



ISET-R Plenary Conference

March 10-11

**@Laboratory of Advanced Research A
in University of Tsukuba**

ISET-R Plenary Conference was held on 10-11 March 2017 at University of Tsukuba.

Six years have passed since Fukushima Dai-ichi Nuclear Power Plant (FDNPP) accident, and ISET-R saw the final year for the study results. Eighty six people participated in the conference where they reported their research and had a vigorous discussion to summarize the result of the project.



Outline of study results

Monitoring technique and simulation model have established for the estimation of emission rate of radioactive substance diffused into the atmosphere. Insoluble Cs particle as one of the forms of primary emission was discovered and Cs re-suspension mechanism as a form of second emission was elucidated. Interaction between atmosphere and terrestrial area has been quantitatively elucidated by model calculation of flux by taking into account of origin of re-suspension including the primary emission and deposition.

The state of contamination in the sea area around FDNPP at an early stage of the accident was successfully reproduced, which has enabled to estimate the leakage amount to the ocean. Observations over large areas in North Pacific Ocean have elucidated a major process of the accident-derived Cs transport.

Data on transfer of contamination in marine ecosystem has successfully exhibited the pathway of ecosystem contamination transfer. Also the difference of deposited radioactive substance behavior between different tree-species in the forests were shown quantitatively. It is shown that within radioactive substance deposited on terrestrial area, Cs concentration of dissolved form and suspended sediment, and temporal change of their solid-liquid distribution coefficient in the river have strong correlation with land use.

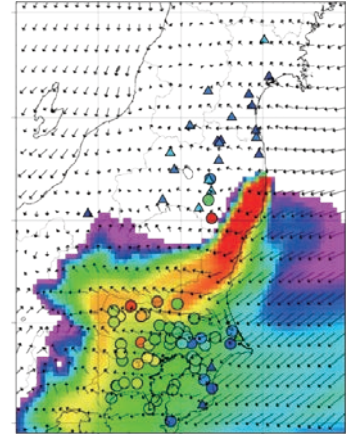
Simulation method to calculate the transition of suspended sediments in the coastal area has established by using the discharge amount from the terrestrial area into the ocean as the input to the ocean. Other outstanding results include developments of analytical method for radionuclides by using Accelerator Mass Spectrometry, analysis for diffusion process of radionuclides and elucidation of determination factor of solid-liquid distribution, representing the possibility for the use of isotopic tracer by using spectroscopic method and physicochemical modeling, all together contributed to establish an unprecedented interdisciplinary study.

Major research results

Group A01 The effect of radionuclides on the atmosphere

A01-1 [Teruyuki Nakajima (The effect of radionuclides on the atmosphere)]

- A new method to estimate hourly atmospheric concentration of ¹³⁷Cs and ¹²⁹I at multiple spots from a specimen tape analysis from SPM observation network and estimation method for atmospheric concentration of polynuclear species from the data obtained at monitoring posts were established.
- Simulations of multiple radioactive substances through atmospheric transfer model were conducted to grasp an outbreak of plumes at the time of FDNPP accident. Their generation, fluctuation and decay were examined and created a united scenario of A01 Group for the diffusion. Estimation of re-suspended amount of radioactive substances by modeling showed that re-suspension process is not crucial.



A01-2 [Yasuhito Igarashi (Land atmosphere)]

- It is shown for the first time in the world that Cs diffusion at an early stage contains a gross insoluble Cs particle with several μm in diameter in addition to submicron soluble sulfate particle which is conventionally assumed to exist.
- Those insoluble Cs particle contains not only Fe, Zn, Cs, O as a major constituent element but also a middle weight element as Ba, Te, Sn, Mo, Rb, U. They are noncrystalline and contained metal are in highly oxidized state.
- It was found that re-suspension hardly contributes to a decrease and transfer of deposited Cs. Another finding is that re-sustained Cs concentration rises during summer season in village-vicinity mountain or Satoyama area, falls during winter season, and that Cs in a summer season mostly derives from biological source. (collaboration with A01-1 and A03-6)

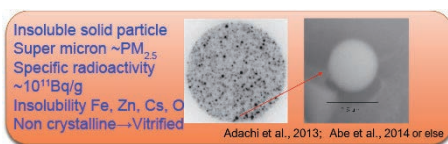


Figure2-1. Nature of insoluble spherical Cs particles and the electron microscopy images.

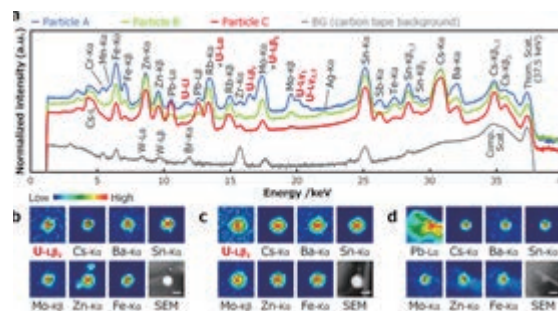


Figure2-2. μ-XRF results of insoluble spherical Cs particles and the electron microscopy image.

