications to various purposes. A demonstration test using a local bus in Fukushima city has been in progress since Dec. 2011 and proves the ability of KURAMA-II to serve continuous monitoring for months. The capability of autonomous operation and the scalability of KURAMA-II allowed MEXT to complete a large scale car-borne survey in March 2012, in which one hundred KURAMA-II were deployed to municipalities in Eastern Japan and simultaneously operated. Furthermore, the applications to foot-borne and bikeborne surveys in playgrounds, rice fields and mountainous areas are about to be started.

This work was partly supported by “Japan recovery grant program”, National Instruments Japan Corporation.

Keywords
car-borne survey, air dose rate

NIRS's activities for the reconstruction of early internal exposure in the TEPCO Fukushima Daiichi Nuclear Power Station accident

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The TEPCO Fukushima Daiichi Nuclear Power Station accident triggered by the Great East Japan Earthquake Disaster of 2011 resulted in an enormous release of radioactive materials into the environment. It is thus indispensable to perform individual dose estimations of populations in affected areas. However, regarding internal exposure, it is difficult to estimate the resulting dose because of limited information available on the intake of each radionuclide via inhalation and ingestion, especially in the early stage of the accident where radioiodine existed as a main contributor to thyroid exposure of concern. To our knowledge, there are only about 1500 human thyroid measurement data obtained from this accident. An insufficient number of air sampling data also makes it difficult to assume a reliable intake scenario via inhalation that is expected to be dominant rather than ingestion in the present accident, unlike situations in the Chernobyl accident. National Institute of Radiological Sciences (NIRS) launched a project for the reconstruction of early internal exposure to the public this year and is now deploying activities for this project. The first NIRS symposium was held last June with the following three aims: (1) collecting human/environmental measurement data available for the reconstruction of the early internal dose, (2) validating the possibility of atmospheric dispersion simulations as a tool for the reconstruction and (3) discussing a strategy for the reconstruction among experts from Japan and overseas. Our current activities in the project will be presented in this symposium.

Keywords
Internal exposure, Radioiodine, Thyroid dose, reconstruction

Release of plutonium isotopes from the Fukushima Daiichi Nuclear Power plant accident

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The Fukushima Daiichi Nuclear Power Plant (FDNPP) accident has caused serious contamination of the environment from the atmospheric fallout and the direct discharges of highly radioactive liquid wastes. Besides the massive releases of highly volatile fission products, such as ^{127m}Te, ^{132}Te, ^{131}I, ^{133}Xe, ^{134}Cs, ^{136}Cs and ^{137}Cs, the possible release of non-volatile Pu isotopes attracted great public attention in the FDNPP accident because Pu isotopes present a large risk for internal radiation exposure via ingestions of contaminated agricultural crops, in particular for ^{241}Pu (a beta-emitter, $T_{1/2}$ = 14.4 years), with its decay, the ingrowth of ^{241}Am (alpha and gamma-emitter, $T_{1/2}$=432.7 years) will present a new radiation risk.

Plutonium is normally produced in reactor fuel as a mixture of isotopes. The predominant isotope, ^{239}Pu is produced by neutron capture in ^{238}U. If a fuel element containing ^{239}Pu is left in a reactor for any length of time further neutron capture can occur to yield higher isotopes like ^{240}Pu, ^{241}Pu and ^{242}Pu. In addition, small quantities of two other isotopes, ^{236}Pu and ^{238}Pu, are produced during the irradiation. To date, information on the release of Pu isotopes from the FDNPP accident in the environment is very limited.

Several studies on the determination of Pu isotopes in environmental samples, such as soil, litter, and aerosols, confirmed the release of Pu isotopes from the FDNPP accident. Recently, core inventory calculation results of Pu isotopes within the FDNPP reactors using ORIGEN model simulation have been reported. These studies suggested that the damaged reactors were the major contributor of Pu to the environment. However, the release of Pu from the spent fuel pools remains unknown. In this work, we summarize and analyze the published studies related to the release of Pu isotopes from the FDNPP accident. Our analysis will focus on: (1) distribution of Pu isotopes derived from the FDNPP accident in the environment; (2) Pu isotopic composition for source identification; (3) sources for Pu release in the FDNPP-damaged reactors or spent fuel pools; and (4) the amounts of Pu isotopes released from the FDNPP accident. The paper concludes with future research directions.

Keywords
Plutonium, Sources, isotopic composition, FDNPP

Poster session

1-1

Wind-Driven Transport of Resuspended Radioactive Dust in Fukushima Prefecture

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Winds are known to transport dust particles and/or aerosols with or without radioactive materials over a long distance. Here the data of air dose rates measured in Fukushima prefecture in 2011 after the accident at the Fukushima Dai-ichi nuclear power plant that took place in mid-March are analyzed to reveal their temporal as well as positional variations, considering the effects of wind in particular.

First, during late March when the governing radionucleides were iodine -131 and xenon-133 the wind effects turned out to be rather outstanding. For example, when daily dose rates in the city of Shirakawa located in southern central Fukushima prefecture are compared with local wind speeds during March 25th ~31st, it appears that increased wind speed resulted in reduced dose rate. Actually, the correlation coefficient between the dose rate and the local wind speed is negative almost every day. However, the wind speed is well correlated with local atmospheric temperature also. Thus, it is necessary to calculate partial correlation coefficients between the dose rates and the wind speed to remove the effects of the temperature. The partial correlation coefficients thus calculated for each day during March 25th~31st are respectively, －0.31, －0.18, 0.25, －0.34, 0.12, －0.49, －0.22, respectively. Namely, it is possible that strong winds had caused resuspension of deposited radio materials and carried some radioactive dust away from Shirakawa to eastward. Similar trend is observable during the same period elsewhere. However, at the village of Iitate locacted in north eastern Fukushima the partial correlation coefficients between the dose rates and the wind speed on each day are 0.74, 0.61. 0.44, 0.45, 0.62, －0.02, and －0.43, respectively. Therefore, at this place during the first five days it is likely that strong winds tended to deposit some radionucleids that were carried from eleswhere. It appears that there exists a general trend of radionucleids being carried from central Fukushima to the Pacific coast driven by seasonal westward winds.

After mid-June the dominant radionucleides responsible for most of the radiation were and still are cesium 134 and cesium 137. The data of air dose rates measured at 155 locations in the eastern Fukushima prefecture by the central and local governments during mainly the period of June through December in 2011 are investigated. It turns out that the mean dose rate in eastern half of Fukushima prefecture had declined at a rather swift pace with half-life of 1.4 years, showing the significance of weathering effects. Actually the mean reduction rate is twice as large as that due to nuclear decay of cesium. Owing to the strong weathering effects driven mainly by rain and wind, the reduction rate tends to strongly depend on the season; in fact, the mean reduction rate in the summer is twice as large as that in the fall.

The variation rates of air dose rates at some places during this period are higher than theoretical values or at some other places they become greater than unity. Hence, it is likely that extensive areas in Fukushima such as Iitate, Namie, Minami-Soma, and Iwaki etc. during this period at least were still being weakly contaminated via wind. Dose rates tended to increase particularly in the fall when approximately westward winds were dominant in consistency with the results of calculations of partial correlation coefficients. Meanwhile, near the Fukushima Daiichi Nuclear Power Plant located on the Pacific coast some increase of dose rates is observed during summer when eastward wind from the ocean became locally dominant. Some other pieces of supporting evidence of the wind-driven secondary contamination will be presented.

Keywords
radionucleides, wind, transport, dust, resuspend

1-2

Environmental radiation status in Bunkyo-ku, Tokyo, after the TEPCO Fukushima Dai-ichi NPP Nuclear Disaster

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Bunkyo-ku is located around the east part of the metropolitan of Tokyo, Japan. The distance from the TEPCO Fukushima Dai-ichi nuclear power plant is about 220 km, south. The population of the city is 201,079 as of August 1st, 2012, and its area is 11.31 km^2. The local government has officially been surveyed environmental radiation status after the disaster with responding to a lot of requests from its citizen. The radiation surveillance in this area has been technically guided by some radiation protection specialists. Main two targets on the surveillance items are; (1) the ambient radiation dose (μSv h^{-1}) at all the school yards, public parks and representative measurement points selected by the local government, and (2) the specific radioactivity (Bq kg^{-1}) on the school lunch. These data have been reported to the citizens timely through the city website in addition to twice a month in the public relations magazine of the local government. This presentation shows the background status and technical information of the related activities, and the estimated environmental radiation data.

The ambient radiation dose in the city has been surveyed since July of 2011. In the 1st season of the surveillance (from July to August of 2012) at the total number of 304 measurement points, the highest value of the ambient radiation dose was 0.22 μSv h^{-1} at the height of 1 meter from the ground, the lowest was 0.05μSv h^{-1}, and the average was around 0.09 μSv h^{-1}, whose values were including natural background dose rate detected by the survey-meters of energy compensation type. In the latest season, the data were 0.10 for the highest, 0.05 for the lowest and 0.07 μSv h^{-1} for the average value.

The specific radioactivity of drinking water has been monitored at the local purification plants since the accident. No water sample supplying to the city has been exceeding the national limitation values to control the intake dose. The specific radioactivity of school lunch has also been surveyed three times (in December of 2011, May of 2012 and July of 2012) by the local government. So far, 127 sets of school lunch in the city have been checked using a Ge spectroscopy system. The highest specific radioactivity of $^{134+137}Cs$ was detected as 2.5 Bq kg^{-1} in a set of school lunch and 15.4 Bq kg^{-1} of milk, which were shown in December of 2011.

Keywords
ambient radiation dose, specific radioactivity, Tokyo

1-3

Environmental radiation status in Kashiwa City (Chiba Prefecture) after the TEPCO Fukushima Dai-ichi NPP Nuclear Disaster

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Kashiwa city is located around the north-west part of Chiba prefecture in the metropolitan area of Tokyo, Japan. The distance from the TEPCO Fukushima Dai-ichi nuclear power plant is about 200 km, south. The population of the city is 404,252 as of April 1st, 2012, and its area is 114.9 km^2. The local government has officially been surveyed environmental radiation status after the disaster with responding to a lot of requests from its citizen. The radiation surveillance in this area has been technically guided by some radiation protection specialists. Main two targets on the surveillance items are; (1) the ambient radiation dose (μSv h^{-1}) at all the school yards, public parks and representative measuring points selected by the local government, and (2) the specific radioactivity (Bq kg^{-1}) of drinking water and local foodstuffs. These data have been reported timely in the city website in addition to twice a month in the public relations magazine of the local government. This presentation shows the background status and technical information of the related activities, and the estimated environmental radiation data.

The ambient radiation dose in the city has been surveyed since June of 2011. In the 1st season of the surveillance (from May to August of 2011) at the total number of about 210 points, the highest value of the ambient radiation dose was 0.65 micro Sv h^{-1} at the height of 1 meter from the ground, the lowest was 0.08μSv h^{-1} and the average was around 0.25μSv h^{-1}, whose values were including natural background dose rate detected by the survey-meters of energy compensation type. In the 4th season, the latest data around school yards were 0.30 for the highest, 0.04 for the lowest and 0.12μSv h^{-1} for the average value. The ambient dose at 41 of 61 school yards and 47 of 635 parks has been in greater or less reduced under the decontamination project by the local government. The net dose reduction rate without natural background dose has been ranged around between 80 and 30 % in the school yards and the parks. Decontamination activity around residential area has just started.

The specific radioactivity of drinking water and local foodstuffs has been surveyed since March of 2011 and July of 2011 respectively. So far, one sample of service water showed 110 Bq kg^{-1} of ^{131}I on March 23th of 2011, however, no water sample other than this has been shown exceeding the limits. About 800 samples of the local foodstuffs as of the end of August of 2012 have been checked using an NaI(Tl) scintillation spectroscopy system. The lower detection limit on this measurement system for $^{134+137}Cs$ was set as about 25 Bq kg^{-1}. An outdoor bamboo shoot sampled in the city on April 9th of 2012 showed 170 Bq kg^{-1} as the specific radioactivity of $^{134+137}Cs$. In addition, a crucian carp sampled in Teganuma-lake on June 23th of 2012 showed 241 Bq kg^{-1}. Specific radioactivity due to the disaster of all of the surveyed samples other than above these three samples has been below the limits.

Keywords
ambient radiation dose, specific radioactivity, Chiba

1-4

Environmental radiation status in Nagareyama City (ChibaPrefecture) after the TEPCO Fukushima Dai-ichi NPP Nuclear Disaster

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Nagareyama city is located around the north-west part of Chiba prefecture in the metropolitan area of Tokyo, Japan. The distance from the TEPCO Fukushima Dai-ichi nuclear power plant is about 200 km, south. The population of the city is 166,493 as of April 1st, 2012, and its area is 35.28 km^2. The local government has officially been surveyed environmental radiation status after the disaster with responding to a lot of requests from its citizen. The radiation surveillance in this area has been technically guided by some radiation protection specialists. Main two targets on the surveillance items are; (1) the ambient radiation dose (μSv h^{-1}) at all the school yards, public parks and representative measuring points selected by the local government, and (2) the specific radioactivity (Bq kg^{-1}) of drinking water and local foodstuffs. These data have been reported timely in the city website in addition to three times a month in the public relations magazine of the local government. This presentation shows the background status and technical information of the related activities, and the estimated environmental radiation data.

The ambient radiation dose in the city has been surveyed since June of 2011. In the 1st season of the surveillance (from May to September of 2011) at the total number of about 40 points, the highest value of the ambient radiation dose was 0.58 μSv h^{-1} at the height of 1 meter from the ground, the lowest was 0.17 μSv h^{-1} and the average was around 0.32 μSv $h^{-1,}$ whose values were including natural background dose rate detected by the survey-meters of energy compensation type. In the latest season, the data around school yards were 0.36 for the highest, 0.08 for the lowest and 0.17 μSv h^{-1} for the average value. The ambient dose at all of the 23 school yards and 57 of 275 parks has been in greater or less reduced under the decontamination project by the local government as of the end of August of 2012. The net dose reduction rate without natural background dose has been ranged around between 80 and 20 % in the school yards and the parks. Decontamination activity around residential area has just started.

The specific radioactivity of drinking water and local foodstuffs has been surveyed since March of 2011 and April of 2011, respectively. So far, one sample of service water showed 110 Bq kg^{-1} of ^{131}I on March 23th of 2011, however, no water sample other than this has been shown exceeding the limits. 205 samples (46 items) of the local foodstuffs have been checked using an NaI(Tl) scintillation spectroscopy system so far. A flat Japanese mushroom cultivated on Japanese oak logs sampled in the city on November 16th of 2011 showed the highest specific radioactivity as 831 Bq kg^{-1} of $^{134+137}Cs$. Specific radioactivity due to the disaster of all of the surveyed food stuffs, other than an outdoor bamboo shoot and above two samples of a water sample and a flat mushroom, has been below the limits for intake dose.

