iER

Institute of Environmental Radioactivity

Overview of the IER

Message from Director

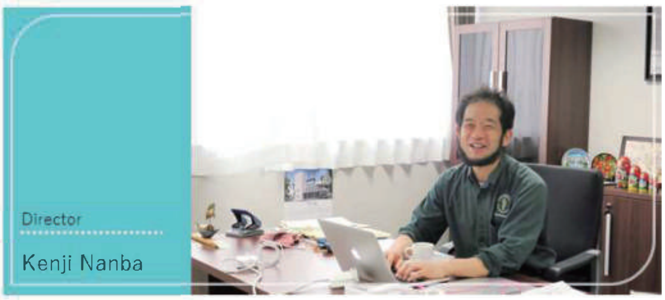
Since its establishment in July 2013, Institute of Environmental Radioactivity (IER) has tackled challenges associated with environmental radioactivity after the Fukushima Daiichi Nuclear Plant accident. Meanwhile, our organizational framework has also been developed into the current form by 2017, including the construction of both analytical and main buildings. In 2019, the IER has launched the Joint Usage / Research Center program with other five institutes: Center for Research in Isotopes and Environmental Dynamics (CRiED) of Tsukuba University, Institute of Radiation Emergency Medicine (IREM) of Hirosaki University, Sector of Fukushima Research and Development of Japan Atomic Energy Agency (JAEA), Department of Radioecology and Fukushima Project of National Institutes for Quantum and Radiological Science and Technology (QST), and National Institute for Environmental Studies (NIES) Fukushima Branch. Through this program, mechanisms have been established (strengthened) for effectively functioning as a hub for accessing to Fukushima samples for collaborative researches between domestic / overseas researchers and the IER researchers. Also in 2019, Master's program of Environmental Radioactivity Science Major was established as part of the educational function of the IER, and the first year students enrolled. Following this, preparations for establishing a doctoral program are underway toward the start in April 2021.

Researchers specializing in radioactivity and radiation in the environment are brought together at the IER. With radioactivity and radiation as common subjects, the research fields behind each researcher range from Topography, to Hydrosphere Ecology, Forest Ecology, and Oceanography. The IER is interdisciplinary in its nature, which naturally encourages internal collaboration and may allow researchers to initiate new research, with finding new perspectives in the gaps between the research fields that are overlooked in the conventional research targets.

Furthermore, researchers in countries that own nuclear power plants and in neighboring countries pay close attention to the impacts of nuclear accidents on the environment and wildlife from the perspective of preparing for the next radioactive contamination. Accordingly, the researchers who study environmental radioactivity in Fukushima become naturally international. Since its establishment, the IER has continued international collaborative researches based on the scientific interests common to researchers in each country. We will continue to promote and enhance collaborative research.

In Fukushima, which was affected by the nuclear accident, the focus gradually shifted to the long-term issues from the urgent challenges that contribute to the emergency measures at the time of the IER establishment. In response to this, we need to switch our research subjects to focus on long-term issues. One of the policies for long-term researches is to explore the basics with radionuclide and radiation in the environment put into perspective. For example, in the field of Environmental Dynamics, it is essential to elucidate the basics of hydrological and ecological mass transfer, and as for the radiation-induced morphological abnormality, it is essential to study the basics of morphogenesis mechanisms. It is expected that these approaches will benefit in suggesting measures based on a deep understanding about the environment and nature.

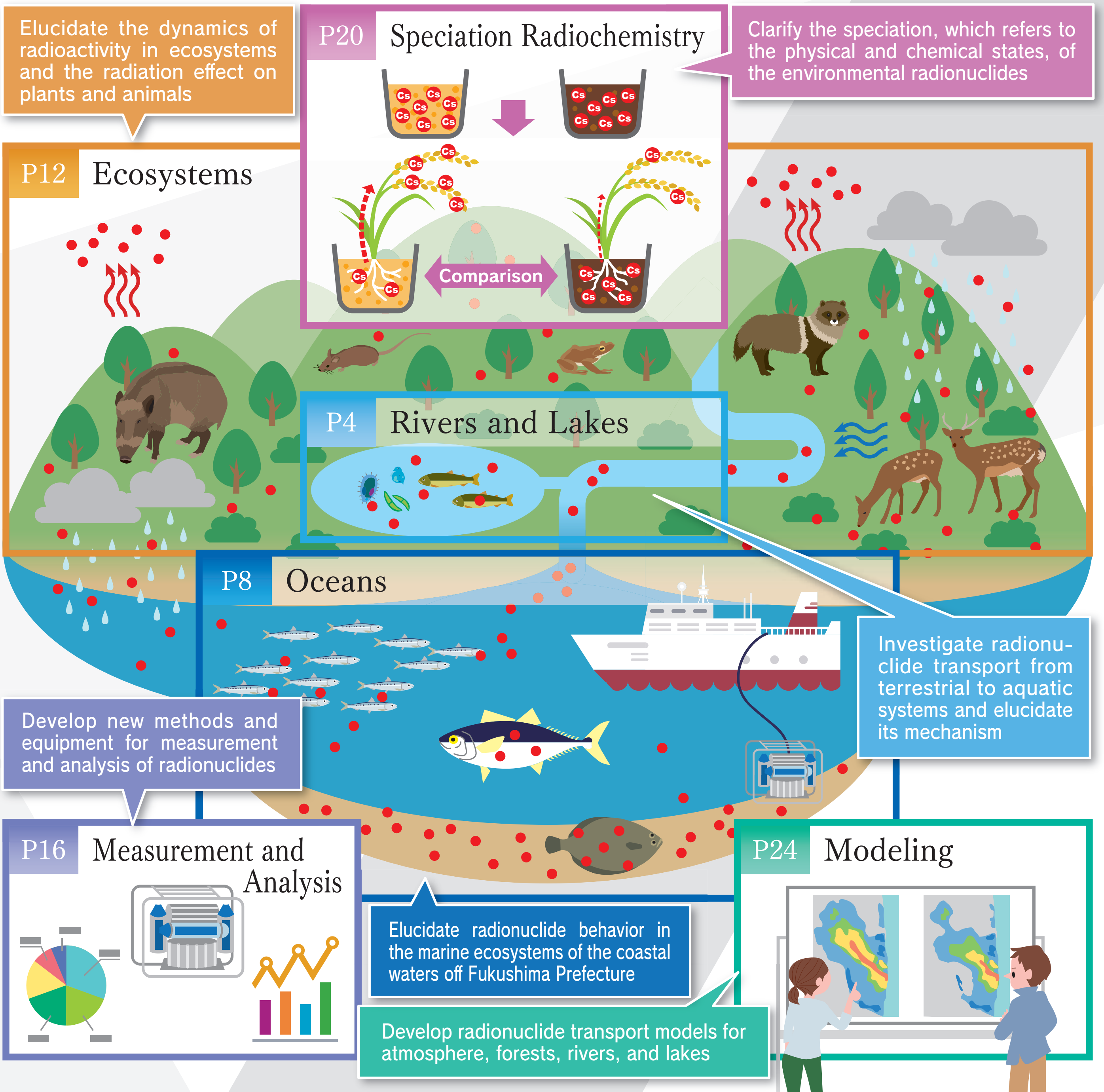
In addition to its interdisciplinary and international characteristics, most importantly, the IER established at Fukushima University after the nuclear accident, has deep ties with the local community. We believe that it is important to value communication with the local people, to conduct research that fits to the changes of their situation and interests, and to continue to share our research results and findings to the local community. We will continue to strive to manage the institute for effectively conducting research with cooperation of the people concerned and local communities. We would be grateful for your continued support and cooperation.



What Our Logo Represents

Our logo symbolizes environments such as water, land, and air. It expresses the dynamics of radioactive materials in the environment, and the dynamics of ecosystems. Its round shape expresses an attitude to be in harmony with the natural world. The colors of blue, green, and orange used in our logo represent the water/sea, earth/forests, and air/sunset, respectively. The sphere in the upper right corner represents a clean earth that is realized by the integration of studies and also stands for research outcomes and added values. The slanting cut in the letter "I" expresses our wishes for ever-increasing progress and outcome.