Group A02 The effect of radionuclides on the ocean

A02-3 [Masatoshi Yamada (Ocean)]

Three major pathways and transportation phase of radioactive cesium in the North Pacific derived from FDNPP were elucidated.

- 1) Radioactive cesium was transported by the North Pacific current to the north at the speed of 7km per day within middle latitude of Pacific ocean, and it reached Pacific central date-line in a year after the

accident. Model simulation also showed an agreement to the transportation phase of radioactive cesium observed on the surface in the North Pacific.

- 2) Subsurface in a subtropical area was transported to the south accompanied by a subduction of North Pacific subtropical mode water.
- 3) It was transported within the ocean to the east accompanied by the subduction of central mode water.
- 4) Direct leakage rate of radiation (Bq/day) into the ocean was estimated.

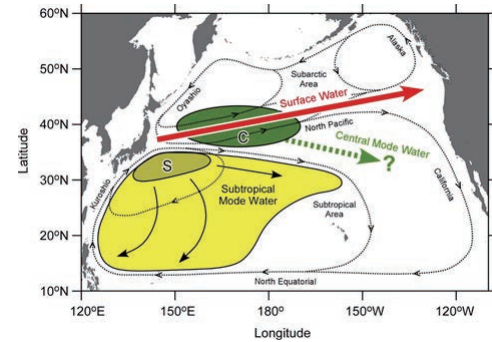


Figure: Transport pathway of radioactive cesium

A02-4 【Jota Kanda (Marine ecosystem)】

- Research on radioactivity contained in zooplankton community was examined in relation to radioactivity in subtropical mode water concerning the status that the change in ocean area and the depth elucidate the decrease with time of radioactivity is much slower than expected. (collaboration with A02-3)
- Simulation for radioactivity transition of biological community performed a reprise based on time-series dataset of radioactive cesium contained in ecosystem around the coast of Fukushima and simulation of seawater and radioactivity variation was performed by A02-3 group. As a result, radioactivity migration from organic sediment to demersal fishes was suggested. (collaboration with A02-3)

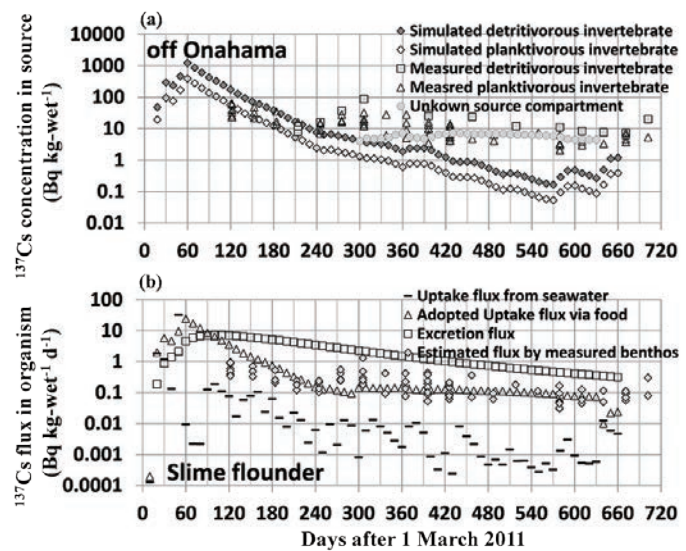


Figure: Reconstruction level of theoretical time course concentration in benthos and the measured value (above), and translocation flux into demersal fish (below).

Group A03 Migration of radionuclides on the land

A03-5 【Yuichi Onda (Migration process at land)】

- Dissolved ^{137}Cs concentration in a stream water from the forested catchment showed a double exponential declining trend and that more than 97% of cesium discharge was comprised by suspended sediment. Observation at paddy fields and farmland elucidated cesium concentration's dependence on a land use
- It was also found that fluctuation of ^{137}Cs concentration in suspended sediment in Abukuma river was one order lower after the second year compared to that in Pripyat river and that the diminishing trend can be explained by land use.
- More than 90% of ^{137}Cs in suspended fraction transported by river has been reached to the ocean without deposited in the river. Also radioactive cesium migration process in the river was successfully simulated with a sufficient accuracy.