Keywords
ambient radiation dose, specific radioactivity, Chiba

1-5

Environmental radiation status in The University of Tokyo after the TEPCO Fukushima Dai-ichi NPP Nuclear Disaster

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The University of Tokyo

The University of Tokyo is located mainly in the metropolitan area of Tokyo, Japan. This university owns three main campuses; the Hongo-campus and the Komaba-campus are located around the middle-east of Tokyo prefecture and Kashiwa-campus is around the north-west of Chiba prefecture. The distance between the Fukushima Dai-ichi nuclear power plant and the three campuses is ranged about 200 to 250 km. The university organized a special corresponding team to survey the environmental radiation status inside the university's site immediately after the nuclear disaster. The team consists of about 20 members, mainly of the radiation protection specialists or technical experts on radiation measurement in the university. The purpose of this project is basically not for research, but for providing the real data on environmental radiation immediately after the accident both to the university members and to surrounding public, under the situation of lack of relating information.

Main two targets on the surveillance items are; (1) the ambient radiation dose (μSv h^{-1}) and (2) the specific radioactivity (Bq kg^{-1}) of soil around ground surface to show the contamination level. The ambient dose data had been reported every day in the web-site in addition to the portal-site magazine of the university, and soil contamination data were reported occasionally and timely. In addition, the daily variation of the specific activity on ^{131}I in urine sampled from a male university staff living in Tokyo had been also monitored. This presentation shows the background status and technical information of the related activities, and the estimated environmental radiation data.

Time variation of the ambient radiation dose rate had been officially surveyed since the morning on 15th March in 2011 at the representative points selected in the campus sites. In addition, area distribution maps on ambient dose rate in three campuses were also drawn. The first peak dose of 0.72 μSv h^{-1} was observed around at 2:30 pm on 15th May of 2011 in the Kashiwa-campus and the second of 0.80 μSv h^{-1} was also observed around at 11:00 am on 21th May of 2011 at the same place. The continuous surveillance ended on the end of March in 2012. At that time, the representative ambient dose rates of the campuses were around 0.11 μSv h^{-1} for Hongo, 0.23 for Kashiwa (at the height of one meter from the ground level) and 0.05 for Komaba (at the height of about 15 meters from the ground level), whose values were including natural background dose rate detected by the survey-meters of energy compensation type. Some parts in the Kashiwa-campus site have been decontaminated following the corresponding plan determined by the Kashiwa local government. The net dose reduction effect was estimated between about 80 and 50 %.

The specific radioactivity of soil around ground surface in three campuses has been surveyed using an NaI(Tl) scintillation spectroscopy system or a Ge spectroscopy system. For example, 0.2 to 0.35 kBq kg^{-1} of ^{131}I and 1.0 to 1.5 kBq kg^{-1} of $^{134+137}Cs$ were measured in the Kashiwa campus site as of the middle of April of 2011. On the daily variation of the specific activity on ^{131}I in urine, the highest concentration as 110 Bq L^{-1} was observed on 16th March of 2011 under the status of average urine discharge volume of 2.1 L day^{-1}.

Keywords
ambient radiation dose, specific radioactivity, Tokyo, Chiba

1-6

Radiation measurement in the East Japan with a GM-tube detector after the Fukushima nuclear accident

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A large amount of radioactive materials was released into the environment by the Fukushima Daiichi nuclear accident. The resulting effect on air dose rate and surface contamination with mainly radioactive iodine and cesium were measured with a GM-tube detector calibrated with a cesium-137 radioactive source. The calibrated values were obtained with a quadratic function of readout value of the detector from 0 to 5μSv/h. The measurements were demonstrated at the Ueno Park in Tokyo, along the Tohoku Expressway from Tochigi to Miyagi prefecture and in Namie town in Fukushima prefecture inside a car, and along the Tohoku Shinkansen (bullet train) Line from Tochigi to Fukushima prefecture during the period from May to August in 2011. The air dose rate at Nezu in the immediate vicinity of the Ueno Park and at a subway exhaust port of the Nezu subway station showed 0.17 - 0.23 μSv/h and 2.0 - 2.2 μSv/h, respectively. Although the detector showed the dose rates from 0.6 to 2.4 μSv/h for just near surface ground of the park, those decreased by a factor of two to three with removing the surface layer of several mm thickness. The dose rates for road gully around the park, however, showed up to 10μSv/h and higher radioactive contamination. The measurement of air dose rate in a car along the Tohoku expressway in May 2011 showed from 0.1 to 1.0μSv/h and the maximum value was obtained at Nihonmatsu city apart from damaged Fukushima Daiichi nuclear power plants by 55 km. The measurement of air dose rate in a train along the Tohoku Shinkansen Line, mostly parallel to the Tohoku expressway, in August 2011 showed from 0.1 to 0.3μSv/h and the maximum value was obtained at Koriyama city. Nihonmatsu and Koriyama is the similar distance from the nuclear power plants, which location would derive the similar variation of air dose rate. The measurement of air dose rate in a car and out of a car in Northwest Namie town apart from the nuclear power plants by about 25 km showed from 0.6 to 5.1μSv/h and from 54 to 175μSv/h, respectively.

Keywords
mobile radiation survey, GM-tube detector, air dose rate, surface contamination

1-7

Measurement of radiation dose by car in Fukushima from 19 to 22 March 2011

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The Fukushima nuclear accident required radiation screening and other support activities for refugees and residents from a very early stage. As one of these activities we traveled from Kumatori town (Osaka prefecture) to Fukushima city (north Fukushima prefecture) on 19 March 2011, moved to demonstrate the radiation screening from Fukushima city to Iwaki city (southeast Fukushima prefecture) on March 20 and to Shirakawa city (south Fukushima prefecture) on March 21 and 22, and traveled back to Kumatori. The variation of air dose rate in a cargo van was measured with a calibrated ion chamber detector during the travel in the Fukushima prefecture. The air dose rate in the Tohoku expressway basically increased toward north and its highest value of 6 μSv/h was obtained at Nihonmatsu city (next to south Fukushima city). The variation of air dose rate in the Banetsu expressway from Koriyama to Iwaki and in Iwaki city showed that the dose rate was around 5.5 μSv/h at Koriyama, dropped to less than 3μSv/h at the point apart from Koriyama by 15 km on the Banetsu expressway and stayed around 2 μSv/h from the point to Nakoso (sounth Iwaki city). The value of air dose rate in Shirakawa city and in Samegawa village between Iwaki and Shirakawa was around 2 μSv/h and 1 μSv/h, respectively. The low dose rate measured in the Banetsu expressway and in Samegawa village can derive low radioactive deposition in Abukuma highlands, which would be obstacle to ingress of radioactive plume. The value of air dose rate in Fukushima city on March 19 to 22 varied from 2 μSv/h to 9 μSv/h and depended on the time and place. The difference of air dose rate between places slightly decreased over time. The value of internal exposure from this activity of radiation screening was measured with a whole body counter to be negligible.

Keywords
mobile radiation survey, ion chamber detector, air dose rate

1-8

Diffusion and transportation dynamics of ^{137}Cs deposited on the forested area in Fukushima after the nuclear power plant accident in March 2011

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Introduction

The accident of the Fukushima Daiichi Nuclear Power Stations in March 2011 emitted 1.5×10^{17}Bq of ^{131}I, 1.2×10^{16}Bq of ^{137}Cs into the surrounding environment1). Those radioactive substances including ^{137}Cs deposited onto the forest areas of the northeastern region of the Honshu Island, Japan. Forests of these regions are especially important for the people not only for their forest production industry, but also for the source areas of drinking water and for the residential environments. The first phase of the governmental survey and investigations showed that major portion of deposited ^{137}Cs is trapped on the canopies and litter layers of soil surface. As ^{137}Cs is easily adsorbed onto clay minerals in soil, major portion of those can be transported by eroded soils and particulate organic matters through the hydrological pathways. Dissolved ^{137}Cs which is relatively free from soil adsorption can be taken up by microbes, algae and plants in soil and aquatic systems. Then, those ^{137}Cs are eventually introduced into soil insects and worms, fishes and birds through the food web.

In order to clarify the mechanisms of diffusion and export of ^{137}Cs from a forested ecosystem, we started to intensive field observations and samplings in the small catchment including forest and farmlands. The study is conducted at the Kami-Oguni River catchment in the northern part of Fukushima Prefecture. Major land uses of the catchment are forests and paddy fields. Expected two major pathways of ^{137}Cs diffusion and export are investigated; 1) transportation by water movement with dissolved and particulate or colloidal forms through the hydrological processes, 2) diffusion through the food web including both detritus food chains based upon plant litters and grazing food chains based upon living plant leaves in the forest ? stream ecological continuum.

Material and method

Study site: The study was conducted at the Kami-Oguni River catchment in the northern part of Fukushima Prefecture. Major land uses of the catchment are forests and paddy fields. The area is located about 50 km from the Fukushima Daiichi Nuclear Power Stations. Last year, rice produced in several paddies of this area had high ^{137}Cs concentration exceeding the controlling criteria. Based on this survey, the Japanese Government decided to prohibit to plant rice in 2012. The local Date city government conducts only the test plantation for investigation of the ^{137}Cs uptake by rice in several selected paddies. The small catchment was selected and implemented for the intensive observations and samplings.

Survey: As preliminary investigations, ^{137}Cs concentrations of stream waters at several sampling points are monitored. Also, ^{137}Cs concentrations of various organisms. Germanium detectors were used for measurements of ^{137}Cs concentrations of all samples at the University of Tokyo and the National Institute of Radiological Sciences.

Preliminary findings:

^{137}Cs export by hydrological processes: Major forms of discharged ^{137}Cs are suspended matters. Especially, particulate organic matters may be most important carrier of ^{137}Cs. High flow generated by a storm event accelerate the transportation of ^{137}Cs by water flows from forested catchments. Estimation of ^{137}Cs export from the forested catchments requires precise evaluation of the high flow acceleration during storm events.

^{137}Cs diffusion through the food web: Because the biggest pool of ^{137}Cs in the forested ecosystem may be litter and its detritus, the ^{137}Cs diffusion is quicker through the detritus food chain than the grazing food chain. Especially in aquatic systems, most predators have already taken ^{137}Cs. An urgent question is when and how the ^{137}Cs diffuses through the grazing food chains, and how quick that process will occur. To solve or predict these phenomena, mechanisms of ^{137}Cs releasing from litters and soil organic matter should be clarified.

Keywords

^{137}Cs deposition, forested ecosystem, hydrological process, food web

1-9

Distribution of gamma-ray dose rate in Fukushima Prefecture by a car borne survey method

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The Tohoku District-off the Pacific Ocean Earthquake and Tsunami caused by the earthquake attacked the Fukushima Dai-ichi Nuclear Power Plant of TEPCO on March 11, 2011. A nuclear accident followed at an unprecedented scale and huge amounts of radioactive material were released into the environment.

Distributions of gamma-ray dose rate in Fukushima prefecture were measured on April 18-21, June 20-22, October 18-21 (2011) and April 9-11, July 30- August 1st (2012) by a car borne survey method using a NaI(Tl) scintillation survey meter. The gamma-ray spectrometry by a NaI(Tl) detector was also done at several points. Dose rate near Fukushima Dai-ichi NPP and at iitate-mura, fukushima-city was high (1 ～ >30 μSv/h). The gamma-ray peak of I-131, Cs-134 and Cs-137 were mainly detected in gamma-ray spectrum on April 2011. For a year and a half has passed after the accident, dose rates have declined. Reduced percentage is different at each point. In particular, weathering effects reflects larger at high dose rate point.

Keywords
gamma-ray dose rate, car borne survey

1-10

Dose rate survey inside and outside three types of public buildings located approximately 40 km northwest from the Fukushima Daiichi Nuclear Power Stations

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For the purpose of contributing to the dose estimation of the external exposure of inhabitants living in radioactivity contaminated areas due to the Fukushima Daiichi Nuclear Power Station accident, we surveyed the reduction of the dose rate inside three types of public buildings compared to outside. The three buildings were A) a wooden construction district meeting place, B) a steel construction public hall, C) a reinforced concrete school building, and they are located approximately 40 km northwest from the Fukushima Daiichi Nuclear Power Stations. The measurement was carried out on January 19, 2012. The dose rates were measured with NaI (Tl) scintillation survey meters (Aloka TCS-171 and 172) at the height of 1m from the floor inside the buildings and from the ground outside. The measured dose rates around the buildings did not show uniform distribution. This is because the distribution of the radioactivity accumulated in environment causing the high dose rate in contaminated areas is not originally uniform affected by various factors such as topography, state of the ground, weather, and so on. The maximum dose rate outside the buildings were A) 3.2 μSv/h obtained on piled-up fallen leaves, B) 4.1 μSv/h obtained on raindrops, C) 6.4 μSv/h obtained on raindrops. These correspond to a rise in dose rate by so-called hotspot. In this work, we evaluated the dose rate reduction inside the building using the reduction factor, which was represented by the ratio of the dose rate inside the building to the dose rate outside the building. The reduction factors at the point of 1m inside from the wall, in fact from the glass window, were less than approximately a half for the three buildings. The reduction factors at the center of the room were 0.48 for A), 0.23 - 0.34 for B), and 0.10 - 0.14 for C). It was C) reinforced concrete school building that showed the most remarkable reduction effect among the three buildings.

Keywords
dose estimation, external exposure, dose rate, hotspot

1-11

Radiation survey along two trails in Mt. Fuji to investigate the influence of the radioactive contamination due to the Fukushima nuclear accident

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A large amount of radioactive materials was released in the environment due to the Fukushima Daiichi Nuclear Power Station accident caused consecutively by the Great East Japan Earthquake occurred on March 11, 2011. From 2007 we have started measurements of cosmic radiation at the top and foot of Mt. Fuji, which is 3,776 m above sea level and the highest mountain in Japan, with the support of a non-profit organization “Valid Utilization of Mt. Fuji Weather Station” to investigate the cosmic radiation environment at high altitude. Mt. Fuji is located approximately 300 km southwest from the Fukushima Daiichi Nuclear Power Stations. We performed the radiation survey along two main Mt. Fuji’s trails where are crowded with a lot of climbers in the summer because the spread of the radioactive contamination has become a concern just after the Fukushima nuclear accident.