Research Projects



Collaboration Agreements

International

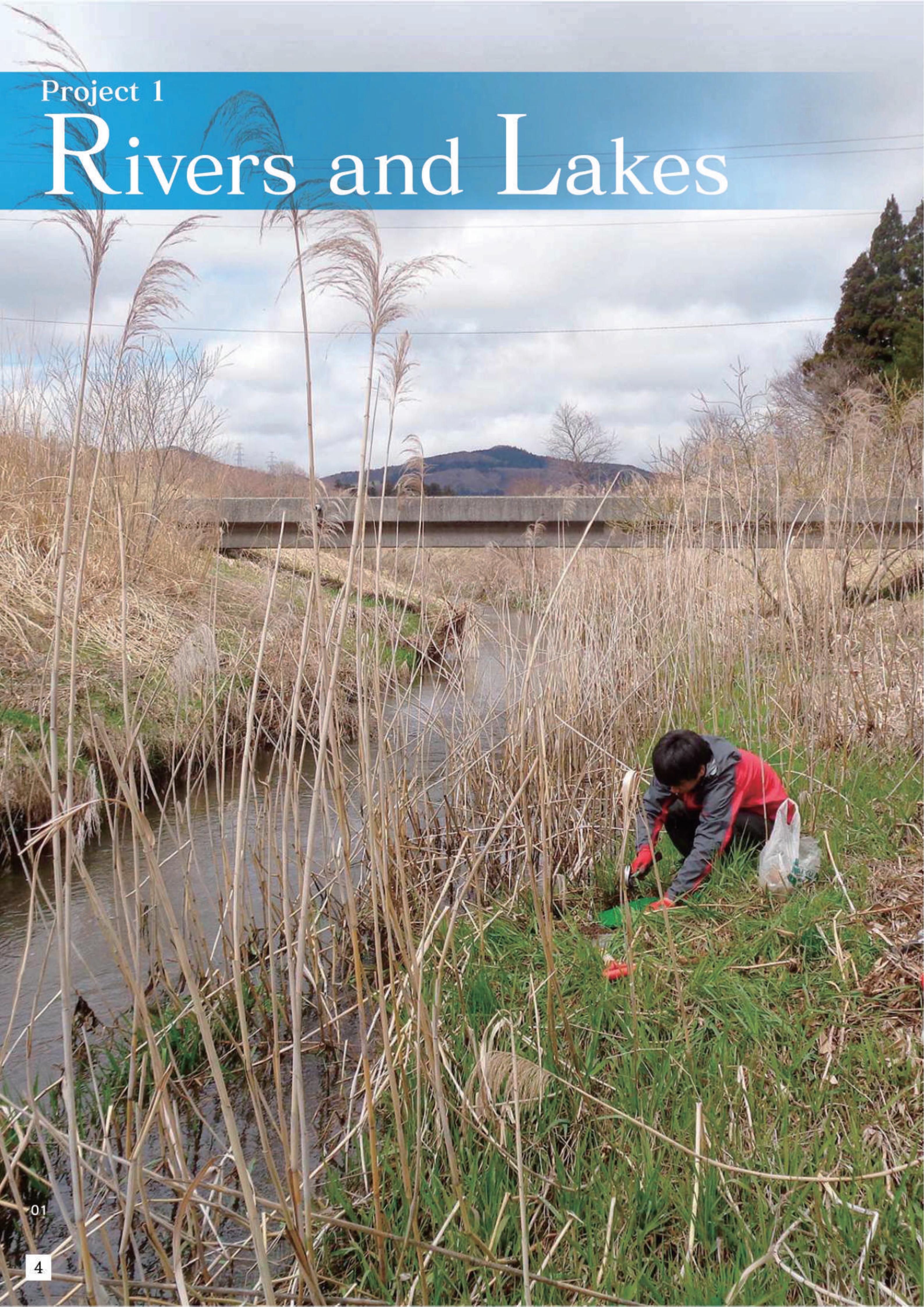
- International Atomic Energy Agency (IAEA)
- Colorado State University (CSU, USA)
- University of Georgia (UGA, USA)
- University of Portsmouth (UoP, UK)
- Scottish Universities Environmental Research Centre (SUERC, UK)
- Odessa State Environmental University (OSENU, Ukraine)
- Chernihiv National University of Technology (ChNUT, Ukraine)
- Ukrainian State Specialised Enterprise “Ecocentre”
- Institute of Mathematical Machines and Systems Problems of the Ukraine National Academy of Science (IMMSP NASU)
- National Academy of Sciences of Ukraine Institute for Nuclear Research (KINR NASU)
- National University of Life and Environmental Sciences of Ukraine (NUBIP)
- Chornobyl Research and Development Institute (CRDI, Ukraine)
- Norwegian University of Life Sciences (NMBU)
- National Food Chain Safety Office (NFCSO, Hungary)
- Department of Chemistry, Faculty of Science, University of Chittagong (CU, Bangladesh)
- Commissariat à l'Energie Atomique et aux Energies Alternatives (CEA, France)
- Agence Nationale pour la Gestion des Déchets Radioactifs (ANDRA, France)
- Institut de Radioprotection et de Sûreté Nucléaire (IRSN, France)
- Institute of Radiobiology of National Academy of Science of Belarus (IRB)
- Belgian Nuclear Research Centre (SCK-CEN)
- Faculty of Geography, Moscow State University (MSU)
- Federal State Budgetary Institution “Russian Institute of Radiology and Agroecology”of Ministry of Science and Higher Education of the Russian Federation (RIRAE)
- Nuclear Safety Institute of the Russian Academy of Sciences (IBRAE RAN)

Japan

- Institute of Environmental Sciences (IES)
- National Institute for Environmental Studies (NIES)
- Japan Atomic Energy Agency (JAEA)
- Quantum Medical Science Directorate of National Institutes for Quantum and Radiological Science and Technology (QST)
- College of Science and Engineering, Kanazawa University
- Hiroshima University
- Institute of Radiation Emergency Medicine (IREM), Hirosaki University
- University of Tsukuba
- Nagasaki University
- Tokyo University of Marine Science and Technology
- Fukushima Medical University

Project 1

Rivers and Lakes



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[01] Setting up an artificial grass mat on Niida River floodplain [02] Water sampling from an irrigation pond [03] Dose rate survey of the waterfront park [04] Study of the Niida River floodplain [05] Runoff plot [06] Surface runoff and soil erosion during heavy rain [07] Decontamination site eroded by rainfall [08] Sampling of suspended sediments in the river

Project 1

Rivers and Lakes

Fate and Transport of Radionuclides in Soil-Water Environment; Understanding Their Dynamics for Future Prediction

Why Did We Start the Project?

Radioactive materials released as a result of a nuclear accident are dispersed in the environment. Following the Fukushima Daiichi nuclear accident, the released radionuclides were deposited on the ground and entered water bodies. Deposited radionuclides were then subjected to transport by surface runoff and wind resuspension. Understanding transport processes of radionuclides is required for predicting their redistribution in the environment, which is critical for reducing radiation risks. Of the accidentally released radionuclides, ^{137}Cs is of higher environmental significance because of its long half-life and large amounts released. ^{137}Cs can be easily associated with sediments because of its strong affinity to soil particles and, during rainfall, it is transported with surface runoff to the ocean via river systems. Radionuclides partially accumulate in closed water systems such as lakes and ponds and are slowly remobilized to water due to ion exchange. These phenomena were elucidated through the studies of the environmental behavior of radionuclides occurring as a result of global fallout after nuclear bomb testing and contamination following the Chernobyl accident. The geographic setting of Fukushima Prefecture, however, is characterized by higher precipitation and steeper topography as compared to other areas studied and, therefore, the site-specific behavior of radionuclides needs to be understood. From this respect, the Rivers and Lakes group is tasked to explore how the climatic and geographical conditions of Fukushima Prefecture influence the current and future radiation situation.

How Do We Study?

To better understand particulate ^{137}Cs migration through the river system and related temporal changes in the contamination levels, the Rivers and Lakes group has conducted monitoring on the Niida River located in the areas contaminated after the Fukushima accident. The characteristics measured on the river basin include the river water flow rate, suspended sediments discharge and ^{137}Cs activity concentration in suspended sediments, which are used to estimate ^{137}Cs wash-off from the catchment. Accumulation and losses of sediments and ^{137}Cs on the floodplain during the floods are also being determined. In addition, we studied the ^{137}Cs activity concentrations in sludge at the sewage-treatment plant of the Abukuma River system. For further understanding temporal variations in the ^{137}Cs activity concentration in closed and semi-closed water systems, samples of water, sediments and soils are collected on a regular basis on the catchments of four irrigation ponds in Okuma town.

The catchments contaminated after the Fukushima accident have become a source of long-term secondary radioactive contamination of rivers and lakes due to radionuclide wash-off by surface runoff. For deepening our knowledge of radionuclides wash-off from areas of various land use, such as forest, farmland and grassland, observational facilities (runoff plots) were set up in Date City. Using these runoff plots, samples of runoff water and eroded sediments are collected to quantify ^{137}Cs discharge in particulate and dissolved states.

Accumulation of radionuclides due to sedimentation and their loss due to erosion lead to changes in the air dose rate (indicative of external radiation risk). For example, in the cases of radionuclides removal from soil surface by erosion or their burial below fresh uncontaminated sediments, the ambient air dose rate is supposed to decrease. For keeping track of such changes; i.e., identifying places and time when such changes occur, we continuously measure the air dose rate at our observation/monitoring sites.

Another important task is evaluating effects of decontamination. In order to investigate the impact of decontamination on migration of radionuclides on contaminated catchments, we have set up runoff plots on a decontaminated area in Kawamata Town. Additionally, geomorphological surveys were conducted in the Iitate Village using a 3D laser profiler for better understanding of soil erosion processes on decontaminated lands.

The comparative analysis of data on radionuclide behavior in the environment has shown that Fukushima-derived ^{137}Cs features a stronger binding to particles than was the case at Mayak and in Chernobyl, which is conducive to faster scavenging of ^{137}Cs in surface waters and predominant transport of ^{137}Cs on suspended material with surface runoff and river flow. Fukushima's soils contain a higher amount of clay, which contains a mineral that can easily adsorb and retain ^{137}Cs. Our analysis of data on the radionuclides activity concentrations in sludge at the sewage-treatment plant has shown that three years after the accident, the concentration of ^{137}Cs in sludge decreased and was about one-tenth of the concentration measured immediately after the nuclear disaster. Fukushima's sewage treatment system is different from systems in Europe including Chernobyl and, consequently, the ^{137}Cs concentrations in sludge in Fukushima are relatively low.

What Did We Find?

Our study of ^{137}Cs in the ponds of Okuma Town shows that the ratio of particulate ^{137}Cs and dissolved ^{137}Cs is approximately 7:3. Similar to what was found in Fukushima rivers, ^{137}Cs was found to be strongly bound to sediments, and the total activity concentration in water column was found to be higher with increasing suspended sediments load in water. We will continue monitoring ^{137}Cs activity concentration in water to elucidate the radionuclide seasonal variations and their controlling factors.

The undertaken measurements of air dose rate indicate that sediment transport during typhoon extreme flood events lead to a decrease in the air dose rate on the river floodplains. A sharp decrease in the air dose rate after a heavy flood was observed on the floodplain of Niida River system, which can be explained by less contaminated coarse-grained sediments covering more contaminated sediments below.