A03-6 【Chisato Takenaka (Terrestrial ecology)】

- Elucidation of absorption and migration process of radioactive Cs in plants: collaboration with research from a public offering and Fukushima.
- It is found that surface absorption from leaf surface and bark contribute to radioactive Cs absorption into plants soon after the accident. An analysis on Cs gene that contributes to a potassium transport to elucidate a behavior in trees exhibited a new mechanism that radioactive Cs derived from root absorption and surface absorption are transported through expression variation of SKOR gene.
- Surface fungi transport radioactive Cs upward to litter layer in deciduous and broad leaf forests.

Group A04 The existence form of radionuclide and development of measurement techniques

A04-7 【Masayoshi Yamamoto (Chemical forms)】

- Determining the quantity of actinoid element and others contained in environmental sample and black substance by the method of α -ray spectrometry and Accelerator Mass Spectrometry was performed to examine in-pile environment of FDNPP and creation and migration process of radionuclides.
- Selective extraction method and XAFS measurement have elucidated a chemical status of Cs and I in the soil and sediments. Local structure analyses by XAFA has explained the role of Radiocesium Interception Potential (RIP). Development of X-ray microscope has enabled an analysis of organic matter in suspended particle.
- Chronological change of solid and liquid distribution was reported through monitoring of radioactive cesium in the river and development of related analysis method.

A04-8 【Atsushi Shinohara (Development of measurement technology)】

- The existence of high concentration radionuclides mainly in the atmosphere was found through the observation on the Pacific side in 2013. Development of quantitative method for radionuclides which are difficult to measure, and quantification from environmental sample have been successfully conducted. Especially, an analysis of ^{90}Sr in the atmosphere has clarified that a ratio of contamination changes along with contamination event.
- Chemical form of radionuclides diffused from the nuclear reactor in the accident is having a big impact on a diffusion process in the environment, adsorption process and environmental dynamics of radionuclides. An experimental system for a simulation of the accident was developed to investigate volatilization process of elements formed by nuclear fission under the high temperature, formation simulation of insoluble radioactive particle discovered in the environment, and radionuclides adsorption to various aerosol and the transport process. Adsorption experiment of nuclear fission by using ^{252}Cf -ray origin has clearly represented an equilibrium process of the radionuclides adsorption as shown in the picture.

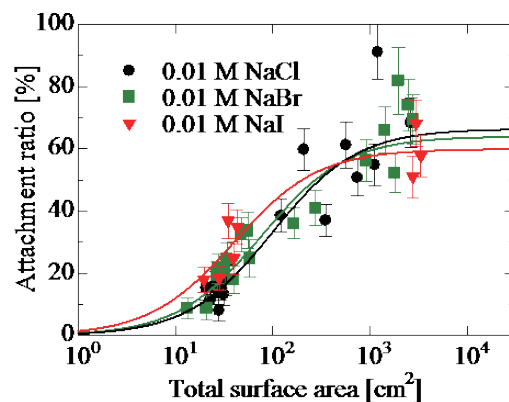


Figure: Relation between attachment ratio of radionuclides and surface area of aerosol.

Working Group of Database: data management and data providing

• Discovering and collecting data of measurement, measuring date, venue of publishing data and results (through searching data on the internet, checking questionnaires of researchers and implementing the site of collecting meta-data), registering the collected data and developing server of searching meta database have made it possible to construct meta database of radioactivity measurement. Searching site including the function of meta database is constructed on the rental server diverting IUOGNET. Transfer of copyright for

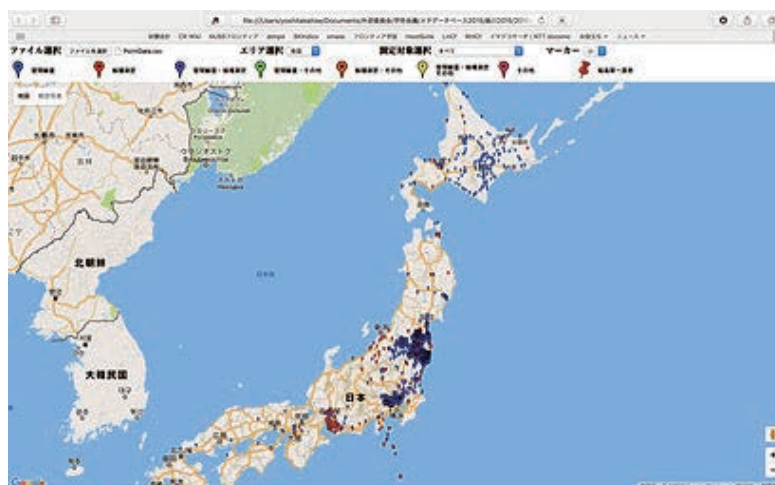


Figure: Measurement spots of collected metadata (about 25,000 measurement spots)

data, and procedure arrangement are under legislative review for the public release (considering of license, privacy protection and preparing terms of service).