The measurement was carried out from 4:30 to 18:30 on July 9, 2011. We climbed the Yoshida trail from the Kawaguchiko starting point of a mountain climb (2,300 m in altitude) to the Yoshida-Subashiri top (3,720 m in altitude) and descended the Subashiri trail from the Yoshida-Subashiri top to the Subashiri starting point of a climb (2,000 m in altitude) on foot while measuring gamma-ray dose rate and energy spectra. The dose rate at the height of 1 m from the ground was measured using a NaI (Tl) scintillation survey meter (Aloka, TCS-172B). The measured dose rates were within the range from 0.03 μSv/h to 0.05 μSv/h throughout our measuring trip. As a result, it was found that the dose rates of the two trails in Mt. Fuji were normal background level. We used a NaI (Tl) scintillation spectrometer (EMF Japan, EMF211) for gamma-ray energy spectra measurement. The gamma-ray spectra obtained under the sixth station both of the Yoshida and Subashiri trail (2,400 m in altitude) showed the peaks of two radioactive cesium isotopes (Cs-134 and Cs-137) and natural radioactive nuclides. It was confirmed that a radioactive plume released from the Fukushima Daiichi Nuclear Power Stations had arrived at the place of 2,400m above sea level of Mt. Fuji.

Keywords
radiation survey, radioactive contamination, dose rate, energy spectra, plume,

1-12

Environmental radiation doses due to the accident at the Fukushima Daiichi Nuclear Power Plants

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On March 11, 2011, an undersea megathrust earthquake caused a tsunami that inflicted serious damage to the Fukushima Daiichi Nuclear Power Plant (FDNPP). On March 12, 2011, we began measuring environmental radiation doses and identifying fission product radionuclides at the International University of Health and Welfare (IUHW). The purpose of this investigation is to estimate the external exposure dose of fission products from FDNPP. Measurements were performed from March 12 to August 31, 2011. A NaI(Tl) scintillation survey meter was used to measure the environmental radiation dose, and air dust samplers and a NaI(Tl) scintillation spectrum analyzer were used to identify radionuclides in the atmosphere and soil. Three lifestyles were considered to estimate external doses to students or office workers, to businesspersons, and to farmers or construction workers. Increasing doses were detected on March 15 around noon, and peaked on March 16. Post-peak, doses decreased exponentially and became stable after 2 months. Immediately after the accident, some fission product radionuclides were detected in atmosphere and soil samples. Approximately 1 month after the first analysis, almost no radionuclides were detected in the atmosphere, but radionuclide decay products were detected in the soil. External dose varied with supposed lifestyle; assuming that the abundance ratio of Cs-134 to Cs-137 was 1:1, the annual external doses for the considered lifestyles were 1.069 mSv for students or office workers, 1.672 mSv for businesspersons, and 2.044 mSv for farmers or construction workers. These doses are sufficiently small that most residents living near IUHW, including children, would not be affected. Further investigation of internal exposure is necessary to better estimate effective doses. External exposure to fission product radionuclides is within safe levels, and while further investigation of internal exposure factors such as milk, water, and mushrooms is still needed, it appears that radiation around IUHW does not pose a health hazard.

Keywords
radiation survey, radiation dose, external dose, Fukushima, fission product

1-13

Survey of environmental radiation in Kawamata-machi, Fukushima-ken

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Large amount of radioactive materials had released by the nuclear power plant accident at Fukushima Dai-ichi site. The level of radiation dose rate has been raised by the radioactive material on the ground. We measured the dose rates in Kawamata-machi, Fukushima-ken, Japan, which is located about 40 km from the power plant in north -west direction. We measured the Cs-137 concentration in soil samples by the Ge diode detector. The result shows more than 90 % of Cs-137 exists the depth from the surface to 10 mm. The soil of shallow depth was sieved to 6 series by particle size. The radioactivity of the parts less than 1 mm diameter account for more than 80 % of the total. The Cs-137 in soil was not solved by water.

Keywords
environment, soil, Cs-137, depth profile, grain diameter

1-14

Environmental radiation measurements immediately after the accident and dose evaluations by soil deposition

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In the Nuclear Safety Technology Center, we have measured the environmental radiation on voluntary basis after the accident in parallel with supporting activities to be based on the request of the government. In this paper, we report the results of major voluntary measurement (Immediately after the accident, after 2-3 weeks and one month). In particular, the radioactive plume that has passed through in the morning, on March 15 at Bunkyo-ku Tokyo, is reported that was peaked on 10:05 am. In addition, as the exposure evaluated from soil deposition based on these measurements, inhalation exposure of radioactive cesium has been rated as less than one-tenth in 10 years.

Keywords
MCNP5, RESRAD6.5

2-1

Radioactivity Survey in Marine Environment in the Pacific off Fukushima after Accident of TEPCO's Fukushima Daiichi Nuclear Power Station

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Monitoring and survey of radioactivity in seawater and organisms of marine environment in the Pacific off Fukushima are important to understand the dispersion of artificial radionuclide after accident of TEPCO's Fukushima Daiichi Nuclear Power Station (F1NPP). The activities of Cs-134+137 in seawater were observed over 10kBq/L around F1NPP in the end of March, 2011 and recently decreased gradually to 1~2 mBq/L, which are almost same level before this accident, without the close of F1NPP. On the other hand, the higher activities of these in sediments have been determined in the Pacific off Fukushima. It is important that the radioactivity in marine organisms, are not only fish and shellfish but also benthos as feed, have been monitored continuously, because it is well-known that marine organisms are accumulated and concentrated elements and radionuclide in the body. The activities of radionuclide in marine organisms, are plankton and benthos etc., off Fukushima are determined to make clear the variation of radioactivity and Concentration ratio (CR) in marine organisms. The observed artificial radionuclide as gamma emitter are not only Cs-134+137 but also Ag-110m in marine organisms. Almost organisms without benthos could not be observed Ag-110m after a year in accident. The variation of Cs-134+137 activity in organisms was classified two types, and showing tendency to gradually decrease and considerable variation. The calculated CRs were higher than these value in compare with IAEA-TRS-422 (2004). It is thought that CRs could be calculated when the concentrations in water and organisms are assumed in an equilibrium state. It is considered that rapid change of the radioactivity in seawater, resuspension of particles from sediment and food chain were led to high CRs after the accident.

Keywords
marine organisms, Cs-134+137, Ag-110m, Concentration ratio

2-2

Dose rate estimation for northern Miyagi Prefecture area at the early stage of Fukushima accident

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Due to Fukushima Daiichi Nuclear Power Plant (FDNPP) accident, Tohoku and northern Kanto area were widely contaminated. Many soil contamination surveys around Fukushima Prefecture and south Miyagi Prefecture area have been reported. However, there are few data for northern Miyagi Prefecture area. Moss sample taken from Tome City on 1 May 2011 was measured with a Ge detector. Radioactive nuclides of $^{129m, 129}$Te, ^{131}I, ^{134,136,137}Cs, ^{110m}Ag and ^{140}La are clearly identified in the moss sample and also ^{132}Te and ^{132}I appeared likely to be present in the spectrum, but were accompanied with large errors. The identified radionuclides are the same as those in Fukushima contaminated plants and soil by FDNPP accident. It was found that the radionuclide concentration in moss sample was originated from FDNPP accident. In order to estimate radiation dose rate in northern Miyagi Prefecture area, soil of 30 cm core sampling was performed at ten locations (Tome City, Kurihara City, Osaki City, Daiwa Town and Sendai City) on 2011.8.19. The soil cores were dried by oven at 120 degrees for overnight. The dried samples were sieved through a 2-mm mesh to remove pebbles and large pieces of organic content. Each soil sample (40 g) was packed into a polystyrene container (4.8 cmφ× 3 cm height) after homogenization in a polyethylene bag. Radioactive concentrations in soil sample were measured and obtained using a Ge detector. The minimum and maximum concentration of the sum of ^{134}Cs and ^{137}Cs in soil were obtained to be 2.76 and 35.2 kBq/m^2 for Michino-eki in Sanbongi Town and the Izu Pond in Kurihara City, respectively.

Radiation dose rate at early stage of the FDNPP accident in the northern Miyagi prefecture has been estimated using radionuclide concentrations in moss and soil samples. The estimated radiation dose rate at the time after radioactive deposition near the Izu Pond in Kurihara City have been estimated to be 1.8 μSv/h on 15 March 2011. Cumulative dose by radioactive deposition for one year from 15 March 2011 is estimated to be 1.2 mSv from radionuclide deposition at maximum in case of outdoor.

Keywords
Fukushima, dose, soil contamination, Miyagi

2-3

Influence of the Fukushima Daiichi Nuclear Power Plant Accident observed from results of environmental radiation monitoring in Kyoto

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We have been continuously observing absorbed dose rates in air at environmental radiation monitoring stations and have carried out analyses of radionuclides in various environmental samples such as deposited materials, soil, plants, and fishes, in order to examine the influence of nuclear power plants located in the adjoining Fukui Prefecture, and of global radioactive fallout. As a result, cesium-137, cesium-134 and iodine-131 were detected in some kinds of vegetables and fish collected in Kyoto Prefecture after the Fukushima Daiichi Nuclear Power Plant accident (FDNPPA), whose concentrations were much lower than 100 Bq/kg. In addition, silver-110m was detected in turban-shell. All concentrations of these four radionuclides are so low that public exposure from ingestion would be much lower than 1 mSv per year. The influence on Kyoto Prefecture from the FDNPPA appears to be less than 10 percent of that from the Chernobyl NPP accident (CNPPA), as indicated by our comparison of the deposited amount of Cs-137 and the concentration of Cs-137 in environmental samples caused by the FDNPPA with those caused by the CNPPA.

Keywords
radioactive cesium, radioactive fallout, soil, sea water, foods

2-4

Comparison between fallout with rain from Fukushima, Chernobyl reactor accidents in Japan, and Hiroshima atomic bomb

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The Fallout with rain from the Fukushima Reactor Accident has been monitored for about two months in Higashi-Hiroshima city, Hiroshima, Japan from March 19 to May 23, 2011. Gamma ray spectra measured by low background HPGe spectrometer show clear evidence of fission products ^{131}I, ^{137}Cs, and ^{134}Cs. The 131I was observed on March 27 and April 8, while ^{137}Cs and ^{134}Cs were observed on March 27, April 18, and April 22. The ^{131}I, ^{137}Cs, and ^{134}Cs activity concentrations in rainwater collected in Hiroshima reached 0.44 on April 8, 0.17 on April 18, and 0.15 Bq/L on April 18, 2011, respectively. These activity levels were compared with the results reported in the world, which were collected in the northern hemisphere. Several samples of rainwater collected in Chiba (Kashiwa) on March 21, April 11, and May 12, Tokyo (Nerima) on March 21 and April 11, Osaka (Hirano) on April 8, Nara (Kitakatsuragi) on April 9, and Fukushima (Fukushima) on April 19, were also measured by our spectrometer and the ratio of activities such as ^{131}I/^{137}Cs and ^{134}Cs/^{137}Cs were compared with the other measurements. Our measured results in Japan due to the Fukushima reactor accident were compared with that due to the Chernobyl reactor accident and the result in black rain caused by fallout of the Hiroshima Atomic Bomb.

Keywords
Radioactive fallout, Fukushima accident, Fission product, Gamma spectrometry

2-5

Survey of radioactive contamination distribution at Naka-Dori area, Tohoku Region, Japan

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Due to the Tohoku Region Pacific Coast Earthquake and the Tsunami after the earthquake, residual heat removal systems of Fukushima Daiichi Nuclear Power Station were down at 11th March 2011. The systems down caused temperature rise and melt down of the nuclear reactor cores. The heat rise of the reactor core had a causal influence on hydrogen explosions of the reactor building and release of radioactive materials to the general environment. The released radioactive materials moved into a large area of Tohoku and Kanto regions with winds, and fall down to the ground with rains and snows. Dose rates in Tohoku and Kanto regions increase after the fall out. The radioactive materials were fixed several objects, for example surface soils, pave materials, and so on, and position distribution of the dose rate has changed with movement of the radioactive objects.

Kinki University atomic Energy Research Institute (Kinki Univ. - AERI) started a survey of radioactive contaminations at 3 points of Naka-Dori area, Tohoku regions in early April 2011. The first survey point is Arakawa-Undo Park neighborhood, Fukushima city of Fukushima prefecture. The second point is Hayama Park neighborhood, Koriyama city of Fukushima prefecture, and the last point is Kuroiso Park neighborhood, Nasu-Shiobara city of Tochigi prefecture. 2 investigations have been run in this survey. One investigation is a position distribution measurement of dose rate in urban area. Kinki Univ. - AERI use a GPS-linked dose rate recorder, that is constructed with a GPS receiver, an NaI(Tl) survey meter, an ADC including microcomputer and a personal computer. The other investigation is identification of the radio isotopes those came from Fukushima Daiichi Nuclear Power Station and still remain in ground soils. Surface soils at Naka-Dori region, Tohoku area has been collected and measured with a high pure germanium counter at Kinki Univ. - AERI.

Some conditions of the radioactive contaminations became clear from the survey results. The first point is that dose rate distribution depends on the condition of the ground surface and alignments of constructions. The dose rate of where is under a construction was lower than where nothing exists on the upper side just after the fall out. Furthermore, the dose rate of non-paved area was higher than the dose rate of neighbor paved area. Though, relative dose rates' distributions changed after the rainy season of 2011. Dose rates at some part of non-paved area became lower than those of neighbor paved area, and the dose rates' difference at paved area has become clear. The dose rate at paved area depends on the paved material. The second point is that component ratio of the radioisotopes in surface soils at Naka-Dori region became clear. ^{95}Nb, ^{129}mTe, ^{129}Te, ^{132}Te, ^{131}I, ^{134}Cs, ^{136}Cs, ^{137}Cs were found from the soil samples collected at Fukushima city, Koriyama city and Nasu-Shiobara city in April 2011. Though, short half life isotopes decayed and almost can't be detected in early July 2011 except for ^{134}Cs and ^{137}Cs.

The third point is that specific activities of radio isotopes in the surface soils are decreasing faster than the physical half life of the radio isotopes. Current specific activities of ^{137}Cs in the surface soils are much less than the activities calculated with physical half life and the detected activities in April 2011.

Keywords
Dose rate, distribution, specific activity

2-6

Elution of radiocesium from soil

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A large amount of radiocesium (^{134}Cs and ^{137}Cs) was released into the environment by the Fukushima Nuclear Accident. These radionuclides have caused serious contamination onto the soil surface and have emitted gamma rays. Most of the people living in the contaminated areas concerned about radiation exposure resulting from the accident. Techniques to reduce radiation dose, therefore, has been desired. Some of local governments tried to remove the surface soil for the reduction of radiation dose, but this technique has problems that must be considered, such as huge cost, disposal of the contaminated soil, and the use of heavy machine. We have thought that the downward migration of radiocesium might be an effective technique, because this technique has the similar effect to deep plowing which inverts the surface soil to the deep soil. Shielding effects on radiation is expected by covering the contaminated surface soil with the non-contaminated deep soil. We studied elution of radiocesium from soil as a first step for the vertical migration of radiocesium into the soil profile. To elute radiocesium, various solutions such as water, potassium chloride, ammonium sulfate, Good's buffers, and treating water with ozone were used.