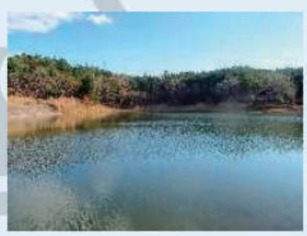
Investigations of the decontaminated areas are providing an insight into the influence of decontamination. Our studies using the runoff plots indicate that the ^{137}Cs activity concentration in sediments on decontaminated areas has decreased almost by half, as compared to those before decontamination. Observations of the Niida River basin are indicative of a decreasing trend in ^{137}Cs activity concentration of suspended sediment in the river, the catchment of which is being decontaminated. These results suggest that decontamination causes ^{137}Cs activity concentration to decrease in sediments transported from land to rivers and lakes. Our current task is to better understand how decontamination influences dynamics of ^{137}Cs and sediments on the river basin scale.

How Will the Research Benefit Society?

Knowing the current situation and better understanding how radionuclides will behave in the future in rivers and lakes is essential from the standpoint of reconstruction of safe living and industrial activities. It should also be remembered that water from rivers and reservoirs is used for agricultural purposes. Determination of activity concentrations and speciation of radionuclides, as well as their temporal dynamics in the soil-water environment, is critical for safe and appropriate farming. It is also of vital importance to understand ^{137}Cs uptake by aquatic organisms, including fish, particularly for recovery of the fishing industry. Quantitative analyses of accumulation of radionuclides in waterfront parks provide an estimate of radiological risk in the area.

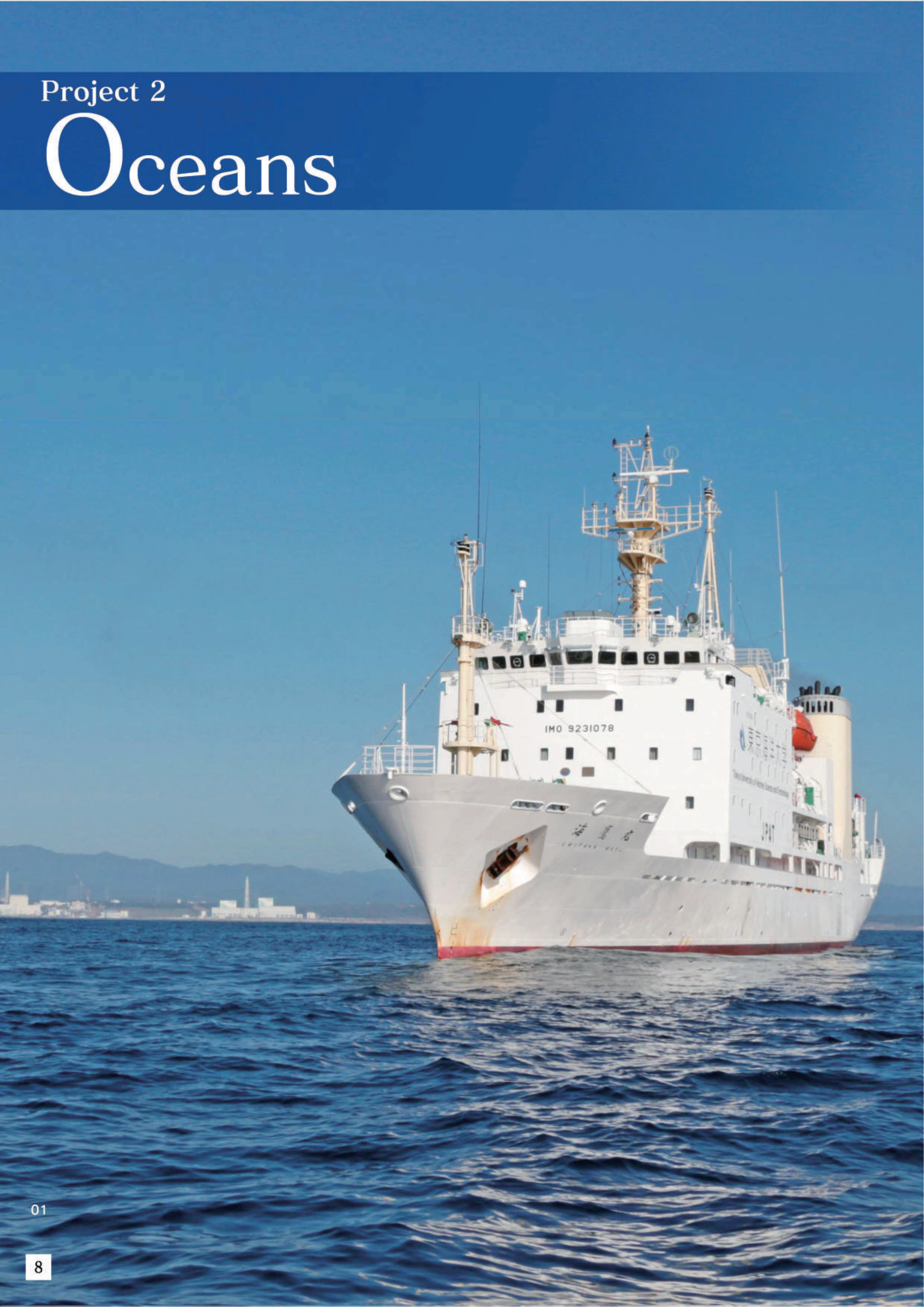
The data obtained by our group are crucial for prediction of radionuclide migration in the environment. Numerical model simulations are used to predict future large-scale spatial and temporal distributions of radionuclides. Validation and calibration based on observational results can help to improve the accuracy of model simulations. Our activity allows us to collect valuable datasets and thereby contributes to better prediction of radionuclides fate.

(PIC) The Niida River



(PIC) A reservoir in Okuma Town

Project 2
Oceans



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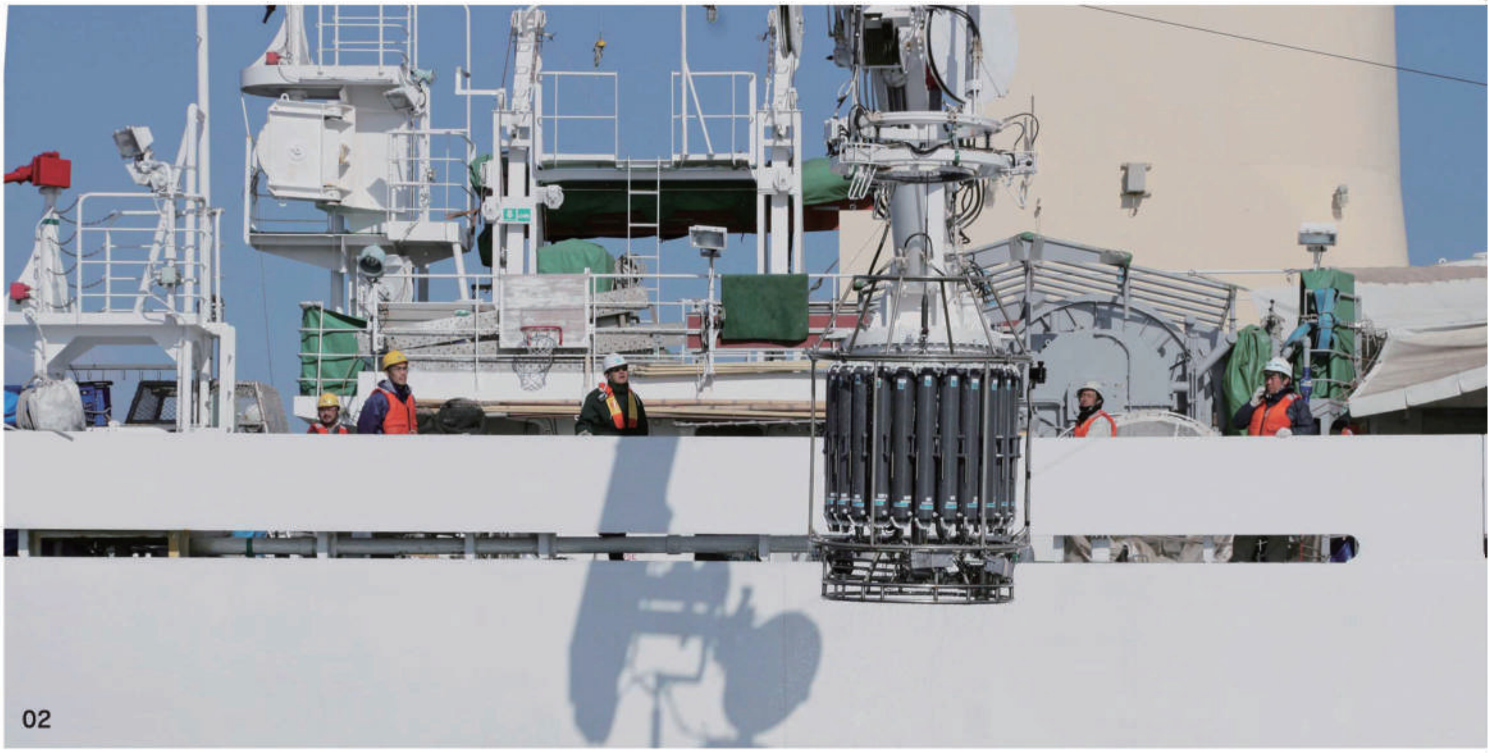


[01] R/V Umitaka-maru, Tokyo University of Marine Science and Technology conducted a research cruise in the waters off the Fukushima Daiichi Nuclear Power Plant [02] Retrieving a seawater sampler that collected seawater at desired depths between the surface to just above the sea bottom. [03] Drawing collected seawater into a container onboard [04] Retrieving a net used for collecting biota samples [05] Radioactivity screening survey on biota samples just after being collected [06] Sorting biota samples by species in the laboratory [07] Sampled sediment [08] Sampling surface seawater at Tomioka, Fukushima Prefecture

Project 2

Oceans

Understanding the dynamics of radionuclides in the marine environment is an important clue for the evaluation of radiation dose effects on human society through food chain

Why Did We Start the Project?