• Comparison of aircraft monitoring data between the third (within 80km) and the fifth survey was performed to prepare for deposition amount data of radioactive cesium. As it is highly likely that a change of deposition amount by weathering, difference of conversion factor and measurement condition may have an impact on measurement data from the fifth aircraft monitoring compared to the third one, data of deposition amount from the fifth aircraft monitoring was revised based on the measurements comparison between the third and the fifth. The data will be registered as a basic data and shared on ISET-R member's page.

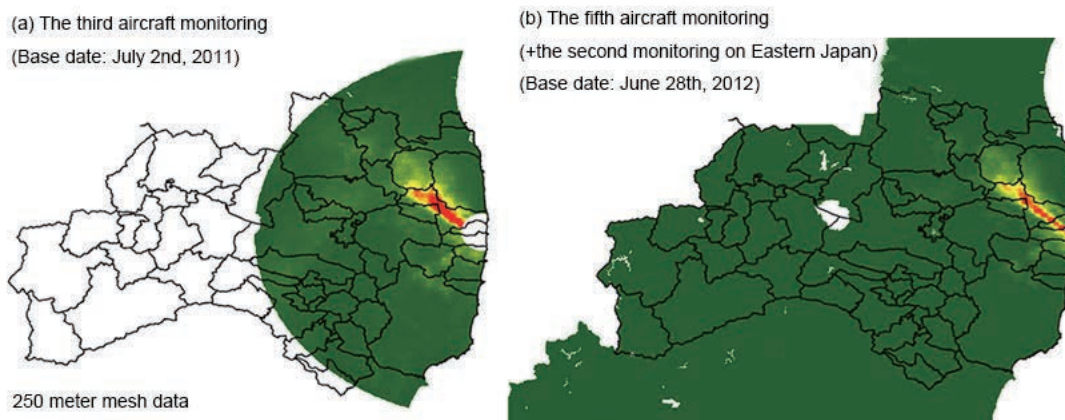


Figure: Comparison between the third (within 80km) and the fifth aircraft monitoring data

Fostering young researchers and students program

The program offered “Training and Research program on environmental dynamics of radionuclides” held by each group (A01-A08) and “travel expense aid for international conferences”. Target of the program is students taking Master's Program or Doctor's Program, researchers and faculty members aged under 39. Total 23 of training program for 5 years gathered 169 participants. The program has 4 scientific fields including Atmosphere, Ocean, Land, and Chemical forms, and 12 participants have completed all of the fields.

Advisors Feedback

Prof. Yuichi Moriguchi **School of Engineering at the University of Tokyo**

Eight research groups that consist the study has produced academically valuable and socially meaningful results in line with the given research subject. Cross-sectional cooperative activity of the study should be specially mentioned. Academic achievements including papers reach sufficient standard in terms of quality and quantity. Outreach activities including television coverage and newspapers, planning sessions at a major conference and lecture meetings for the general public have been active, which has responded to an interest from the public. I can say that the study has laid the important foundation to keep working on a research to scientifically elucidate the influence from the FDNPP accident and has produced a result beyond the initial expectation.

Standing director / Tokushi Shibata **Japan Radioisotope Association**

It is a responsibility of Japanese scientists to internationally deliver their research on environmental behavior of radionuclides after the FDNPP accident, and I would like to appreciate the major result from the project. Tasks and themes have been clarified as the research has progressed, and I believe this will lead to the next step.

The project has published many papers, and I strongly hope that the book summarizing the result of the project both in Japanese and English will be published. It is crucial to the world to organize and publish reports on investigation researches about an environmental behavior of radioactive substance the Ministry of the Environment, JAEA and other organizations have conducted that deliver the whole picture of investigation researches after the FDNPP accident. I would like all of you to examine and propose the idea.

Prof. Gamo Toshitaka **Atmosphere and Ocean Research Institute / The University of Tokyo**

It should be highly appreciated that the project has perfectly dealt with a spatiotemporal transition of event which was initially predicted at the time of radionuclides leakage and has achieved a quite valuable and world-wide performance. Unexpected event has arisen in the course of research as is customary with research of natural science, however, proper steps to meet the situation and skillful correction that have been performed have led to the improvement of research level. I suppose organizing such a diverse interdisciplinary study teams with a field of atmosphere, oceans and lands to achieve the project must have required an enormous effort. It should be especially appreciated that head and principle investigators and coordination committee members have fulfilled the important mission with a skillful arrangement and extensive cooperation, which brought excellent research result.

Upcoming schedule

- Book (University of Tokyo Press, 2014) writing about research of environmental contamination from FDNPP and a lesson from community was published, and the English version will be published by Cambridge University Press in 2017.
- Our research results have been on permanent display since March 2016 with a cooperation with National Museum of Emerging Science and Innovation (Miraikan). Symposium for the public is scheduled on March 10-11 in 2018.