Based on the annual rainfall in Namie-machi where is located inside the evacuation zone, amount of water, equivalent to the rainfall of 7 months and of 17 months, was passed through the contaminated soil. Elution of radiocesium by water, however, was not observed. The contaminated soil which was soaked with water was bubbled with ozone gas for 30 min, but no elution was also observed. Strong oxidation power of ozone has no effects on the elution of radiocesium under our experimental conditions. Although we tried to elute radiocesium with Good's buffers such as MES (pH6.0) and HEPES (pH 7.5), these radionuclides in Good's buffers were under the detection limit. When the contaminated soil was soaked with 100 mM KCl and 100 mM $(NH_4)_2SO_4$, elution ratios were 3.9% and 15.4%, respectively. The elution ratios for the addition of KCl were constant for 13 weeks, but the ratios for $(NH_4)_2SO_4$ decreased with time. After 13 weeks from the addition of $(NH_4)_2SO_4$ the ratio was 11.7%. As one of the reasons for the decreasing ratio, it is considered that the concentration of ammonium ion decreased.

From these results, $(NH_4)_2SO_4$ is the most effective chemical agent for the elution of radiocesium. The downward migration distance and shielding effects by the use of $(NH_4)_2SO_4$ must be studied to establish practical techniques for reducing radiation dose to the people in the nest step.

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Keywords
Elution, radiocesium, ammonium sulfate

2-7

Development of rapid self-absorption correction method used for HPGe detector

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Quantitative analysis for food products and natural samples to determine the activity of each radionuclide is done by using high-purity germanium (HPGe) gamma-ray spectrometer system. An analysis procedure is based upon the guidelines established by the Nuclear Safety Division of Ministry of Education, Culture, Sports, Science and Technology in Japan (JP MEXT).

In case of gamma-ray spectrum analysis for large volume samples, re-entrant (marinelli) containers are commonly used. The effect of photon attenuation in large volume sample, so-called “self-absorption”, should be corrected in order to determine the activity. As for marinelli beakers, two accurate geometries are shown in the guideline for 700 milliliters and 2 liters in volume. In the document, the functions to obtain self-absorption coefficients for these specific shapes are also shown. Therefore, self-absorption correction has been carried out only for these two containers with practical medium.

However, in order to determine the activity in samples, those are filled in the containers, which are not described in the guideline, functions for self-absorption correction must be obtained by measuring at least two standard multinuclide volume sources which consist of different media or different linear attenuation coefficients.

In this work, we developed a method to obtain functions over a wide range of linear attenuation coefficient for self-absorption in various shapes of marinelli beakers using Monte Carlo simulation. This method was applied to a 1-liter marinelli beaker, which is widely used for quantitative analysis, but its self-absorption method is not established yet. As a result, validity of this method was shown by processing an analysis of natural sample filled in this container, that its activity is pre-verified.

Keywords
HPGe detector, self absorption, marinelli beaker, quantitative radioactive analysis, Monte Carlo simulation, peak efficiency

2-8

Distribution of radioactive 137Cs and 134Cs in river water and bottom sand for major rivers at Minami-Souma City in Fukushima

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A nuclear accident occurred on March 11, 2011 caused a catastrophic radioactive contamination in Fukushima. Minami-Souma City locates at 10 km-40 km to the north of the TEPCO's Fukushima Daiichi Nuclear Power Plant. The eastern sea coast area of the city was severely damaged by tsunami and west ern area of the city where Abukuma chain of mountains located were known to be highly contaminated areas. Most of rivers in Minami-Souma city has its origins at around highly contaminated areas. We have started environmental radioactive survey along four rivers and branches in Minami-Souma City since October 2011. Sampling points were four to six locations along one river. One-litter of water and bottom sands of about 300 g were collected at the same points for each river. Water sample of 1 L was dried up on a thin naflon sheet using hot-plate keeping temperature at 100℃. Then the sheet was folded to 10 mm dia.×30 mm length to measure gamma-rays with a well-type Ge detector. Sand samples were dried with an drying oven, then mixed well and about 50 g of sand was taken in a polypropylene container (U9: 50mm dia.×30 mm height) . Gamma-ray measurement was performed using a low-background coaxial Ge detector. Detection efficiencies for each sample size were determined by using a reference gamma-ray source.

The Cs concentration ($^{137}Cs+^{134}Cs$) were 10,000-20,000 Bq/kg in the bottom sand at upper reaches of the river, whereas the concentration at down reaches near the sea coast were about 200 Bq/kg. The Cs concentration in river water were about 0.8 Bq/L at upper reaches of the river and 0.3 Bq/L at down reaches, indicating the Cs concentration in water is quite low. It is necessary to follow how the contamination at the upstream of the river will move to the down stream area hereafter.

Keywords
Minami-Souma, river water, bottom sand, Cs concentration

2-9

Determination of radiostrontium released from Fukushima Daiichi Nuclear Power Plant by extraction chromatography and liquid scintillation counting

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Various kinds of radionuclides were released from Fukushima Daiichi Nuclear Power Plant (FDNPP) due to the accident occurred on March 2011. Sr-89 and Sr-90 are hazardous because they accumulate in bone. However, only a few data of radiostrontium in contaminated soil has been reported because of time consuming analytical steps for radiostrontium. We adopted extraction chromatography that utilizes crown ether as the extractant to simplify analysis of radiostrontium. The extraction chromatography is simpler and faster than classical precipitation methods. The purpose of this study is to establish the analysis of radiostrontium by extraction chromatography and apply to determination of radiostrontium in soil at Fukushima. Two soil samples were collected on April 18-20, 2011 at Namie town and Tomioka town located at 26 km north-west and 11 km south from FDNPP, respectively. The 0-1 cm soil layer was used for experiment. The soil samples were ashed, acid digested, and strontium was separated from interferences with an extraction chromatography resin (Sr resin, Eichrom Technologies). The isolation and purification of strontium from matrix components can be completed in 12 hours. After 2 weeks for ingrowth of Y-90, the measurement of beta-ray was conducted with a liquid scintillation counter for 1200 minutes. The concentration of Sr-90 was 57.4 Bq kg^{-1} and 10.1 Bq kg^{-1} for Namie town and Tomioka town, respectively. Sr-89 was not detected from both samples. When 2 g of soil was used, the chemical yield of strontium was about 70 % and the detection limit of Sr-90 was 2.7 Bq kg^{-1}. The extraction chromatography method was successfully applied to determination of radiostrontium in the contaminated soil.

Keywords
Radiostrontium, Soil, Sr resin

2-10

Radioactivity in vegetation at Fukushima area contaminated with radionuclides released from TEPCO's Fukushima Daiichi Nuclear Power Stations

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The Fukushima Daiichi nuclear power stations lost the reactor cooling functions following the earthquake on March 11, 2011 occurred at Pacific Ocean near Japan and the Tunami that attacked the east coast of Tohoku area, resulting to the release of radionuclides into the environment and a wide range contamination by radioactivity at Tohoku area, Japan. At the time of the deposition vegetations in this area were not well grown on the ground surface because of the end of winter, and we did not see any green vegetation on the ground surface on middle of April 2011 even one month after the accident except leaves of ever green trees. The radionuclides deposited on the ground surface would move down to deep layer and would be taken up by vegetation which comes out this spring. The fate of radionuclide deposited on the ground surface is crucial information to understand an impact of accident on ecosystem. We measured radionuclides supplied from the accident in vegetation with an imaging plate and Ge detector to understand soil-plant interaction in the ecosystem.

Pueraria lobata, Japanese name Kuzu, was collected on June 21, 2011 at Futaba town, Fukushima prefecture and collected on July 30-31 and August 1, 2012 at several points at Fukushima prefecture. On March, 2011 at the time of the accidents, the ground surface was not covered by green plants. However, on June 2011, Kuzu grown after the accidents showed considerable activity. ^{134}Cs, ^{137}Cs, ^{110m}Ag and ^{129m}Te-^{129}Te were identified by gamma spectrometry. The IP analysis of Kuzu leaves reveals that the contamination occurred internally and surface deposition. Obviously the radionuclides deposited on litter and soil surface have taken up through roots. The Kuzu grown in spring 2012 the deposition of radionuclides on leaf surface was not clearly identify due to low sensitivity of the IP, but Ge measurements suggest active root uptake. The radiocesium activity in vegetation showed weak correlation with radiation dose rate.

Keywords
vegetation, Kuzu, contamination, Imaging plate, Ge detector

2-11

Characteristics of radiocesium concentration in stream water from a catchment in hilly and mountainous area at rainfall event

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The terrestrial and aquatic systems have been contaminated by the radioactive ingredients since a nuclei accident at Fukushima Daiichi Nuclear Power Station. Monitoring the concentration of radiocesium in stream water from a catchment is important because it is used for paddy irrigation and domestic water, and the soil particles and organic matter in stream water deposit in the river, estuary, and ocean. Especially, it is predicted that the amount of radioactive cesium by runoff may increase at the intense rainfall event. The some regions of hilly and mountainous areas in Fukushima Prefecture are seriously contaminated and the cultivation in the large area of agricultural field has been abandoned since the accident.

We have observed the temporal changes in the amount of runoff and the concentration of radiocesium of stream water from a catchment in hilly and mountainous area in the northwest from the power plant. The catchment area is about 0.1 km2 and consisted of forest (90 %) and abandoned agricultural field (10%). Stream water at the end of a catchment was sampled roughly once a month and was automatically sampled at two hours interval from the time point when water level of the stream exceeded a certain level at the rainfall event. Concentrations of suspended solid (mg/L) were measured by filtering sampled water using membrane filters of 0.45 micrometer and the concentrations of radiocesium (134Cs and 137Cs) of the residue (Bq/kg) were measured using gamma-ray spectrometry with a Ge semiconductor detector. The concentrations of radioactive Cs absorbed to the residue in the water (Bq/L) were calculated. The concentrations of the filtrate (dissolved Cs) were below the detection limit (0.2Bq/L).

The concentration of radioactive Cs in the stream water at low-water stage was 0.2 ? 0.3Bq/L and the SS was 2 ? 7 mg/L in March and April, 2012. At the heavy rainfall events, we observed the changes in SS similar to stream water flow rate. The peak time of SS was roughly in accordance with one of water flow rate. The maximum of SS was 6894mg/L at the rainfall of 71.0mm (rainfall duration = 2.3hours) on July 23, 2012 (event 1) and 36000mg/L at the rainfall of 37.4mm (rainfall duration = 4.3hours) on September 4, 2012 (event 2). The radioactive Cs of SS was 20800Bq/kg at the beginning of rainfall runoff at the event 1, decreased to 400Bq/kg along with the increase of runoff and SS, and increased to 15100Bq/kg gradually along with the decrease of runoff and SS 33.4hours after the start of rainfall. At the event 2, the concentration of radioactive Cs of SS changed from 15300Bq/kg to 400Bq/kg and increased to 3300Bq/kg 4.7hours after the start of rainfall. The concentration of radioactive Cs absorbed to SS in water was 23Bq/L at the beginning of the rainfall runoff and decreased gradually to 0.3Bq/L at the event 1. This concentration at the event 2 decreased from 52Bq/L to 1.1Bq/L.

It is considered that the radioactive Cs of SS in stream water (Bq/kg) depends on the difference of suspended solid particle size composition induced by stream water flow rate. The amount of organic matter in stream water may also influence the radioactive Cs of suspended solid. The concentration of radioactive Cs of suspended solid is high at the beginning of the rainfall and after the rainfall event. We may have to pay attention to stream water with such suspended solids for irrigation and domestic water use for a prolonged period.

Keywords
stream water, radioactive Cs, suspended solid, rainfall runoff, catchment

2-12

Specific activity and time dependence of radionuclides in soils affected by the accident of the Fukushima Dai-ichi nuclear power plant.

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The Fukushima Dai-ichi Nuclear Power Plant (FDNPP) lost all electricity due to a huge tsunami after the Richter-scale magnitude 9 earthquake of March 11, 2011. The water circulation system was severely damaged, and the radionuclides were released to the environment, specially for days in the middle of March. The purpose of this study is to clear the specific activity and the time dependence of the radionuclides in soils at Fukushima prefecture and neighborhood area. We performed soil sampling for six times at several points within 60km from FDNPP and at Tokyo to January 30, 2012 from March 23, 2011. The concentration of ^{131}I, ^{134}Cs, ^{136}Cs, $^{13}_{7}$Cs and ^{139}mTe were obtained, but only trace amounts of ^{95}Nb, ^{110}mAg and ^{140}La were detected whitch were too low to provide accurate concentrations. The concentration of radioactivity on March 15, 2011 is 8234 kBq/m^2 for ^{131}I and 882 kBq/m^2 for ^{137}Cs at Fukaya, Iitate village. Some radionuclides, such as ^{103}Ru, and ^{106}Ru and ^{140}Ba, observed in the Chernobyl accident, were not measured in the soil samples. This is estimated that mainly noble gasses and volantile radionuclides were released from FDNPP. For the time dependence of ^{137}Cs concentration in soil, it was decreased approximately 10-15% in 10 months at Fukaya, Iitate village. However, at some sampling points, there was not a change at all.

Keywords
Fukushima Dai-ichi N, Cesium-137, specific activity, time dependence, Cesium-134

2-13

Early air sampling in Higashi-Hiroshima after the accident of the Fukushima daiichi nuclear power plant and subsequent sampling in Minami-Souma City during October 2011 to September 2012.

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After the accident of TEPCP's Fukushima Daiichi Nuclear Power Plant on March 11, 2011, we stared air sampling at Higashi-Hiroshima since March 20. The air sampling was performed with a high-volume air sampler of 500 l/min with a glass fiber filter for three hours in the morning and three hours in the afternoon. Radioactive ^{131}I was first observed on March 30, thereafter ^{137}Cs, ^{134}Cs, ^{136}Cs, ^{132}Te were also observed. The concentration in air showed a maximum on April 7 (^{137}Cs: $8 \times 10\text{-}3$Bq/m^3), 2012, and also April 18 (^{137}Cs: $1 \times 10\text{-}3$Bq/m^3). After April 30, no radionuclides originated to the accident were observed reflecting no release of radionuclides. Since ^{137}Cs and ^{134}Cs have long half life; 30 y and 2 y, respectively, all air filters were measured again during February-March 2012. The dust filter was folded to 10 mm dia. × 30 mm length for the measurement with the well-type Ge detector. As a result, it was found ^{137}Cs was already observed on March 26, 2011.