How are radionuclides transported to the ocean

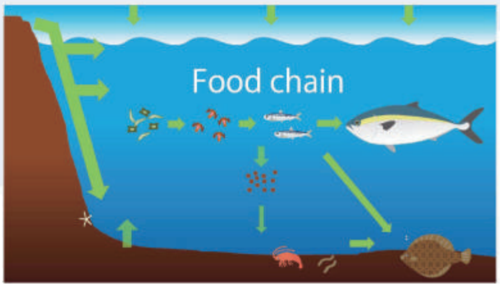
Artificial radionuclides released in the environment will be deposited on land and ocean surfaces mainly due to precipitation (wet deposition), gravity, or its interactions with ocean surface (dry deposition). In addition, artificial radionuclides deposited on land can be transported to the marine environment via rivers, the atmosphere. Or, they are directly introduced into the marine environment from facilities located on the coast.

Behavior of radionuclides in the ocean

Artificial radionuclides spread throughout the ocean due to advection and diffusion. Part of them are deposited in sediments or transported into ecosystems as sinking particles. Such behavior of radionuclides is called "biogeochemical cycles". Although spatiotemporal distribution of radionuclides in the ocean is complicated by various factors, understanding biogeochemical cycles of radionuclides results in evaluating radiation dose effects on human society through food chain.

What to understand

It is important to study biogeochemical cycles in the ocean and how artificial radionuclides reach the ocean from rivers and the atmosphere. It is also important to understand "how much of the radionuclides are deposited in the bottom sediments of the ocean and transported into ecosystems". Thus, field observation is required. Modelling & simulation and laboratory experiments under the environmental conditions are also necessary for further evaluation. In addition, there are natural radionuclides and stable nuclides in the ocean as natural analogue to artificial radionuclides. Understanding their behaviors also helps to predict those of artificial radionuclides.



Overview of biogeochemical cycles

How Do We Study?

In our project, we conduct the following studies in collaboration with other institutions to clarify the biogeochemical cycles of artificial radionuclides in the ocean released by the accident at TEPCO Fukushima Daiichi Nuclear Power Plant (FDNPP).

1.Field observation in estuarine and coastal waters, and the ocean/Modelling & simulation/Laboratory experiments with a method of solution chemistry

We collect and measure samples such as seawater and sediments from estuarine and coastal waters, and the ocean in order to understand the dynamics of radionuclides in these systems. We also estimate the amount of radionuclides (fluxes) which flow into the ocean through rivers. In addition, we conduct laboratory experiments based on their particle-water interactions, in order to elucidate the factors of desorption of radionuclides in particulate phase along the salinity gradient from rivers to the ocean.

2.Transfer parameters of radionuclides from seawater to sediments or organisms

We obtain transfer parameters to understand how much of the artificial radionuclides are transported from seawater to sediments or organisms. Using radioactive data on sediments, organisms, and corresponding seawater, we calculate the ratio of radioactivity between the samples and seawater, as a transfer parameter. This information is important for modelling & simulation to evaluate the effects of radionuclides to human society through food chain.

3.Prediction of long-term dynamics of artificial radionuclides in the ocean using natural radionuclides and stable nuclides

By understanding the spatiotemporal distributions of radionuclides and stable nuclides existing in the marine environment, we elucidate the long-term behaviors of some artificial radionuclides of which dynamics have not been fully understood yet.

What Did We Find?

From the investigations carried out so far, we have found some spatiotemporal changes of artificial radionuclides discharged into the ocean by the FDNPP accident.

1.Dynamics of radiocaesium in seawater and sediments during the two years immediately after the accident

Radiocaesium discharged into the ocean by the accident decreased rapidly due to the mixing of the plume with relatively uncontaminated open-ocean waters. It was also found that vigorous vertical mixing during the winter contributed to the downward flux of part of the FDNPP-derived radiocaesium into bottom waters. Additionally, we revealed that at least 0.2 % of the radiocaesium directly discharged into the ocean was deposited in sediments.

2.Mass balance of radiocaesium in seawater around FDNPP

We investigated the inventory of radiocaesium in the coastal water off Fukushima Prefecture and neighboring prefectures (surface area: 6160 km^2, volume: 753 km^3) from May 2011 to February 2015. The rediocesium inventory about four years after the accident was approximately twice the background inventory. Quantitative analysis suggested that the on-going direct discharge from the FDNPP is the principal source of radiocaesium to maintain the relatively high inventory in the offshore area.

3.Influx of FDNPP-derived radiocaesium into the Sea of Japan

A nationwide investigation of radioactivity that has been conducted since 1984 in coastal areas where there are nuclear power plants around showed that the FDNPP-derived radiocaesium was transported to the Sea of Japan by the Tsushima Warm Current through the Tsushima Strait. The net increase of radiocaesium inventory in the Japan Sea through the addition of FDNPP-derived radiocaesium accounts for less than 1% of the total flux from the FDNPP to the ocean.

4.Estimation of riverine radiocaesium fluxes to the marine environment

Part of radiocaesium deposited on land is eventually transported to the ocean through rivers. In order to study the effects of radiocaesium fluxes from rivers to the ocean, we conducted laboratory experiments. As a result, desorption of this nuclide from riverine particles by change of salinity from rivers should be considered for the total radiocesium flux in dissolved phase. However, since the extent of desorption depends on the physico-chemical properties of the particles, laboratory experiments are also highly required to evaluate the relationship between desorptive behavior and particle composition.

How Will the Research Benefit Society?

● Outreach activities for the explanation of principal information on biogeochemical cycles in order to support public better understanding

Fisheries have been a basic industry in Japan. Ensuring the integrity of the marine environment, especially the safety of fishery products and their impacts on human society through the food chain, with respect to radioactivity after the FDNPP accident is a high priority of the public.

We will continue to provide principal information of the current status of the radio-contaminated marine environment for the dose assessment by publishing results to the scientific journals and by presenting to the public. We believe that outreach activities help to prevent spreading of bad rumor based on the wrong information.

● The research of radionuclides plays an important role to solve other issues

Radionuclides and applying their radioactive decay and isotope effects can be used as analogues for tracing the transient dynamics of materials. For example, natural radionuclides are used to determine not only the sources of water masses but also biogeochemical dynamics of other contaminants. They are also used to trace elements in aquatic systems such as rivers, estuaries and oceans, thereby providing us clues to solve climate change or even other new environmental problems.

Project 3

Ecosystems

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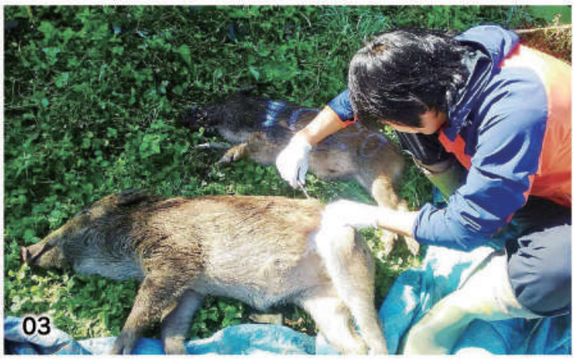

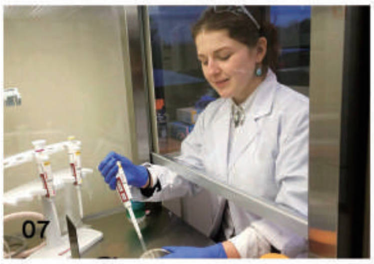

[01] Fukushima's rich nature, forest and stream [02] Sampling a tree using an increment borer [03] Biopsy of contaminated boars [04] Investigating the distribution of radiation in Lake Numazawa to determine contaminant transfers to fish [05, 06] Research on the behavior of wild boar and their radiation dose by using special GPS-dosimeter collars [07] Laboratory preparation of samples to examine microbial community structure [08] Studies of fish at a contaminated reservoir in Okuma Town [09] Research on landlocked masu salmons at the Katsurao River

Project 3

Ecosystems

Research on the Behavior of Radioactive Materials in Ecosystems and Radiation Effects on Plants and Animals

Why Did We Start the Project?

Our ecosystem group conducts research related to Radioecology.

[Radioecology] is a branch of science that studies the behavior of environmental radioactive materials and determines the effects of radiation on humans and the environment. It is an integrated science covering multiple disciplines, such as nuclear physics, chemistry, biology, toxicology, physiology, ecology, modeling, and risk analysis. Naturally occurring radioactive materials have existed in our atmosphere, lands, water, plants and animals since the earth's formation. All creatures are therefore routinely exposed to background radioactivity. The cells of all creatures have evolved highly effective mechanisms to repair damage caused from such low-level radioactivity.

However, when accidents occur at nuclear facilities, large amounts of man-made radioactive materials can be released into the environment. It is then necessary to know the environmental behavior of the released radioactive materials to evaluate the risks to humans and the environment. The Fukushima Daiichi nuclear accident released large quantities of radioactive materials into the environment, including radioactive caesium. In view of this, we investigate where the radioactive contamination has been distributed among environmental components (air, soil, lakes, rivers, agricultural lands, forests, plants and animals). We also measure the radiation dose received by plants and animals and determine their associated health risks. We then develop computer simulation models that allow us to predict how the contaminant's concentration, distribution, and health risks will change with time.

How Do We Study?

We conduct field research on the radioactive contamination of plants and animals within aquatic and terrestrial environments of the Fukushima Prefecture, as well as conduct research under more controlled laboratory conditions. We also study the effects of radiation on plants, animals, and microbial communities. The six members of the Ecosystem group contribute their diverse backgrounds and expertise and jointly collaborate on various research projects.

- **Radioactive caesium concentrations when dissolved in water, and when the Cs is attached to small particles suspended in the water column**
  The Abukuma River, Lake Hibara, and Lake Numazawa
- **Trends in radioactive caesium concentrations in fish and how they take up radioactive caesium**
  The Abukuma River system, rivers in Hamadori, and reservoirs around the Fukushima Daiichi Nuclear Power Plant
- **Radioactive caesium in forest ecosystems**
  Yamakiya area in Kawamata Town and the area surrounding the Fukushima Daiichi Nuclear Power Plant
- **Tracking wildlife, measuring their contaminant levels and radiation dose**
  The evacuation zone and the area surrounding the Fukushima Daiichi Nuclear Power Plant
- **Influence of radioactive caesium contamination on microbial composition of forest soil**
  The area surrounding the Fukushima Daiichi Nuclear Power Plant

What Did We Find?

Radioactive caesium concentrations when dissolved in water, and when the Cs is attached to small particles suspended in the water column

Our research showed that radioactive caesium concentrations in lakes and rivers, in both the dissolved and suspended states, decreased rapidly after the nuclear accident.

Trends in the radioactive caesium concentrations in fish and how they take in radioactive Caesium

We found that radioactive caesium concentrations in landlocked masu salmon in rivers of the Aizu area and west of Nakadori contained low levels of radiation. Whereas, there were still some samples with caesium concentrations above the reference value (100 Bq/kg) from tributaries northeast of Nakadori. This means that fresh water fish, including those living in mountain streams, retain radioactive caesium for long periods and are thus subject to the effects of chronic exposures. We also found that radioactive caesium concentrations in fish from reservoirs around the Fukushima Daiichi Nuclear Power Plant are among the most contaminated and can have radioactivity concentrations that reach several thousand becquerels per kg.

Radioactive caesium in forest ecosystems

We found that radioactive caesium initially deposited in the top crowns of trees mostly transferred to the soil, due to defoliation and rainfall in the forest ecosystem (as of 2016). New leaves increased in radioactive caesium concentration. This suggests that their intake of radioactive caesium was from the contaminated soil via root uptake. We also found that a high percentage of Japanese red pine trees exposed to radioactivity in the juvenile stage have morphological abnormalities.

Tracking wildlife, measuring their contaminant levels and radiation dose

We found that boar and raccoons prefer the areas evacuated by humans, even though these are areas with the highest radiation levels. Boar and raccoons are increasing in the evacuation zone because of the abundance of abandoned homes that provide shelter. Fukushima boars, like those at Chernobyl, can contain very high radioactive caesium levels, several thousands of becquerels per kg. Using specialized GPS collars that contain dosimeters, we found that the dose from external exposure experienced by Fukushima boars can be far greater than the dose they receive from ingesting radioactive food and water. We also found that the level of external dose can vary greatly over short time periods (less than a week) because of the large variation in contaminant levels that exists in environments.

How Will the Research Benefit Society?

Our research has documented the level of radioactive contamination in many different environmental components of Fukushima's ecosystems. Information on radioactive contaminant uptake by various ecosystem components is useful in understanding the transport and fate of radiocaesium contamination within the environment. For example, the data collected by the Ecosystem Group will make it possible to estimate the radiation dose received by humans as influenced by forest and forest products. This is important to people that return to their homes after the evacuation order is lifted. Our data provide additional information on the distribution and habits of wildlife that are considered pests because they are destroying property and could potentially spread disease. Moreover, research on radiation effects to wildlife can provide insights into what humans might have experienced if evacuation orders were less stringent.

The IER openly shares the results of our research, and strives to be unbiased and neutral in presenting our scientific data to general citizens, administrative bodies, and domestic and foreign researchers. Such scientific information is extremely important to the people of Fukushima, as well as those residing near the 442 nuclear reactors the world-over (Source: IAEA's PRIS as of March 28, 2016).

Radioactive materials moving in the ecosystem

Project 4
Measurement and Analysis

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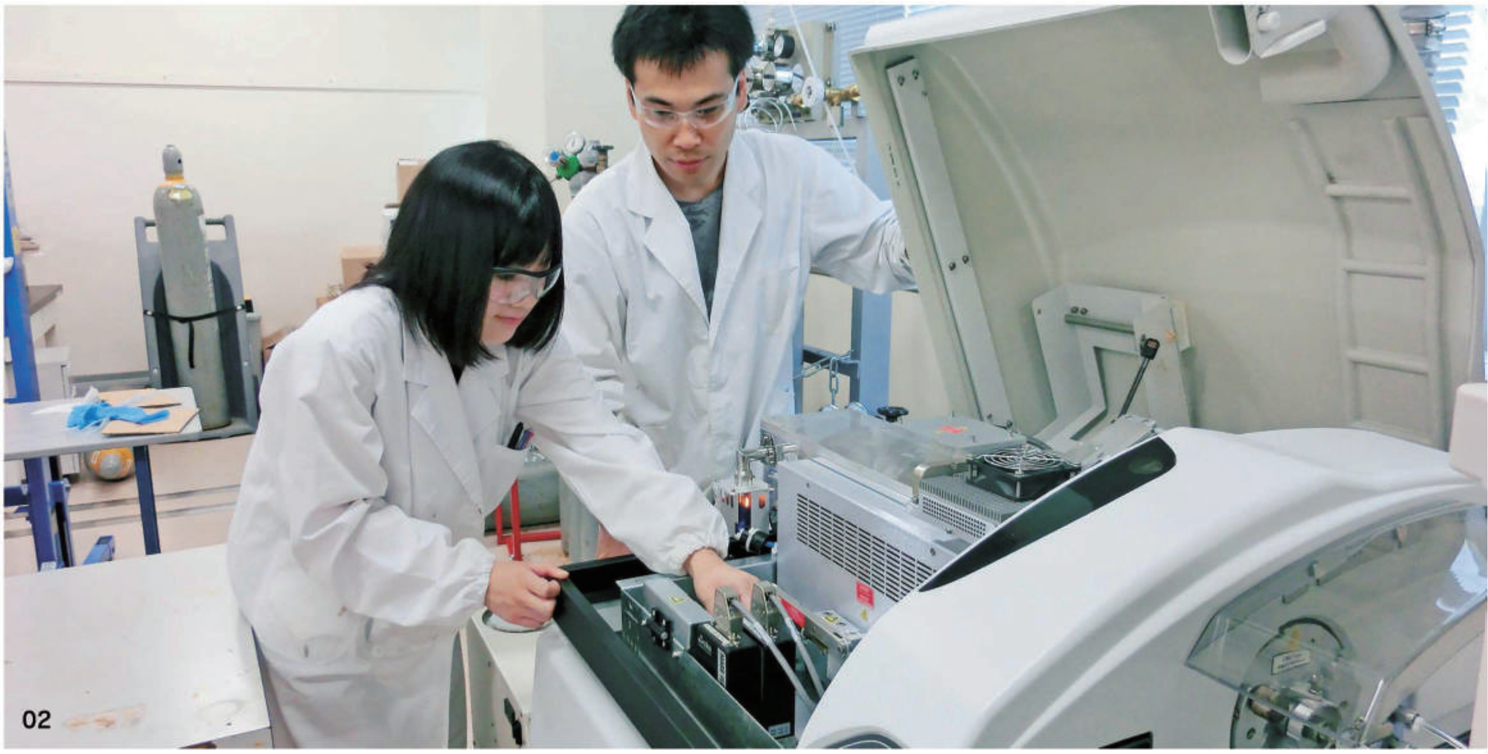
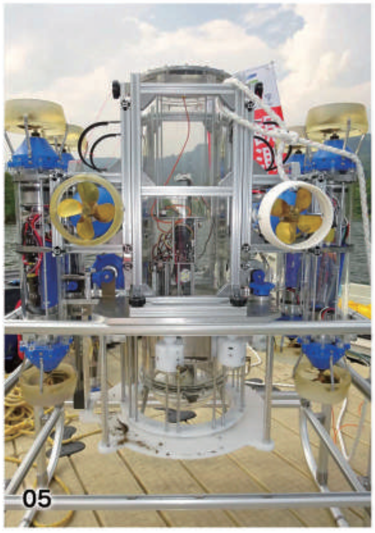
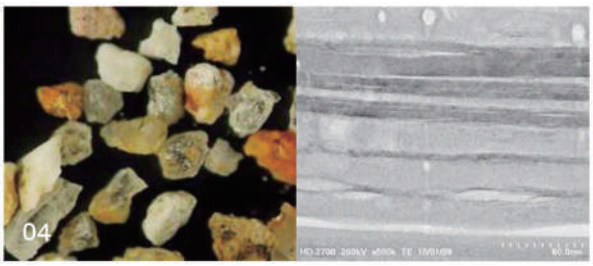






[01] Assembling an underwater robot by a lake [02, 07] Adjusting an ICP-MS system for rapid analysis of radioactive strontium [03] Outdoor radioactive nuclide mapping using a portable gamma-ray spectrometer [04] Minerals contained in soil (observation using an optical microscope and transmission electron microscope) [05] A full view of the underwater robot for sampling soil [06] Test operation of the underwater robot in the lake [08] Press release on a radioactive strontium rapid analysis technique

Project 4

Measurement and Analysis

From Environmental Measurement to Infinitesimal-Scale Analysis Toward the Establishment of New Measurement and Analysis Methods

Why Did We Start the Project?