Air sampling was performed at Minami-Souma City, Fukushima since October, 2011 to September 2012. The purpose of this sampling was to investigate the release of radionuclides from the forest and fly up into the air from the ground by the wind in winter and the release with pollen in spring. The sampling was performed for 30 min with high volume air sampler. The results showed that the radioactive concentration of ^{137}Cs in air was $5 \times 10\text{-}4 \sim 2 \times 10\text{-}3$ Bq/m^3. This means that fly up or release of radioactivity from the forest by the wind or release with pollen were no occurred indicating radioactivities are strongly attached to leaves of trees or soils on the ground.

Keywords
early dust sampling, radionuclides, Hiroshima, fly up, Minami -Souma

2-14

Estimation of Tellurium-132 distribution in Fukushima prefecture

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Tellurium-132 (Te-132, half-life: 3.2 d) is one of the major contributors to the radiation dose from the Fukushima Daiichi Nuclear Power Plant (FDNPP) during the early stages of accident, that is, in March 2011. The Nuclear and Industrial Safety Agency (2011) estimated total amount of radionuclides discharged to the air from the FDNPP, and the most released radionuclide was non-reactive Xe-133 ($1.1x10^{19}$ Bq) followed by I-131 ($1.6x10^{17}$ Bq) and Te-132 ($8.8x10^{16}$ Bq). Indeed, high-volume air sampling results in March 2011 carried out by JAEA in Takasaki (2012) and KEK in Tsukuba (2012) showed that observed Te-132 activity was as high as that of I-131 in both institutes. However, there is far less available data for Te-132 in soil because of the nuclide's short half-life. Thus, its distribution has not yet been adequately described. The Ministry of Education, Culture, Sports, Science and Technology (MEXT) has reported Te-129m (half-life: 33.6 d) distribution in soils of Fukushima, but presents no data for Te-132 because the soil sampling (May-June 2011) was too late to detect it. In this study, therefore several reliable data sets were compiled to estimate Te-132 distribution in the soils of Fukushima Prefecture in March 2011.

The radionuclide activities were collected from published monitoring data reported at homepage of METI (http://radioactivity.mext.go.jp/ja/list/111/list-1.html, accessed 11 Sept. 2012) as well as research papers. For many available data, concentrations of radionuclides (I-131, Cs-134, Cs-137, Te-129m, Te-132, Cs-136 and La-140) in soil samples were reported in Bq/kg at the time of sampling. Using these data sets, comparison of Te-132 with Te-129m and I-131 were carried out; all the data were decay-corrected to 11 March 2012.When Te-132 and Te-129m were compared, high correlation was observed by Student's t-test with $R=0.99$ ($p<0.001$). No distance and direction dependences were also revealed. Thus Te-129m could be used to estimate Te-132. However, Te would be in the anionic forms ($HTeO_3^-$ or $HTeO_4^-$) in soil under oxic conditions; therefore, it was suspected that Te-129m might migrate with water to other places from its initial deposited sites and/or leach into deeper soil layers. Thus activity ratios between Te-129m and Cs-137 were analyzed with time, because radiocesium is one of the less mobile radionulcide in soil. The ratio was almost constant for the 2 month period considered indicating the relative immobility of Te-129m during the data collection period. The published Te-129m data in Bq/kg was converted into Bq/m2 using a conversion factor, and finally, Te-132 in soil (Bq/m2) was roughly calculated. Te-132 concentration was high in the north-west direction from FDNPP, a trend also seen with radiocesium; however, higher Te-132/Cs-137 was also observed to the south from the FDNPP. Thus the distributions of Te-132 and radiocesium were not the same.

Concentrations of Te-132 and I-131 were also compared and their correlation was also high ($R=0.91$, $p<0.001$). The results indicated that it would be also roughly possible to estimate Te-132 concentration using I-131 data.

The authors thank Dr. E. R. Landa (U.S. Geological Survey) for his valuable comments. This work was partially supported by the Agency for Natural Resources and Energy, the Ministry of Economy, Trade and Industry (METI), Japan.

Keywords
Tellurium-132, Distribution, Soil, Tellurium-129m, Iodine-131

2-15

Effects of radionuclide contamination on forest trees in 20 km exclusion zone around the Fukushima Daiichi Nuclear Power Plant

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During the Fukushima nuclear accident in March 2011, radionuclides released to the atmosphere contaminated the surrounding environment. The largest radioactive plumes from the power plant flew west to north-westward, where forest land is widely distributed. In the past nuclear accident in Chernobyl in 1986, radioactive plumes have contaminated the surrounding forest, which have caused massive radiation damage in forest trees. The damages became obvious by the first summer after the accident in the highly contaminated forest area, where have been called the Red Forest from the color of the dead tree stands. In this study, a preliminary survey was made in forest areas within the 20 km exclusion zone around the Fukushima Daiichi Nuclear Power Plant for the distribution of radionuclides and the radiation effects on trees during the first year after the accident. The collection of the tree samples was carried out for three native coniferous species, Japanese red pine, Japanese cedar and Japanese cypress at 3 sampling locations differing in distance and direction from the nuclear power plant during the period from November 2011 to March 2012 as part of a project by the Ministry of the Environment, Japan. The external gamma dose rate in each sampling location was measured at 1 m above the ground with NaI scintillation or ionization chamber type survey meter. Radioactive contamination in the samples was first analyzed nondestructively with an imaging plate. The separated and homogenized samples were further analyzed for radionuclides using a Ge semiconductor detector. One of the sampling locations situated in the highest contaminated area in approximately 3 km in the northwest direction from the power plant. Even in the area, no externally visible symptoms of radiation damages including yellowing, malformation and early withering of leaves were observed in trees, indicating massive radiation damage like the Red Forest did not occur in the forest after the Fukushima accident. The external gamma dose rate exceeded 50 μSv/h in the highest contaminated sampling location, and varied widely among the sampling locations. The levels of radionuclides, ^{134}Cs and ^{137}Cs, in the tree changed depending on the contamination level of the forest, approximately on external radiation dose rate. The radionuclides not only adhered to the surface of the old leaves, but also distributed in the new leaves, flowers, cones and seeds that developed during the spring to autumn after the accident. This indicates translocation of the radionuclides to newly developing tissues, which should have caused an additional internal exposure of meristematic and reproductive tissues. The exposed dose rate of trees in the highest contaminated forest was likely to be higher than a criteria dose rate of 4-40 μGy/h selected for pine trees by ICRP (2009), which raises the necessity of more detailed analyses of cytogenetic and reproductive damages in forest trees in the area.

Keywords
Environmental effect, Forest tree, Biological effects, Exclusion zone

2-16

Geographical distribution of radioactive nuclides released from the Fukushima Daiichi Nuclear Power Station accident in the metropolitan area, Japan

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The pollution and distribution of ^{134}Cs and ^{137}Cs released from the Fukushima Daiichi Nuclear Power Station accident in the metropolitan area and the eastern Japan district were investigated in order to reveal the behavior of the radionuclides in environmental ecosystem. The wide region of the eastern Japan was contaminated by radioactivity, after the hydrogen exploded in Fukushima Daiichi Nuclear Power Station. The radionuclides deposited in the Fukushima area by the rain fall on March 16, and the metropolitan area also contaminated on March 21, 2011. The many radionuclides which deposited in the ground absorbed on clay minerals in soil by ion exchange.

In this study, the concentrations of radionuclides, such as ^{131}I, ^{134}Cs and ^{137}Cs, in soil and biological samples collected in the metropolitan area and the eastern Japan were analyzed. Soil samples were collected in Fukushima City and the Imperial Palace of the central Tokyo. Fukushima City and the Imperial Palace are 60 km and 200 km distant from Fukushima Daiichi Nuclear Power Station. The radioactivity of ^{131}I (364 keV), ^{134}Cs (605 keV) and ^{137}Cs (662 keV) in soil and biological samples were determined byγray spectrometry using HPGe detector connected with 4096 channel MCA. Theγray spectrum was measured in energy regions from 20 to 800 keV. The detection efficiency of the detector and geometrical efficiency for the sample volume were corrected using NIST Environmental Radioactivity Standard SRM 4350B (River Sediment), SRM 4354 (Freshwater Lake Sediment), and SRM 4357 (a blend of ocean sediment collected off the coast of the Sellafield and Chesapeake Bay). The detection limits of ^{134}Cs and ^{137}Cs were estimated within 0.6 Bq/kg. The radioactivity of ^{131}I was corrected to the value on March 16, 2011.

In the soil sample collected from Fukushima City on March 18, 2011, ^{129}Te, ^{129m}Te, ^{132}Te, ^{131}I, ^{132}I, ^{134}Cs, ^{136}Cs, ^{137}Cs and ^{140}Ba were detected. The first data of radioactive contamination in the metropolitan area was measured in the soil collected from the outer garden of the Imperial Palace on April 10, 2011, and ^{131}I, ^{134}Cs and ^{137}Cs were found. Radioactive equilibrium fission products ^{95}Zr-^{95}Nb was detected in airborne dust collected from Higashiosaka City (The distance from Fukushima Daiichi Nuclear Power Station is about 600 km) on April 18, 2011. Trace amounts of ^{110m}Ag were also found in the shellfish samples. The concentrations of ^{134}Cs, ^{137}Cs and ^{131}I in the soil sediment collected from Fukushima City on March 18 were 11600, 14000, and 72800 Bq/kg. On the other hand, the concentrations of these nuclides in the soil sediment collected from the outer garden of Imperial Palace on April 10 were 800, 960, 1520 Bq/kg. The highest concentrations of ^{134}Cs, ^{137}Cs and ^{131}I in the soil sample collected in Tokyo were 2860, 3590, 30400 Bq/kg. Over 95% of these nuclides existed in the layer from surface to one cm depth. In Kashiwa City located in 20 km northeast of the Imperial Palace, the concentrations of ^{134}Cs, ^{137}Cs and ^{131}I in the gutter sludge soil collected on June 11 were 26200, 33700 and 101000 Bq/kg. It is considered that the high level contaminated hot spot was formed by moving the radionuclides in the environmental ecosystem.
Analytical results of biological samples are also reported.

Keywords
Fukushima Daiichi Nuclear Power Station, Radioactivity Pollution, Soil, Ecosystem, Food Chain

2-17

Spatial and temporal distribution of ^{134}Cs and ^{137}Cs derived from Fukushima Daiichi Nuclear Power Station in the sediment of Tokyo Bay, Japan

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The spatial and temporal distribution of ^{134}Cs and ^{137}Cs released from Fukushima Daiichi Nuclear Power Station in the sediment of Tokyo Bay were investigated. The metropolitan area and the Kanto district, Japan, received the radioactive pollution by the Fukushima Daiichi Nuclear Power Station accident. The radioactive nuclides such as ^{131}I, ^{134}Cs and ^{137}Cs in the atmosphere reached the ground with rainfall on March 21, 2011. The radioactive nuclides flow through the rivers from the watershed, and will be deposited on the sediment after flowing into Tokyo Bay. Therefore, the Tokyo Bay sediment may also receive the radioactive contamination. In this study, the spatial and temporal distribution of the radioactive cesium in the sediment of Tokyo Bay was revealed.

The sediment samples were collected between August 20, 2011 and April 3, 2012. The core samples were collected by the divers using the acrylic pipes of 10cm-inner diameter and 100cm-length. The surface sediments were collected by using an Ekman-Birge sampler. The samples were collected at 36 sites in a northern area in Tokyo Bay and 12 sites of the Edogawa River water system. The sediment samples were dried at 60 ° C to constant weight. The radioactivity of ^{134}Cs (605 keV) and ^{137}Cs (662 keV) was determined byγray spectrometry using HPGe detector connected with 4096 channel MCA. The detection efficiency of the detector and geometrical efficiency of the sample volume was corrected using NIST Environmental Radioactivity Standard SRM 4350B (River Sediment), SRM 4354 (Freshwater Lake Sediment), and SRM 4357 (a blend of ocean sediment collected off the coast of the Sellafield and Chesapeake Bay). The detection limit of ^{134}Cs and ^{137}Cs in the dry sediment samples was estimated within 0.6 Bq/kg.

The total radioactivities of ^{134}Cs and ^{137}Cs in the Tokyo Bay sediments were detected from 100 to 1000 Bq/kg in the estuary of Arakawa River, but the concentrations of the other sites were 100 Bq/kg or less. It was indicated that the radioactive cesium rapidly deposits following flow into the river mouth. The maximum concentration of radioactive cesium ($^{134+137}Cs$) was 2100 Bq/kg at 14-15 cm depth of the sediment in 200 m offshore from TDR, and its inventory was 120000 Bq/m^2. The radioactive cesium in the sediment seems to have strongly adsorbed on clay minerals by ion exchange. The vertical distribution of radioactive cesium showed that it invaded deeper than estimated from the accumulation rate of the sediment. It was estimated that the vertical distribution of radioactive cesium was affected by physical mixing of sediments by tidal current, flood, and bioturbation of benthos. The radioactive cesium adsorbed on ultrafine particle may also move by diffusion in interstitial water of the sediment.

Keywords
Fukushima Daiichi Nuclear Power Station, Radioactivity Pollution, Tokyo Bay, Sediment, Radioactive Cesium

2-18

Monitoring dissolved radioactive cesium in the Abukuma river water in Fukushima Prefecture

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Radioactive materials were released into the atmosphere and deposited over wide areas of farmland, forests, and cities in the Kanto district; elevated levels of ^{131}I, ^{134}Cs, and ^{137}Cs have been detected in these areas by the accident at the Tokyo Power Fukushima Daiichi Nuclear Power Plant accompanying the April 2011 earthquake in eastern Japan. Due to precipitation, radioactive Cs deposited on farmland, forests, and organic matter in the bark litter layer in the forest gradually leaches into water bodies such as mountain streams and rivers adsorbed onto particles or in a dissolved state. It is known that dissolved radioactive Cs can easily migrate to plants. Therefore, it is important to monitor its concentration in the Fukushima prefecture over time. In this research, we monitored the concentration of the dissolved radioactive Cs in Abukuma River using a conventional evaporative concentrate method. As a result of monitoring from September in 2012, it was estimated that the concentrations of dissolved radioactive Cs in main stream and brunches of Abukuma River were in the range 0.010 - 0.128Bq/L. be reported at poster session.

Keywords
Radioactive Cesium, River water

2-19

Investigating plutonium contamination in marine sediments off Fukushima following the Fukushima Daiichi Nuclear Power Plant accident

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On March 11, 2011, a catastrophic earthquake occurred in the northwest Pacific about 130 km off northeastern Japan, followed by a gigantic tsunami, caused serious damage of the electric system of the Fukushima Dai-ichi Nuclear Power Plant (FDNPP). As a result, the cooling system of nuclear reactors failed, resulting in hydrogen explosions in the reactors. In addition to the large amount of atmospheric releases caused by the hydrogen explosions and venting activities, the cooling of the reactors with fresh water and seawater, and the release of highly contaminated water from the damaged reactor buildings resulted in the direct discharges of radionuclides into the sea.