"Analysis" refers to measuring, separating and looking. Since the dawn of history, humans have been conducting analysis in a broad sense to obtain information essential to making judgements and effectively proceeding with the next action or step. That is to say, everyone conducts analysis in order to make judgements or decisions. Analysis is not a basic act limited to only scientists, but is an integral part of policymaking in administrative bodies.

Shorter, more accurate analysis allows swift decision-making for the next step. In other words, swiftness and accuracy are very important keys in measurement and analysis.

What is being sought in the field of measurement and analysis following the Fukushima Daiichi nuclear accident is "the conducting of measurements in environments never before experienced by humans." Although this nuclear disaster is often compared to the Chernobyl accident, Fukushima is similar to, but not the same as Chernobyl due to the fact that Fukushima is hot and humid, has a precipitous landform, and has a very fast hydrological circulation. There are many phenomena that are being measured for the first time in this environment; however, it is difficult to conduct measurement because the measurement environment is severe in some cases. Therefore, it is necessary to conduct analysis and measurement in parallel with the development of new measurement techniques. While it is important to obtain new information through such measurement and analysis, continued execution of these activities is essential in order to maintain a safe environment.

How Do We Study?

Our measurement and analysis project is developing devices for measuring and analyzing radiation and radioactive nuclides (development of new measurement/analysis devices ready for investigation/research of the environmental dynamics of radioactive nuclides in forests, rivers and lakes). Furthermore, we are developing novel analysis techniques using conventional analyzing devices for evaluating radioactive nuclides quantitatively and swiftly, as well as for analyzing the environmental dynamics of radioactive nuclides at the micro-level. Examples include development of:

- **an underwater robot capable of sampling sediment on the lake bottom without destroying the layered structure of sediment in deep lakes such as Lake Inawashiro.**
- **a handy mapping system, combining a portable gamma-ray spectrometer and GPS, capable of measuring the distribution of radioactive nuclides in forests and agricultural land swiftly and with a high degree of accuracy.**
- **a radioactive strontium (^{90}Sr) rapid detection system integrating an automated multi-step ^{90}Sr separation/concentration technique and a high-accuracy separation detection technique using ICP mass spectrometry (ICP-MS).**
- **an analysis technique for imaging the micro-level distribution of a radioactive material in minerals or cells by an autoradiographic imaging technique and a local structure analysis technique using an electron microscope.**

What Did We Find?

Development of an underwater robot capable of preserving layered structure of sediments during lakebed sampling

Shipments of several kinds of fresh water fish such as the landlocked masu salmons and Japanese daces from lakes in the Fukushima Prefecture are still suspended. One of the reasons for this suspension is the possible contamination of lakes with radioactive materials (^{134}Cs and ^{137}Cs) brought by meltwater and rainfall coming from mountain forests. However, since a detailed mapping of radioactive concentration in the lakes has not been conducted, the dynamics of radioactive materials are unknown. In view of this, we are developing a small and lightweight underwater robot that allows easy operation to realize a technique for obtaining core samples without destroying the layered structure of bottom sediments. We hope to determine the state of radioactive materials in the bottom sediment of these lakes.

Development of a radioactive nuclide mapping system using a portable gamma-ray spectrometer

Environmental radioactivity monitoring using conventional survey meters does not allow monitoring of the distribution of environmental radioactive nuclides. We are developing a new system for mapping the distribution of radioactive materials in agricultural land and forests swiftly with a high degree of accuracy by combining a handy, high accuracy detector capable of measuring gamma-ray spectra and determining the quantity of radioactive nuclides with GPS.

Radioactive strontium (^{90}Sr) rapid analysis technique

Unlike caesium, mass atmospheric diffusion of ^{90}Sr, which is a nuclide emitting beta rays, is hardly observed. However, ^{90}Sr is still present in the nuclear reactor building in high concentration. Conventional measurement based on beta-ray measurement normally takes two weeks to one month since complicated chemical separation is necessary. We are focusing on the mass separation capacity of ICP-MS (mass separation capacity and isobar removal function) and started development of a technique, not for measuring beta rays but for separating and detecting radioactive nuclides on the basis of their mass. By integrating an automated multistep technique for separation (Sr isolation) and concentration with the functions of ICP-MS, we have succeeded in establishing an analysis technique that allows rapid and accurate (down to 1 Bq/L or lower) measurement.

Development of a technique for imaging micro-level distribution of a radioactive material

Research on the transfer process (e.g. from forests to rivers or from soil to creatures) of environmental radioactive caesium to a clay mineral, abundantly contained in Fukushima's soil, is gathering attention as a "reservoir of radioactive caesium" since it has a high Cs adsorptive capacity. We are trying to find "to what site inside the clay mineral Cs is likely to adsorb" by an autoradiographic imaging technique and a local structure analysis technique using an electron microscope.

How Will the Research Benefit Society?

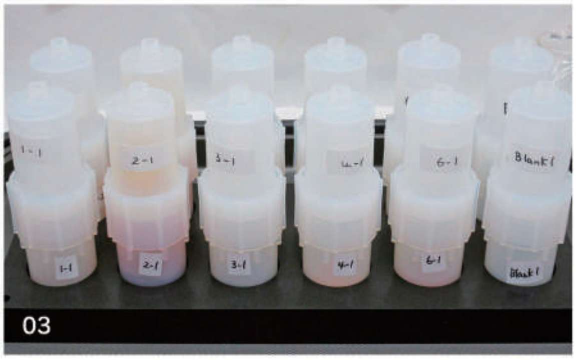
The IER is advancing research so that our measurement and analysis may clarify the situation of environmental radioactivity, which may contribute to the realization of a safe and secure environment for local residents. Environmental sampling, rapid analysis of radioactive nuclides and infinitesimal-scale analysis are some of the techniques that have been developed by our measurement and analysis project, which, together with other international research projects of the IER, contribute to the elucidation of environmental dynamics of radioactive material released into the environment due to the Fukushima Daiichi nuclear disaster.

Techniques developed by our project are actually used in environmental radioactive material monitoring. In particular, a radioactive strontium rapid analysis system is used in measuring strontium in rainwater accumulated around the contaminated water storage tank at the Fukushima Daiichi Nuclear Power Plant and the use of a radioactive nuclide mapping system using a portable gamma-ray spectrometer is being considered for monitoring for environmental recovery.

Project 5

Speciation Radiochemistry

01



[01] Sampling at Nagadoro agricultural pond in Iitate Village [02] A high-speed continuous centrifugal pump for sampling suspended matters [03] Radiocaesium extraction from bound-to-organic fractions by decomposition [04] Sampling of suspended matters in agricultural water at Ota in Minamisoma City [05] Laboratory experiment to study the transfer of radiocaesium from soil/water to rice [06] Sampling at a reservoir in Nagadoro, Iitate Village [07] Sampling of agricultural water using a submersible pump [08] An irrigation canal in Ota area, Minamisoma City

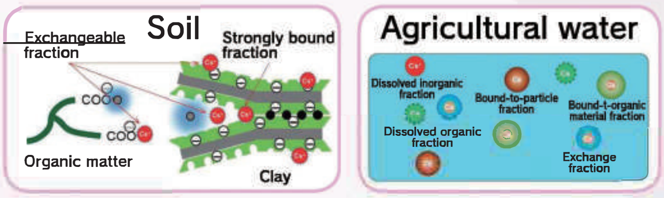
Project 5

Speciation Radiochemistry

Research on the Speciation and Behavior of Environmental Radionuclides for the Development of Efficient Decontamination Technology

Why Did We Start the Project?

It is crucial to measure radionuclides concentrations and distributions in the environment to understand their behavior and potential impacts. However, knowing the total amount of radionuclides in an environment is not sufficient to be able to predict their uptake into plants and animals. The movement of radionuclides in different environmental compartments, as well as uptake by plants and animals, varies greatly depending on the speciation of the radionuclides. Speciation refers to the various chemical and physical states in which radionuclides can exist. Determining the speciation of radionuclides is necessary to predict their movement and potential effects on environments. We, at the IER, aim to clarify the speciation of radionuclides. Our objective is to advance research by determining how speciation influences the environmental behavior of radionuclides. Understanding radionuclide speciation is also critical to separation technologies used in radioactive waste management.



(FIG) Chemical speciation of radiocaesium in soil and irrigation water

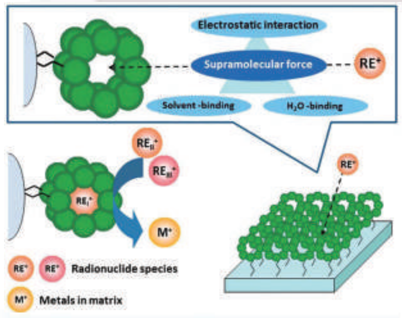
How Do We Study?

Speciation research determines the states in which radionuclides exist, and how speciation influences their movement in the environment. For example, radiocaesium in soil is taken up by plants at very different rates depending on the type of clay particles in the soil. Another example is radiocaesium that is in a dissolved state in water. It can move great distances and be easily absorbed into living tissues. In contrast, if the radiocaesium is not dissolved, but instead attached to particles in lake water, then the particles sink to the bottom sediments and the release of radiocaesium from the particle can take a long time. While the radiocaesium is attached to the particle, it is not available for uptake by plants. Therefore, it is important to find where, in which form, and how much radioactive caesium exists in a particular environment.

The following explains a specific research case. To understand the transfer of radiocaesium into rice, it is necessary to take into account the properties of soil and agricultural water. The rate of radiocaesium transfer to rice varies greatly depending on the type of soil. For example, the uptake of radiocaesium is relatively high if the rice is growing in sandy or humic soils. By adding various chemical solutions to samples of a soil, we can determine the speciation of the radionuclide and better predict its bioavailability to rice and other components in the environment. Water used for agricultural purposes contains both suspended and dissolved components. Radiocaesium is present in both, and knowing its fractional distribution in the suspended and dissolved states is critical to predicting its movement in the environment. We are also developing non-destructive techniques for effective removal or immobilization of radionuclides based on selective separation using a solid-phase extraction system equipped with molecular recognition capability.