To make a quick assessment on the environmental impact of possible Pu contamination from the FDNPP accident, last year, we analyzed the activities of $^{239+240}$Pu and ^{241}Pu, and the isotopic compositions (^{240}Pu/^{239}Pu and ^{241}Pu/^{239}Pu atom ratios) in surface marine sediments 30 km off the Fukushima Prefecture coast collected in July-August, 2011. Both the activities of Pu isotopes and their atom ratios detected in the surface sediments were in the same levels of the baseline data established before the accident, indicating no immediate Pu contamination in the marine sediments off Fukushima coast.

In this work, we investigate the vertical distributions of Pu activities and Pu atom ratios (^{240}Pu/^{239}Pu and ^{241}Pu/^{239}Pu) in sediments collected in July-August, 2011 and in June, 2012, to obtain information on Pu inventory in the sediment column and temporal variation of Pu activity and isotopic composition, and understand the transport of Pu from seawater to sediment column and the sources of deposited in marine sediments before and after the Fukushima sediments. In addition, a comprehensive review on the Pu inventory in sediments in the Northwest Pacific and its marginal seas will be made to establish baseline data for accurate assessment of Pu contamination in the marine environment.

Keywords
Plutonium, marine sediment, SF-ICP-MS, FDNPP

3-1

The use of rice seedlings to estimate the transfer of radiocaesium from soil to plants in Fukushima Prefecture

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Large amounts of radionuclides were released into the environment as a consequence of the accident at Fukushima Daiichi Nuclear Power Plant that was caused by the earthquake and subsequent tsunami on May 11, 2011. Since two isotopes of radiocaesium (^{134}Cs and ^{137}Cs) have relatively long half-lives and have high biological availability, concentrations of radiocaesium in agricultural fields have been monitored during the 2011 and 2012 growing seasons. Agricultural production continues to be restricted in parts of Fukushima prefecture in order to avoid food contamination. A working estimate of the transfer of soil radiocaesium to crops in contaminated fields is necessary before agricultural production can be resumed in the restricted areas. Although the transfer of radiocaesium to crops from the soil is affected by many environmental factors such as the concentrations of radiocaesium and extractable potassium, and the clay content of the soil, the net effect that these factors and interactions is not clear. In addition, these environmental factors should be investigated independently for each field, a process that is both labor-intensive and time-consuming. The aim of this study was to develop a practical and simple method for the estimate of transfer of soil radiocaesium to crops. Rice seedlings were used to estimate the transfer of soil radiocaesium since rice seedlings are able to be cultivated under conditions of high plant-density and the amount of absorbed radiocaesium by rice seedlings can be relatively easily measured. To examine the hypothesis that radioocaesium concentrations in rice seedlings are reasonably similar to those observed in brown rice; the rice seedlings and the brown rice were cultivated under identical soil conditions. Seven different combinations of soil types, radiocaesium concentrations and extractable potassium concentrations were used. Rice seeds were seeded directly on the soil in small cups (250 cm^3) placed inside a phytotron and were germinated. Rice seedlings were cultivated for a week from the germination inside the phytotron and the concentrations of ^{137}Cs in rice seedlings above ground were determined. To produce brown rice, rice was cultivated either in a pot (1 / 5000 a Wagner pot, 4000 cm^3) placed in a glass house or in a paddy field in Fukushima prefecture for about five months. The concentration of ^{137}Cs in the rice seedlings ranged from 150 to 1900 Bq kg^{-1}, and brown rice ranged from 2 to 890 Bq kg^{-1}. The correlation between the measured concentration of ^{137}Cs in rice seedlings and the measured concentration in brown rice was significant, as determined by Spearman's rank correlation coefficient. This suggests that the use of rice seedlings in this experiment over a period of two weeks provides an effective proxy for the transfer of ^{137}Cs from soil to crops over a longer period of time. The two-week experimental time for the rice seedlings includes the time necessary for preparation, cultivation, post-sampling treatment as well as the measurement of ^{137}Cs concentrations.

Keywords
Rice, Cs -137, uptake, soil

3-2

Deduction of useful information from dose rate monitoring data in an emergency

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After the TEPCO's FDNPS accident in March, 2011, dose rate monitoring has been enhanced and many monitoring stations and posts have been deployed not only in the vicinity of the NPPs in Japan but also at distant locations to reinforce the monitoring capability for emergency situations. Although this increase in the number of dose rate monitoring points significantly improve the emergency preparedness, it still remains as a substantial weakness of the emergency monitoring that the dose rate is only an item out of many other monitoring items indispensable for emergency decision making. These items include concentrations and composition of radionuclides in air, soil and environmental media. The purpose of this study is to explore possibilities of deducing these data items from the dose rate monitoring data by using rigorous modeling approach on the relation between the dose rate and the concentrations. This approach was tested for the radon decay products deposition cases and was applied to the dose rate monitoring data from the FDNPS accident.

The fundamental part of the modeling approach consists of a gamma dose rate model that explicitly expresses the geometry of source distribution, attenuation and scattering of gamma rays in air, soil and building materials around a monitoring post. This model has been tested for the non-accidental cases to show that it can reasonably reproduce the background dose rate from the radioactivity in the natural environment and in the building materials. Application of the model to the cases with precipitation showed that the model can also evaluate the activity concentration of the radon decay products on the ground surface. It was also pointed out that, by applying this model to the radon decay products deposition cases, the surface run-off of deposited radionuclides can be analyzed.

The second part of the modeling approach is the use of an atmospheric dispersion model in the analyses of dose rate data measured in the vicinity of the accidental site. The dispersion model with a random-walk method was applied to evaluate the release rate of radionuclides from the dose rate data measured by TEPCO at the site boundary. Reasonable release rates of I-131 and Cs-137 were obtained for the maximum dose rate of 11.9 mSv/h. However, it is also pointed out by the sensitivity analysis that the release rate estimation is very sensitive to the parameters and the wind data used in the analysis such as radionuclide composition, wind direction/speed, release height and atmospheric stability, and hence that the estimated release rate has a very large uncertainty.

The last part of the approach is a mathematical representation of temporal trend in the measured dose rate. It was shown that the cloud-shine and ground-shine components were discernible by carefully reviewing dose rate trends. It is also pointed out that the fractions of these two components differed depending on the geometry of the source distribution and obstacles. Although the trend in the ground-shine components was found to potentially have information on radionuclide composition, it was difficult to evaluate the composition quantitatively singly from the dose rate trend. If the fractional inventory of radionuclides in the accidental reactor is available, the surface concentrations of nuclide groups can be inferred.

Keywords
gamma dose rate, radioactivity concentration, release rate, radon decay products

3-3

Possibility of removing radionuclides in landfill leachate using advanced wastewater treatment processes

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The nuclear accident at the Fukushima Daiichi Nuclear Power Plant that followed the Great East Japan Earthquake on March 11, 2011 resulted in the significant release of radionuclides to the environment. With time the part of the radionuclides has transferred to sewage sludge ash and waste ash. Japanese government has allowed those ashes in which radiocesium concentration is lower than 8000 Bq/kg to be disposed in a controlled landfill site. The leachate from the landfill site, which possibly contains radionuclides dissolved from the ash, is treated in a leachate treatment plant before it is discharged into receiving water. The leachate treatment system is a combination of several treatment steps to remove alkaline components, organic pollutants, suspended solids, heavy metals, and so on. However, the extent of removal of radionuclides in the leachate by each step is not clear. In this study, in place of radionuclides, stable element concentrations in the leachate and treated water at each treatment step were measured to estimate the possible extent of radionuclide removal from the leachate step-by-step. Sample collections were done in July 2012 at a leachate treatment plant in a controlled landfill site in Iwate Prefecture in which ash (e.g., sewage sludge ash and waste ash) known to be containing radionuclides is being buried. The treatment process steps consist of: alkali crystallization, aeration treatment, membrane separation, activated carbon adsorption, and adsorption using chelate resin and zeolite. Samples of the leachate and treated water were collected at each treatment step. Concentrations of stable elements (e.g., Cs, Sr) and major elements such as Ca and K in these samples were determined by inductively-coupled plasma atomic emission spectrometry and inductively-coupled plasma mass spectrometry. Additionally, water characteristics such as suspended solids and total carbon concentration were determined in each sample.

For Sr, its concentrations were 6.0 mg/L in the leachate, 0.07 mg/L in the sample collected after the alkali crystallization step, 0.34 mg/L in the sample collected after the aeration treatment step, 0.40 mg/L in the sample collected after the membrane separation process, and 0.52 mg/L in discharged water. The results indicated the alkali crystallization step was effective for Sr removal. For Cs, its concentrations were 2.8 μg/L in the leachate, 2.6 μg/L in the sample collected after the alkali crystallization step, 2.7 μg/L in the samples collected after the aeration treatment process, 2.9 μg/L in the samples collected after the membrane separation step, and 2.7 μg/L in the discharged water. The results indicated no treatment process, even adsorption using zeolite, was effective for the removal of Cs in the leachate from the landfill site. Further data for samples collected in September 2012 and relationships between element removal efficiency and water characteristics will be given in the presentation.

Acknowledgement: This work was partly supported by JSPS KAKENHI Grant Number 12014030.

Keywords
landfill leachate, stable isotopes, cesium, strontium

3-4

Estimation of ecological half-lives of radiocesium in marine biota at the offshore of Fukushima, Japan

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The TEPCO's Fukushima Daiichi Nuclear Power Plant (FDNPP) accident of March 11, 2011 was the result of a magnitude 9.0 earthquake and the resultant tsunami, which severely damaged several reactors. A large amount of radionuclides released from FDNPP into the environment. One and half years after the FDNPP accident, although it is considerably easier to estimate the internal exposure through inhalation from the concentration of the radioactive materials in the air, estimating the degree of exposure from ingestion is problematic due to the variety of human diets, the distinct levels of food contamination, and the indeterminate chemical dynamics of nuclides. Factors, such as ecological half-life (T_{eco}) estimated in organisms in selected biota, have a significant impact on dose by the ingestion pathway and the associated bioaccumulation. We focused on cesium-137 ($T_{1/2}$=30y) which was one of the major radionuclides released.

This paper aims to provide the field data of radiocesium concentrations in marine biota that are related to the FDNPP accident, and to compare and contrast the T_{eco} in nature and biological half-life (T_b) in the laboratory setting. The T_{eco} of ^{137}Cs in the oceanic community along the coastline of Fukushima was calculated based on food monitoring data. The selection of sampled fish species is based on the typical Japanese diet. The monitoring data is organized by the sampling areas: the southern (Iwaki-shi) and the northern parts (Shinchi-cho, Soma-shi, Minami Soma-shi) with respect to the FDNPP site. A total of 16 species were investigated: all species were collected in the southern part, as compared to 11 species in the northern part. Plotting the data on a logarithmic scale and getting an exponential trend line and a best-fit linear equation are required to calculate each T_{eco}.

The ^{137}Cs contamination in the southern and the northern was compared using the concentration estimated on the 100th day in each species. Higher 100th-day concentrations were observed in the south area, as compared to in the north area in all the common species. The range of the concentration ratios of the south to the north was from approximately 1.1 to 6.4. This result revealed that the concentration in the southern region was higher than that in the northern region, which was likely caused by a weak southward current along the coastline of Fukushima. Although the degree of contamination was different between the south and north, the calculated T_{eco} for each species was similar in the southern and northern regions. The range of T_{eco} ratio (south/north) was from 0.80 to 1.33. This result indicates that the concentration in the biota does not influence T_{eco} among the same species. Furthermore, T_{eco} obtained from the field data was compared to T_b of laboratory experiments. The result shows that seaweed and shellfish have T_{eco} that is similar to T_b obtained in laboratory experiments. On the other hand, demersal fish, which live near the bottom of the sea, such as flatfish, have longer T_{eco}, compared to T_b of laboratory experiments. It is conceivable that a reason for the longer T_{eco} of demersal fish obtained in the field may result from the leverage of the diet. However, it cannot be concluded due to the short-term field data and insufficient number of laboratory data. Thus, it is necessary to collect and analyze more data.

Keywords
radiocesium, marine environment, biota, ecological half-life, trophic level

3-5

Estimation of accident source terms for the Fukushima Daiichi Nuclear Power Plant using RAMS/HYPACT

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The source terms for the Fukushima accident were preliminarily estimated by the reverse calculation method which used the atmospheric dispersion and deposition model in RAMS/HYPACT. In the calculation, atmospheric and ground concentrations were obtained assuming the release rate of 1 Bq/h and then, the results were compared with monitoring data of soil samples and atmospheric dust samples. Furthermore, this study took into account dry and wet deposition processes of aerosols and iodine, and the decay of radionuclides.

Keywords
source terms, RAMS/HYPACT, iodine, dispersion, deposition

3-6

Sedimentation diffusion of radioactive cesium in a paddy field.

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The purpose of this research is to make the radioactive cesium deposited on a paddy field sediment to the depths. Radioactive cesium is made to sediment to the depths which the root of a rice does not reach by using chitosan. And it aims at reducing the absorptivity of radioactive cesium. A rice crop becomes possible in the paddy field of radioactive contamination, and radioactive cesium is not detected from the harvested rice.

The paddy field in Fukushima was made into the actual proof examination site, 40kg of macromolecule chitosan powder of 5% of the concentration per 1000 square meters was sprinkled, and soil improvement was performed. The depths soil of each paddy field was extracted and activity concentration was measured using the NaI scintillation detector.

In the paddy field which has not processed, most radioactive cesium was detected from the topsoil which is 0 - 5 cm. When radioactive cesium adhered to the clayey ground, sedimenting to the depths automatically also by osmosis of water stopped at topsoil few. In the paddy field which sprinkled chitosan, the relative value of radioactive cesium was 120.40% in 10 - 15 cm, 179.44% from topsoil at 5 - 10 cm. Even if it was the 25cm depths, 32.53% was shown, and the effect that chitosan carried out sedimentation diffusion of the radioactive cesium to the depths became clear. Although radioactive cesium had adhered to topsoil, the 30cm depths were reversed by tilling. If chitosan spraying is performed after tilling, radioactive cesium can be further sedimented to the depths rather than 30cm. By combining this work, it becomes possible to raise a sedimentation rate and to reduce a cesium absorptivity.

It was effective to have sprinkled chitosan, in order to make the radioactive cesium deposited on a paddy field sediment to the depths. Radioactive cesium is separated from the ground by using the shape of chelate, and it can sediment to the depths of a paddy field as water solubility. Radioactive cesium is diffused to the depths by combining tilling.

Keywords
Sedimentation diffus, Radioactive cesium, Macromolecule chitos

3-7

Distribution of radiocesium on cultivated field and suppressive effect of radiocesium uptake in brown rice by potassium

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Objective

After the accident by the Fukushima Daiichi Nuclear Power Plant of Tokyo electric power company (TEPCO), brown rices were produced, including the highly radiocesium from paddy fields in some areas of Fukushima Prefecture. For this reason, we examined the distribution of radiocesium on cultivated field and the suppressive effect on radiocesium uptake in brown rice by potassium in order to suppress the migration of radiocesium into brown rice.