What Did We Find?

Radiocaesium transfer from soil to brown rice can be quantified by “transfer factor”, defined as the ratio of radionuclide concentration in the crop to the radionuclide concentration in soil. A transfer factor for rice of 0.001 means that if the concentration of radiocaesium is 1,000 Bq/kg in soil, the amount that would be taken up by brown rice is only 1 Bq/kg. Radiocaesium existing in agricultural water is transferred to paddy fields in both dissolved and suspended forms. Therefore, to clarify the transfer of radiocaesium from agricultural water to brown rice, it is necessary to analyze both forms. The radiocaesium content in the dissolved form can be measured by straining the water through a filter with a tiny pore size (0.45 μm). The amount of radiocaesium in the suspended form requires filtering large amounts of agricultural water (2,000 to 4,000 L) using a high-speed centrifugal pump. Then the fractions of radiocaesium can be determined by sequential extraction methods. The transfer factor of radiocaesium from the dissolved fraction to brown rice is approximately 10 (1 Bq/L in water results in 10 Bq/kg in brown rice), which is 10,000 times higher than the radiocaesium transfer from soil. However, the good news is that only small amounts of radiocaesium exist in the dissolved fraction of agricultural water. Therefore, the radiocaesium content in brown rice is mainly due to its uptake from contaminated soil, and that uptake is low. Uptake of radioactive iodine released from the Fukushima Daiichi nuclear accident into plants also varied depending on iodine’s speciation. It is well-known that iodide (I^-) is easily absorbed, whereas iodate (IO_3^-) is unlikely to be absorbed. To better understand the environmental movement of radioactive iodine, we are studying the use of solid-phase extraction agents for speciation analysis of iodine in the agricultural waters.



The Supramolecular Chemistry leads to the selective recognition of elements based on the charge and ion size

(PIC) An experimental farm field in Okuma Town

(PIC) A reservoir in Nagadoro, Iitate Village

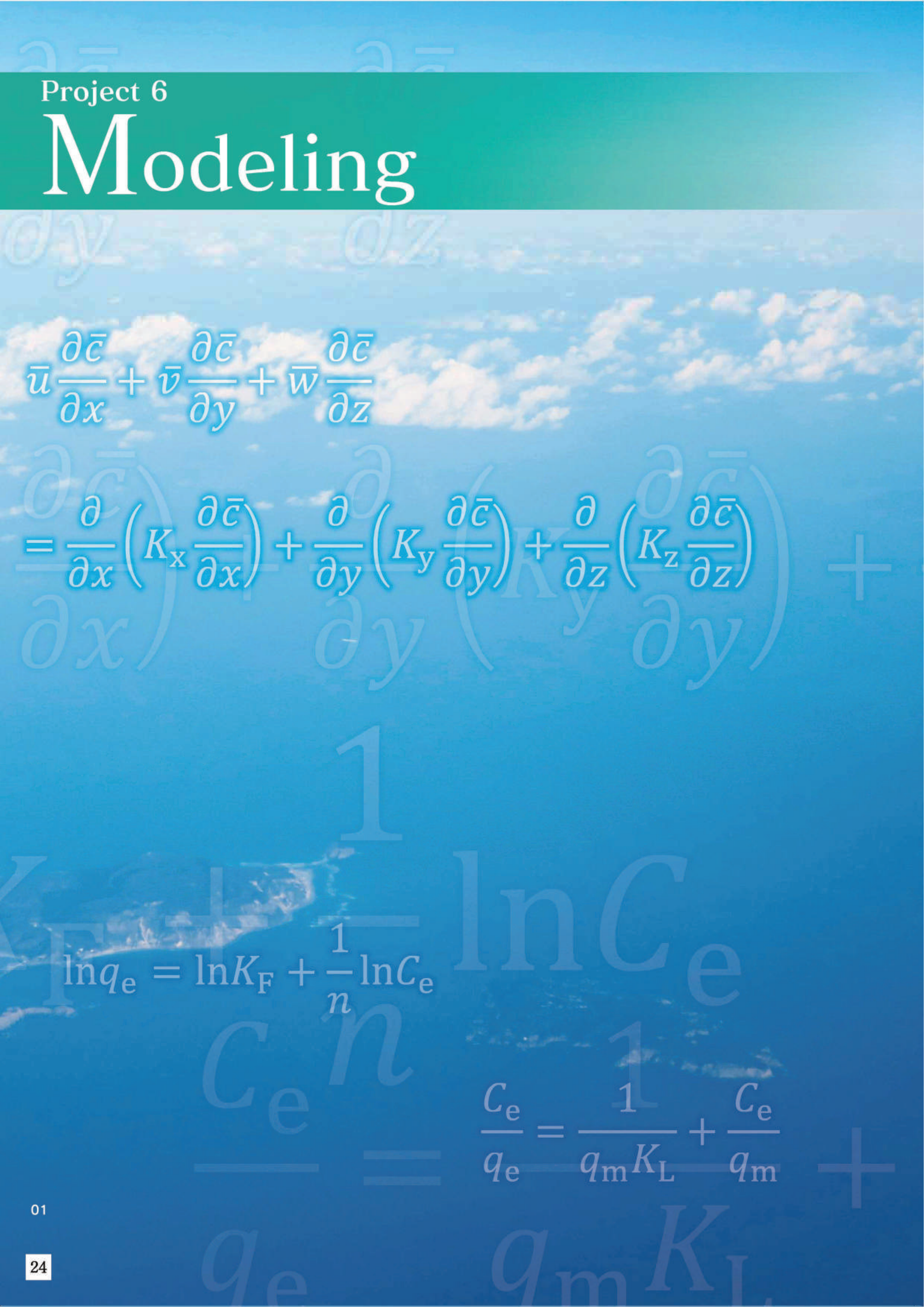
How Will the Research Benefit Society?

As explained above, research on speciation of radionuclides is necessary since environmental movement and absorption in living beings and plants largely vary depending on it.

As an example, the previous section shows that transfers of radiocaesium to plants from soil and agricultural water depend largely on speciation of the radionuclide. We are also conducting research on re-elution of radiocaesium accumulated in the reservoir bottom sediments, and the proportion of radiocaesium in boar food that is absorbed by their body.

Innovative information on the speciation of radionuclides clarifies the environment in which a radionuclide is likely to be mobile and thus taken up by organisms. Such information also clarifies in which form of radionuclide the transfer can be controlled or minimized. Furthermore, we are working to establish eco-friendly, cost-effective techniques for selective separation of radionuclides from solutions and soil and to develop an efficient method for radioactive waste remediation.

(PIC) A temporary storage area of contaminated soil in Okuma



Project 6

Modeling

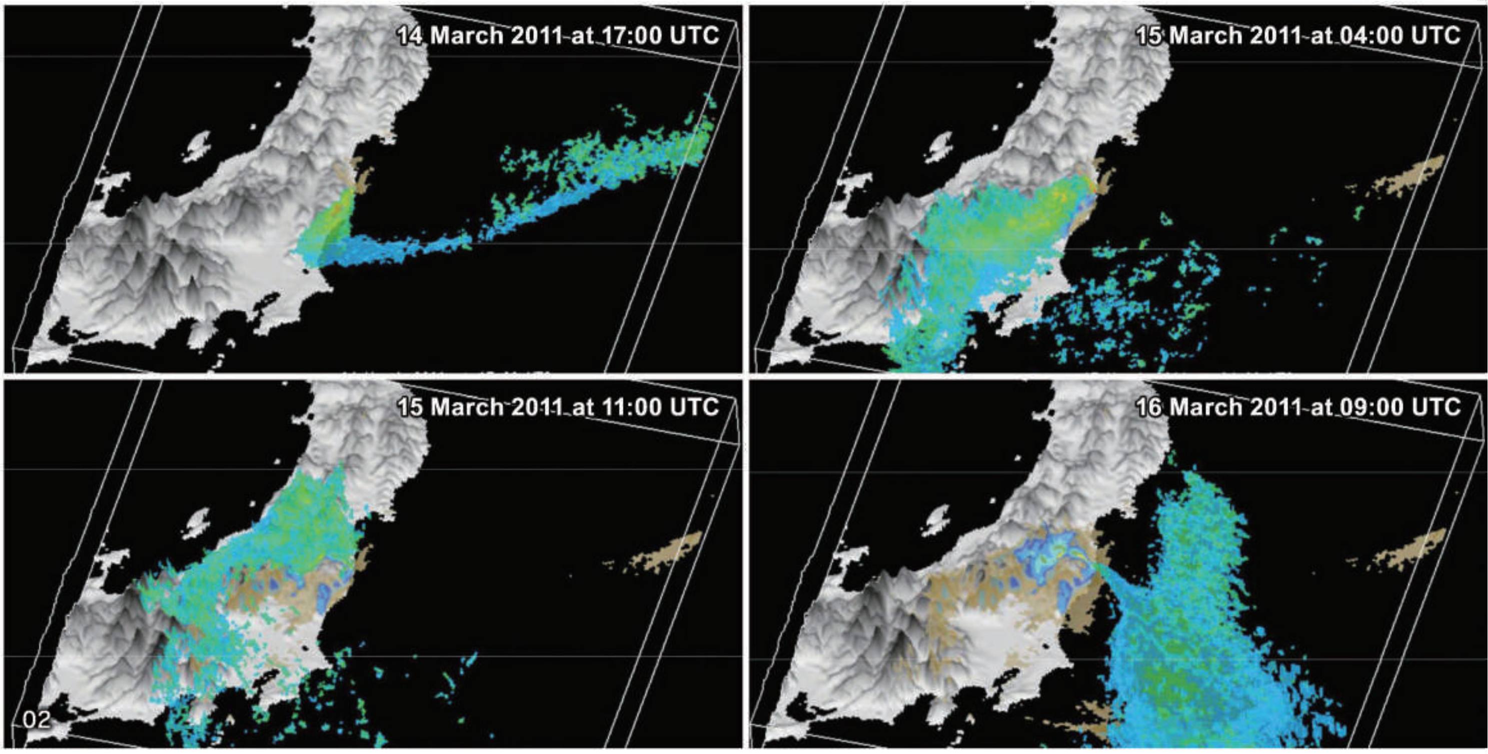
$$\bar{u}\frac{\partial \bar{c}}{\partial x}+\bar{v}\frac{\partial \bar{c}}{\partial y}+\bar{w}\frac{\partial \bar{c}}{\partial z}$$