Materials and Methods

1) Vertical and horizontal distribution of radiocesium in the cultivated field (Experiment 1)

Five samples of soil (at depths of 0-15 cm) were collected after cultivating on five fields horizontally using a stainless steel soil auger of 30 cm in length and 5cm in diameter. The inside of soil auger was lined with a transparent polyvinyl chloride tube for isolating soil samples immediately and protection against soil contamination. These samples were divided into three parts（0-5 cm, 5-10 cm, 10-15 cm) in order to investigate the vertical distribution of cultivated field. After being air-dried, the soils were crushed and sieved through a 2-mm mesh.

2) Relationship between concentration of radiocesium in brown rice and concentration of radiocesium in soil, exchangeable potassium content in the soil (Experiment 2)

The brown rices, after being harvested from five fields in Experimental 1, were dried 30° C. After threshing and pickpocket, these samples sieved through a 1.85-mm mesh. The concentrations of radiocesium were measured using a Ge semiconductor detector. Exchangeable potassium was determined using the semimicro Schollenberger method and an atomic absorption spectrophotometer.

Results and Discussion

1) Experiment1

The concentrations of radiocesium in soil in five fields of depths 0-5.0 cm, 5.0-10 cm, 10-15 cm were 5879 Bq/kg DW, 3223 Bq/kg DW, 1835 Bq/kg DW, respectively. The results showed that the vertical distribution was not uniform. Even though there was no difference in the vertical distribution of radioactive cesium after plowing in the same area of upland, in the paddy was observed concentration gradient. We supposed that a small fraction of particles such as clay adsorbed radiocesium emerged on top by puddling.

The concentration of radiocesium in soils in five fields of depths 0-5.0 cm after plowing were in the range of 2465-7823Bq/kg DW, showing apprpximately three-fold variations. The results showed that the horizontal distribution was not uniform. Therefore, we suggest that in order to accurately evaluate the radiocesium uptake by brown rice, it is necessary to use the measurements of radiocesium in soil around the root.

2) Experiment2

The concentrations of radiocesium in brown rice were in the range of 52-485 Bq/kg (convert 15% moisture). The relationship between concentration of radiocesium in brown rice and concentration of radiocesium in soils, were not showed a correlation. We found that there is not a variation in transfer factor (TF) even same field. On the other hand, the radiocesium concentrarion in brown rice showed a tendency to decrease by increase exchangeable potassium in soil. In addition, the radiocesium concentrarion in brown rice showed a tendency to decrease by top-dressing in potassium. From these results, we found that radiocesium in brown rices were little related the concentration of radiocesium in soils, depended on exchangeable potassium in soils. Therefore, we propose to increase the potassium fertilizer in order to suppress radiocesium uptake in paddy soil.

Keywords: Radiocesium, Brown rice, Potassium

3-8

Phytoremediation of radiocesium in different soil using cultivated plant

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Objective

After the Fukushima Dai-ichi Nuclear Power Plant accident, a huge amount of radionuclides released into the environment. Radiocesium, which is major radionuclide, was deposited on the soil. It well known that radiocesium adsorbed onto the soil and strongly bound to clay. Therefore, it is difficult to reduce the contamination level in the soil. We examine the possibility of decontamination by means of phytoremediation.

Material and methods

Four species of plants (sunflower, sorghum, amaranth, buckwheat) were sown to grow (cultivated) in three 1.6 m^2 (2.0 × 0.6 m) farming plots of Light-colored Andosol and Gray Lowland soil. The planting density was 625 plants 100 m^{-2} for sunflower, sorghum, amaranth. The density for the buckwheat was 18,000 plants per 100 m^{-2}. The amount of N and P_2O_5 (Excluding K_2O) applied was 6 kg per 100 m^{-2} for sunflower, sorghum, and was 1 kg per 100 m^{-2} for the amaranth and buckwheat. When the plants matured, they were removed and separated into the different parts of flower, leaf, stem, and root to make samples for analysis, except for sorghum (of which only the leaves, stems and roots were sampled).

The separated samples were rinsed in water, and dried at 80° C for 3 d. The dried samples were pulverized with cutter and filled in compressed into plastic vials (U-8). The soil sample in which the plants were cultivated were collected at the time of sowing, air-dried at room temperature 25° C for 10 d, and passed through a 2-mm mesh sieve. The soil samples were also compressed into the plastic vials. The radioactivity of the samples was measured by a germanium semiconductor detector with a multichannel analyzer, over a period of 3,000-48,000 seconds for the plant and 1,200 seconds for the soil samples.

Results and discussion

The highest yield among the plants was 2.9 kg dry wt m^{-2} in the sorghum cultivated in Gray Lowland soil, and the lowest was 0.57 kg dry wt m^{-2} in the buckwheat cultivated in the Light-colored Andosol. The concentration of ^{137}Cs in each plant was from 20.6 to 82.9 Bq kg^{-1} dry wt, which was 4.0 times differences between the amaranth cultivated in the Light-colored Andosol and the sorghum cultivated in Gray Lowland soil.

The total content of ^{137}Cs in the four plant biomass was 24.2-153.9 Bq m^{-2} cultivated in the Light-colored Andosol, and 19.7-83.9 Bq m^{-2} cultivated in the Gray Lowland soil. The removal percentage of ^{137}Cs, which was defined as the total content of ^{137}Cs in the plant biomass divided into that in the cultivated soil of 0-15 cm depth, was 0.013-0.100 % for the Light-colored Andosol and 0.008-0.039 % for the Gray Lowland soil. The plants showing the highest value cultivated in the Light-colored Andosol and Gray Lowland soil was the amaranth (0.10 %) and the sunflower (0.039 %), respectively. It indicates that the remove of radiocesium from the contaminated soil by means of the phytoremediation techniques is difficult.

Keywords
phytoremediation, soil, cultivated plant

3-9

Direct determination of tellurium in soil and plant samples by sector-field inductively coupled plasma mass spectrometry for the study of soil-plant transfer of radioactive tellurium following the Fukushima Daiichi Nuclear Power Plant accident

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The Fukushima Daiichi Nuclear Power Plant (FDNPP) accident caused release of large amounts of radionuclides, including Te-127m, Te-129m, Te-131 and Te-132, into the environment. Among the released Te isotopes, Te-127m has a half-life of 109 days, much longer than those of other Te isotopes. Therefore, the release of ^{127m}Te may have increased the internal radiation dose due to the crops uptake. The internal radiation dose estimation, however, was found to be difficult because of the lack of environmental transfer data for Te.

Stable Te, as an analogue, is considered to be useful and important for the estimation of soil-plant transfer of radioactive Te. Due to the low concentrations of Te in the environment, for example, 10-109 ng/g in Japanese soils and 18-33 ng/g in plants, the determination of Te in soils and plants has been a great analytical challenge. Although many analytical techniques, such as INAA, ICP-AES, HG-AFS, and quadruple ICP-MS have been developed for Te determination in environmental samples, in most case, tedious preconcentration and separation operations are inevitable because of the relatively high detection limit. These drawbacks made them unsuitable for the determination of Te in soil and plant samples to study the soil-plant transfer factor.

In this work, we report a sensitive and high sample throughput analytical method for direct determination of trace Te in soil and plant samples using a sector-field-ICP-MS combined with a high efficiency sample introduction system (APEX-Q). Efforts were made to improve the sensitivity for Te analysis. We investigated: (1) the addition of ethanol to increase Te ionization in the plasma, and reduce the interferences of Xe-128 and Xe-130 on Te-128 and Te-130 analysis; and (2) increase the ICP-MS resolution from low mode to medium mode to eliminate the polyatomic interferences for Te-125 and Te-126 analysis. We also optimized sample digestion methods using *aqua regia* and mixture acids (HNO_3-HF-$HClO_4$). The developed analytical method is characterized by a very low detection limit at sub-ppb level in soil and plant samples, and has been applied for the study of soil-plant transfer to accumulate transfer factor data in Japan.

Keywords
Tellurium, Analytical method, SF-ICP-MS, soil-plant, transfer factor

4-1

Source term estimation using environmental monitoring data

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The purpose of this study is to estimate atmospheric release rates of the radionuclides discharged from FDNPS by using environmental monitoring data and an atmospheric dispersion model and to investigate the uncertainty of the estimated release rates. Environmental monitoring in emergency has played an important role to estimate source term inversely as well as to assess internal and external dose. Inverse source term estimations have been carried out by several researchers (e.g. Chino *et al.* 2011, Stohl *et al.* 2012, Terada *et al.* 2012, Hirao *et al.* 2012), after the accident. All studies indicated similar temporal variations in the atmospheric release rate of radionuclides despite of the use of different monitoring data and atmospheric dispersion models. According to these studies, the release started in the morning of 12 March 2011, the largest release occurred on 15 March and during other periods the releases were one to two orders of magnitude smaller than that on 15 March. Although this similarity implies the reliability of the release rate estimated by inverse methods, the uncertainty in the estimated release rate has not been discussed well. Since the main source of the uncertainty is errors in the modeling of deposition processes for regional scale model calculations, we focused on the analysis of the influence of these errors on release rate estimation.

Release rates of I-131 and Cs-137 in March 2011 were estimated by comparing the calculated deposition rates with an atmospheric dispersion model and the measured ones in regional area. The deposition rates used in this study were the daily data sampled at Chiba, Gunma, Ibaraki, Kanagawa, Tochigi, Tokyo, Saitama and Yamagata with a 24-hour sampling time from 18 March. A Lagrangian particle random-walk model coupled with the atmospheric meteorological model MM5 was used to calculate dispersion and deposition of radionuclides in plume. The dry and wet depositions were simply parameterized by a deposition velocity and a scavenging coefficient, respectively. The model domain was a 600 km square and 6 km depth above the ground in the vertical direction to cover most of the Tohoku and Kanto regions.

The release rates of I-131 and Cs-137 were estimated to be in the range of $0.6-4 \times 10^2$ TBq h^{-1} for I-131 and $0.3-5 \times 10^1$ TBq h^{-1} for Cs-137 for the period of 20−30 March. The temporal change in the estimated release rates were similar to that reported by others. It was pointed out that, by the sensitivity analysis to deposition parameters, the estimated release rates varied by a factor of about 10 when the scavenging coefficient varied by a factor of three. The sensitivity to the deposition velocity was smaller than that to the scavenging coefficient. In addition, the ratio of the estimated release rate of I-131 to that of Cs-137 was obtained to be about 10 on 20−21 March and about 80 on 22 March that was the maximum value. The increase in the ratio similar to our result was obtained in the ratio of measured air concentrations near FDNPS. According to the sensitivity analysis, the increases in the ratio of the estimated release rate by the different deposition parameters were also obtained during 21−22 March. It implied that the ratio of I-131 to Cs-137 was large in the time when the nuclides were released.

The release rate estimated by the inverse method still has a large uncertainty if the radioactive plume passed through rainfall areas. The uncertainty in the estimated release rates affected by the plume transported in rainfall areas will be further discussed.

Keywords
release rate estimation, deposition rate, atmospheric dispersion model

5-1

Radiation doses from external and internal by inhalation of atmosphere and ingestion of drinking water contaminated by the Fukushima Daiichi Nuclear Power Plants Accident for the people living in the Chiba district.

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Large amounts of radioactive substances were released into the environment from the damaged Fukushima Daiichi Nuclear Power Plants. Radioactive substances discharged into the atmosphere first reached the Chiba Metropolitan Area on 15 March, 2011. Atmosphere and fallout deposition samples were collected from 14 March, 2011, and tap water samples were collected from 19 March, 2011 at Japan Chemical Analysis Center (JCAC) in Chiba city, located about 220 km SSE of the Fukushima NPPs. Neighboring downtown Tokyo is 216 km SSE of the Fukushima NPPs. Sampling of airborne particles and gaseous chemical species was carried out at a height of 1.5 m above ground level at JCAC. Airborne particles and gaseous iodine were collected continuously using a cellulose glass-fiber filter (Toyo HE 40T) in combination with an activated charcoal cartridge containing 10% triethylenediamine (TEDA) (Toyo CHC-50). The filter and cartridge were changed every day until 17th June, 2011, then once a week. Air sampling was performed using a low-volume air sampler, and the air flow rate was regulated at around 90 L/min. Wet and dry deposition samples were collected continuously in a tray (0.0283 m^2) on the roof of the laboratory. Samples were collected every day in the first 3 months, then seven days sampling has been performed. Tap water was collected in a 2 L Marinelli beaker type container every day in the first 3 months, then once for one week has been performed from the faucet in a laboratory room at JCAC.

Radioactivity of the samples was directly measured by gamma-ray spectrometry with a Ge detector. The coincidence summing was corrected in activity of ^{134}Cs. The counting efficiency of the Ge detector was calibrated using agar standard samples of the same shape and volume prepared from standard sources. The counting times were usually 3600 s and longer directly after the accident.

Total external gamma-radiation doses were continuously monitored at JCAC using a NaI(Tl) scintillation detector at a height of 1.5 m above ground level located at the center of a 10 m × 10 m lawn. The dose levels peaked three times (15, 16, and 21 March), and the maximum dose rate was 0.5 μGy h^{-1}. The rises on 15 and 16 March were caused mainly by ^{133}Xe, ^{131}I, and ^{132}I. The rises on 21 March were caused mainly by ^{131}I, ^{132}I, ^{134}Cs, and ^{137}Cs delivered by rainfall. Radiation doses were estimated from external radiation and internal radiation by inhalation and ingestion of tap water for people living in the Chiba Area following the accident.

External exposure was estimated to be 135 μSv in the first month (15 March to 14 April) and 101 μSv in the second month (15 April to 14 May), including the exposure from natural background radiation. These doses are calculated for people standing outside on the lawn for the whole day. During the first three months maximum daily concentrations of airborne radionuclides observed at the Japan Chemical Analysis Center in the Chiba Metropolitan Area were 4.7 × 101 Bq m^{-3} of ^{131}I, 7.5 Bq m^{-3} of ^{137}Cs, and 6.1 Bq m^{-3} of ^{134}Cs, respectively.

The inhalation committed effective dose was dominated by ^{131}I in the first month, but in the second month the doses from ^{134}Cs and ^{137}Cs were only a little lower than the dose from ^{131}I. The ingestion dose was dominated by ^{131}I throughout the study period.

Keywords
Fukushima accident, Atmosphere, Fallout, Tap water, Dose estimation

5-2

Internal dosimetry for continuous chronic intake of caesium-137 in cedar pollen after the Fukushima Daiichi Nuclear Power Plant accident

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The Fukushima Daiichi nuclear power plant accident that occurred in March 2011 resulted in widespread contamination of caesium in the eastern region of Japan. It is predicted that caesium deposited in cedar forests would be released as cedar pollen after caesium uptake by cedar trees. Internal exposure from chronic intakes of caesium in cedar pollen is of considerable concern from the standpoint of public exposure. In the present study, internal dose assessments for chronic intake of caesium-137 in cedar pollen were carried out for members of the public –adult residents in Fukushima, Ibaraki and Tokyo– on the basis of data on cedar pollen from a pollen observation system in the Ministry of the Environment (MOE) of Japan. Committed effective doses, retention and excretion functions for caesium-137 in whole-body were evaluated using DSYS-chronic code that was developed at the Japan Atomic Energy Agency (JAEA). The DSYS-chronic code can treat internal dosimetry for chronic intakes using the International Commission on Radiological Protection's (ICRP's) respiratory tract, gastrointestinal tract, biokinetic and bioassay models for ICRP Publ.71. The Activity Median Aerodynamic Diameter (AMAD) and particle density for cedar pollen were assumed to be 32 μm, 0.699 $g \cdot cm^{-3}$, respectively. The observation period was from early February to the end of May 2012. Consequently, it was found that the committed effective doses for adults in Fukushima, Ibaraki and Tokyo were $1.6\text{-}1.8 \times 10^{-3}$μSv, 4.5×10^{-4}μSv and 3.0×10^{-4}μSv, respectively. Hence, it can be stated that internal doses from chronic intakes of caesium-137 in cedar pollen are small and insignificant in 2012. In addition, retention and excretion functions for caesium-137 in whole-body were found to be dependence on the times of intakes. Retention and excretion functions for continuous chronic intakes, which are evaluated by the DSYS-chronic code, may be useful since they may provide reassurance that intakes are indeed low.

Keywords
chronic, internal dose, Cs, cedar pollen, DSYS-chronic

5-3

Internal radiation dose of KURRI volunteers working at evacuation shelters after TEPCO`s Fukushima Daiichi nuclear Power Plant accident

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We report the radiation doses encountered by 59 KURRI (Kyoto University Research Reactor Institute) staff members who had been dispatched to screen refugees for radiation at the emergency evacuation sites 45-80 km from the TEPCO's Fukushima daiichi nuclear power plant.From 20th March to 30th April in 2011, 42 members as teams consisting of 2-4 staff were dispatched 15 times to 7 emergency evacuation sites located 45-80 km from the power plant to examine the radioactive contamination affecting refugees. Continuously, from 10th to 23th May in 2011, 17 members as teams consisting of 2-5 staff were dispatched 6 times to Fukushima prefecture to establish the KURAMA (Kyoto University Radiation Mapping) system. Internal burden of radioactive nuclides were estimated using a whole-body counter consisting of an iron room, four NaI (Tl) scintillation detectors, and a digital multichannel analyzer (MCA7600; Seiko EG&G). The calibration of the whole-body counter and the conversion of the measured body burden to the committed effective dose by internal exposure were carried out in accordance with the Nuclear Safety Research Association (NSRA) technical manual. The external radiation dose to each staff member was measured with a personal dosimeter (ADM-112; Hitachi-Aloka Medical K. K.). The first dispatched team showed 1300-1929 Bq of the internal radiation activity of the cesium (including cesium137 and cesium134), and 48-118 Bq of the iodine131. The internal doses of four members of the first team were estimated 26-39μSv. The doses from internal exposure were almost similar to the cumulative external doses for the dispatch period (20th to 22th March in 2011), when the radiation plumes following the explosion of Unit1 and 3 in TEPCO's Fukushima Daiichi nuclear plant had diffused around the Fukushima city. The external radiation doses of dispatched members after the second team had fallen one third to lower than one tenth of the external doses of the first dispatched team. The internal radiation doses of 55 members after the second team showed that 51 cases were undetectable and 4 cases showed 1-15μSv. These fallen down of the internal radiation doses after the second team owe to the warning statement for the protection of the internal radiation to the dispatched staff of KURRI.

Keywords
internal radiation, cesium137, cesium134, whole-body counter, iodine131

5-4

Distribution of doses to residents evacuated after Fukushima Nuclear Power Station accident

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The statistical analysis is essentially useful not only for an adequate interpretation of radiological data measured in environmental space-time fields but also for the comprehensive dose assessment in such space-time exposure situations because there are many sources of uncertainty leading to biased conclusion. Radiological data are often analyzed by lognormal (LN) distribution because of quantities varied in several orders of magnitude. Doses to residents evacuated are reduced largely for those in higher exposure fields but the doses are reduced insignificantly for those in low exposure fields. Such countermeasures might distort the lognormality of doses to residents evaluated or protected to avoid higher doses. This paper presents an interpretation of the distortion in terms of statistical variation and shows the skewed lognormal distributions of doses to evacuated residents and other data relevant to the accident of TEPCO's Fukushima Daiichi Nuclear Power Station.

The hybrid lognormal (HLN) distribution proposed by Kumazawa and Numakunai (1981) was cited by paragraph 20, ANNEX H "Occupational exposures" of UNSCEAR 1982 Report: the control of doses approaching the dose limits leads to a normal distribution in the higher dose range; this presumption can be used to carry out analysis as a hybrid normal/lognormal distribution. Therefore the control of doses approaching some reference levels in emergency exposure situations or existing exposure situations may lead to a normal distribution in the higher dose range and then this presumption can be used to carry out the HLN analysis.

The HLN distribution is defined for positive variate X so that the transformation $Y=\rho X+\ln(\rho X)$ should be distributed normally with mean μ and variance $\sigma^{\wedge 2}$ of Y. The parameter $\rho>0$ represents the degree of reasonable feedback efforts for reducing unnecessary controllable radiological risk. When residents, however, are selected to protect those to be exposed above dose a (to limit the number of evacuees practically) and to be strongly reduced below dose b (to be seldom beyond reference levels), the HLN distribution of doses to the residents selected can be defined as $\rho W+\ln(\rho W)\sim N(\mu,\sigma^{\wedge 2})$ by putting $W=X-a$ or $W=(X-a)/(b-X)$. The former is called the 4-parameter HLN distribution, and the latter is called the hybrid SB distribution that is corresponding to the Johnson's SB distribution defined as $\ln[(X-a)/(b-X)]\sim N(\mu,\sigma^{\wedge 2})$.

The Fukushima Health Management Survey presents the tentative dose statistics of residents in Namie, Iidate and Kawamata for the period of March 12 to July 11, 2011. The MEXT (Ministry of education, culture, sports, science and technology) reports periodically the integrated doses at a point of monitoring in planned evacuation area, restriction area and others. By matching the area (Namie, Iidate and Kawamata) and the period (3/12/2011-7/11/2011), the results of analyzing dose distributions based on these data are given to interpret the effectiveness of evacuation or protection to avoid the higher doses to residents after the accident.

The paper also shows that the statistical distribution analysis is essential to confirm the homogeneity of data monitored in space and time against possible bias due to the degree of difficulty to obtain data. The environmental data likely to follow the extreme value distribution (maximum) can be well modeled by using the transformation of $X+\ln(X)$ or $W+\ln(W)$. Thus in this paper the linear-plus-logarithm type of hybrid function is also shown to provide the better estimation for radiological data analysis relating to the Fukushima nuclear accident.

In conclusion, the feasible distributions of doses to residents evacuated after the accident are presented based on data tentatively reported in the Fukushima Health Management Survey, including some methods for confirming the statistical homogeneity of relevant data obtained against biased estimation.

Keywords
dose distribution, residents evacuated, protection feedback, hybrid lognormal, homogeneity of data

5-5

Measurement of radioactivity in air-borne dust and estimation of public dose in Tokyo after the Fukushima Daiichi Nuclear Power Plant Accident

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We report the results of emergency monitoring of environmental radiation in Tokyo in response to the severe accident at Fukushima Daiichi Nuclear Power Plant (NPP). Tokyo Metropolitan Industrial Technology Research Institute (TIRI) has been in charge of environmental radiation monitoring since 1975. The monitoring is based on 'Regional Disaster Prevention Plan' formulated by Tokyo Metropolitan Government. After the Great East Japan Earthquake occurred on 11 March 2011, we have also started the emergency monitoring of the environmental radiation from March 13 to detect gamma-emitting nuclides in air-borne dust. Based on the results, the public internal doses due to inhalation were estimated during the period 13 March 2011–12 March 2012.

Air-borne dusts were collected at TIRI in Setagaya (13 March–12 October 2011) and Koto districts (13 October 2011–present date) in Tokyo which are located at distances of 220 km and 230 km from the Fukushima Daiichi NPP, respectively. Air-borne dusts were collected with a glass-fiber filter using a high-volume air sampler which was set at a height of 1 m above ground level. Air flow rate was set to be 0.6 m^3/min. The radioactivity of the collected samples was measured by a Ge semiconductor detector with measuring times ranging from 1,000 s to 20,000 s. The Coincidence summing was corrected. The measurement of each sample was carried out immediately after the sampling, and the decay corrections of radionuclides were not considered. To determine the concentration of ^{134}Cs and ^{137}Cs per weight (Bq/mg), air-borne dusts adsorbed on the filter (April 19–October 20) were weighed.

Gamma-emitting nuclides were detected for the first time in the sample collected in 0:00–7:12 a.m. of 15 March 2011 at Setagaya district, and we started to collect samples in an interval of 1 h. The second peak that showed the highest concentration of major fission products was detected in 10:00–11:00 a.m. of March 15. The concentrations were as follows: 2.4×10^2 Bq/m^3 of ^{131}I, 6.4×10^1 Bq/m^3 of ^{134}Cs, 6.0×10^1 Bq/m^3 of ^{137}Cs. The third peak was observed in 2:00–10:00 a.m. of March 16, then the concentrations decreased and leveled off to almost undetectable levels. The concentration increased again in 21–23 March, probably due to rainfall. The concentration of ^{131}I reached undetectable level in June 2011. On the other hand, ^{134}Cs and ^{137}Cs had been detected intermittently for a year. There was no correlation between yield of air-borne dusts and the concentrations of ^{134}Cs and ^{137}Cs.

The internal effective dose due to inhalation was estimated from the concentrations of all radionuclides that were detected by the detector (Bq/m^3) according to the effective dose coefficients listed in ICRP Publication 72, where it was assumed that people stayed outdoors continuously. The dose to the adult was estimated to be 25μSv. We must note that the contribution of gaseous radionuclides such as ^{131}I was not considered in the estimation. These data can be used to understand the potential risk of stochastic effects for the people in Tokyo.

Keywords
Fukushima Daiichi NPP, Radiation monitoring, Effective dose

5-6

Assessment of doses to the public in the contaminated areas resulting from the Fukushima Daiichi Nuclear Power Station accident

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The present study provides, in order to reconstruct the doses received by the public, the preliminary results from the assessment of the effective doses for one year since the accident. The assessment took into account all major pathways of external exposures and internal exposures. As far as possible, the assessment was based on the measured levels of radioactive materials in the environment. In addition, an atmospheric dispersion modeling was used to estimate the time of radioactive plumes passing and radionuclides depositing on the ground.

Keywords
Dose assessment, measurement data, exposure pathways

5-7

Initial substantial reduction in air dose rate of Cs-origin and personal dose to residents due to the Fukushima nuclear accident

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The earthquake of magnitude 9.0 and tsunami on 11 March 2011 in Japan resulted in severe damage to the Fukushima Daiichi nuclear power plant (NPP), causing a month-long release of radioactive materials into the atmosphere. Aerial measurements carried out by the Ministry of Education, Culture, Sports, Science and Technology, Japan (MEXT) survey showed that the radioactive plumes spread towards the northwest from the NPP, causing radionuclide deposition. Marumori and Kosugo in Miyagi, a neighboring Fukushima prefecture, is located 46 km northwest of the NPP at the closest approach. A distribution map of the radioactivity concentration in the soil by the MEXT revealed that this area was strongly affected by the radioactive plumes and the ^{137}Cs deposition level ranged from 100 to 300 kBq/m^2. After ^{131}I (with a half-life of 8 d) decayed, Cs nuclei predominantly have been responsible for radiation doses since June. In this study, the personal dose equivalent [*H*p(10)] for residents in Marumori and Kosugo regions was evaluated using optically stimulated luminescent (OSL) dosemeters from 1 September 2011. The data of air dose rates in those regions acquired from the local governments through the period of July 2011 and September 2012 were analysed to investigate their temporal variation of Cs-origin. The initial substantial reduction in air dose rate and personal dose to residents were compared.

The *H*p(10) for 54 Marumori and 71 Kosugo residents (125 in total) was evaluated. The measurements were carried out using OSL personal dosemeters and the OSL reader (InLight badge and microStar system, Nagase Landauer, Ltd). The dosemeters are small devices worn on a neck strap. Worn close to the torso, they measure the radiation coming to the body as a whole. Each dosemeter was replaced every 1.5-2 months for reading. During the time the dosemeters were worn, the residents were instructed to record their daily activity history and whether they followed the dosemeter wearing instructions correctly. The data on individuals who did not follow the instructions were excluded in the analysis. The data of air dose rates were analysed by comparing them with the calculated rate attributed to the radioactive decay of ^{134}Cs and ^{137}Cs, obtained using Equation (1).

$$E(t) = E(0)/3.7 \times \{ 2.7 \times \exp(-\lambda_1 t) + \exp(-\lambda_2 t) \} \quad (1)$$

where λ_1 and λ_2 are the decay constants of ^{134}Cs and ^{137}Cs, respectively.

The data of air dose rates in both regions showed the similar tendency. The rapid reduction appeared until around the end of July, followed the long-term decrease in accordance with the radioactive decay process of ^{134}Cs and ^{137}Cs from August to December. During the heavy snow season, air dose rates dropped down and remained low through January to the beginning of March 2012. The air dose rates returned after the snow thawed then followed the relatively faster reduction than the radioactive decay of ^{134}Cs and ^{137}Cs. This reduction is considered to be caused by weathering and/or migration of radionuclides down the soil column. It might be accelelated by snow melting. The half-lives of this reduction were estimated 450 and 300 days in Marumori and Kosugo, respectively when it is expressed using Equation (2)

$$E(t) = E(0) \times \exp(-\lambda_3 t) \quad (2)$$

The decrease in *H*p(10) of residents in two regions seemed quite differently. The result in *H*p(10) of Marumori residents showed the similar tendency with that obtained from the data of air dose rates before and after the snow season, however, no faster reduction due to weathering and/or migration of radionuclides was obserbed in *H*p(10) of Kosugo residents. This difference can be explained by dose contributions from contamination on roof pavings and typically to a lesser extent, walls in the urban environment of Kosugo.

Keywords
personal dose to residents, weathering, air dose rate