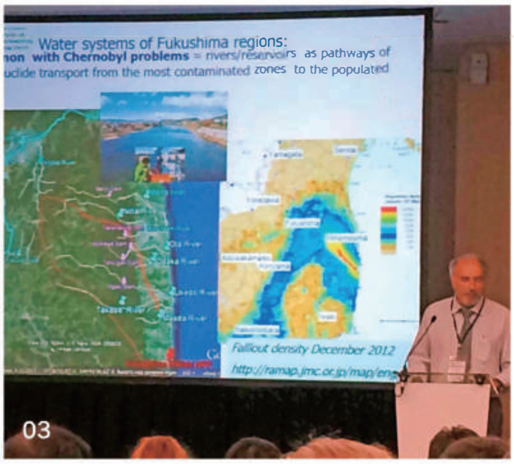
$$=\frac{\partial}{\partial x}\left(K_{\mathrm{x}}\frac{\partial \bar{c}}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_{\mathrm{y}}\frac{\partial \bar{c}}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_{\mathrm{z}}\frac{\partial \bar{c}}{\partial z}\right)$$

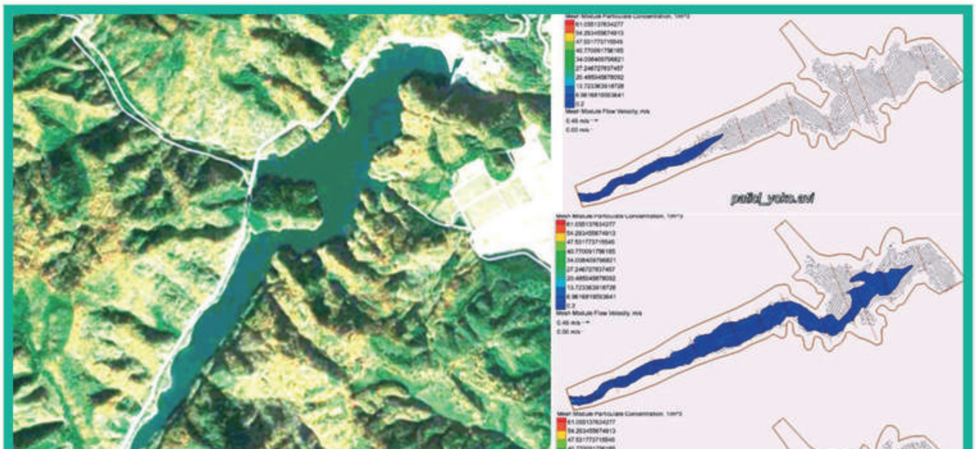
$$\ln q_{\mathrm{e}} = \ln K_{\mathrm{F}} + \frac{1}{n}\ln C_{\mathrm{e}}$$

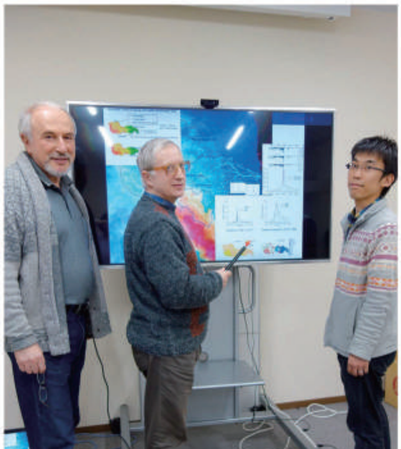
$$\frac{C_{\mathrm{e}}}{q_{\mathrm{e}}} = \frac{1}{q_{\mathrm{m}}K_{\mathrm{L}}} + \frac{C_{\mathrm{e}}}{q_{\mathrm{m}}}$$

01









[01] An aerial photo of the Pacific [02] An example of an atmospheric dispersion model calculation result [03] Presentation at the international academic conference [04] An example of a river model calculation result [05] Joint reservoir investigation with our river/lake project [06] Explanation of a restoration plan using a diorama at Okuma Town community center [07] Discussion of calculation results

Project 6

Modeling

Development of Radionuclide Transport Models for Atmosphere, Forests, Rivers, and Lakes for Emergency and Long-term Prediction

Why Did We Start the Project?

How are the radioactive materials released as a result of the Fukushima Daiichi nuclear accident in March 2011 spreading? What will happen to the released radioactivity in Fukushima in the future? What can happen in terms of contamination levels under extreme climate conditions such as heavy rain and strong wind?

All these questions can be answered based on tools and techniques for predicting transport of radioactive materials. To accomplish this task, both monitoring and numerical modeling are to be employed.

In the numerical model used, atmospheric dispersion of radioactivity is modelled using mathematical formulations in an integrated way, which enables deriving time evolution of activity concentration or air dose rate for any location. The wealth of experience gained following the Chernobyl accident is available; however, the Fukushima environment has its own features and the existing knowledge is not always sufficient to account for the ongoing processes. The challenging task before our group is: to further develop the models using emerging knowledge after the Fukushima accident. Based on a newly developed and more reliable model, we seek to understand the current radiation situation and predict its development in the future.

The goals of our group include:

1. Collating new knowledge about radioactivity dispersion in the environmental media of Fukushima prefecture (air, forests, rivers, and lakes), in cooperation with the IER monitoring group, with a view of developing models.
2. Using models to predict radioactivity dispersion under extreme climate conditions on a short time scale from several days to several weeks, as well as long-term transport on a scale of up to several decades.
3. Using models to verify whether the countermeasures implemented will ensure containment of environmental contamination and reduce radiation dose for the general public in affected regions. Our research using numerical calculation models will contribute to the scientific knowledge required for nuclear emergency preparedness and development of countermeasures.

How Do We Study?

The IER modeling group comprises researchers of complementary backgrounds: members with more than 30 years' experience in post-Chernobyl studies and expertise in radionuclide dynamics and relevant fields, as well as capable young Japanese researchers. Close cooperation with the IER monitoring group allows us to incorporate the latest Fukushima data into mathematical models. Observations of forests, rivers, and lakes have been conducted by this group since the IER establishment in 2013. Radionuclide transport models were actively developed for Europe and US based on observational data primarily after the Chernobyl accident. These models are now employed to understand transport processes in the

Fukushima environment based on the current observations and will be further developed in the future. The models serve to predict, among other things, spatial and temporal distribution of radioactivity and address basically three environmental compartments: air, forests, and rivers/lakes. Using the atmospheric dispersion model developed by members of our group prior to the Fukushima accident, inverse modeling was performed for the processes; e.g., advection, diffusion, dry and wet deposition of radioactive materials released from FDNP. Understanding changes in the airborne concentrations of radionuclides and their depositions is important to explain the current situation. Use of models also allows us to clarify temporal spatial distribution of materials for which information could not be obtained through monitoring in the early stage of the nuclear disaster. There is no question that comparison of observational data, measurements and simulated results will help to improve emergency countermeasures and prediction of radionuclide transport processes, in particular, in extreme climate conditions.

What Did We Find?

Another model under development is the forest transfer model which is a compartment model based on measurements in the Yamakiya area forest. In this model the forest is divided into the tree and soil sections, which are subdivided into compartments; for example, leaves, crowns, branches and roots. Mass transfer flux between the compartments is integrated over time to estimate activity concentrations in each compartment. The model allows prediction of long-term transfer of radioactivity as a function of the forest age.

The model applied to rivers and lakes is the basin model of radionuclide water transport. It includes sub-models accounting for 1) wash-off 2) river transport and 3) dispersion in a water body for estimating 2D or 3D distributions of radionuclide activity concentrations.

As shown by calculations, the radiocaesium washoff to rivers during floods in heavy rains is higher as compared to Chernobyl because of steeper slopes. At the same time, radioactivity can be transported along the river from water reservoirs in highly contaminated areas (such as evacuation zone) to densely populated territories. To be able to predict radiocaesium transport, with consideration of floods, a model is being developed for water reservoirs upstream of the Mano River, nearby rivers and the Niida River basin. These models are expected to provide scientific data for assessing effects of decontamination activities for water reservoirs used for agricultural purposes on contaminated areas.

How Will the Research Benefit Society?

In the future, we will continue elaboration and verification of our models using observational data. Several avenues for applying our models can be envisaged: the forest model can be used to predict radionuclides transfer to wood, which is essential for revival of the forest industry. The same model can actually be employed to evaluate effects of decontamination measures. Likewise, the rivers/lakes model can be used to identify effective decontamination technique for dry riverbeds and specifically to help decision-making for recreational activities on former dry riverbeds. The rivers/lakes model is useful for predicting radionuclide transport to downstream basins and developing appropriate mitigation methods. The atmospheric dispersion model will be applicable in case of a nuclear accident to predict atmospheric transport and resuspension of radioactivity. The lessons learned with respect to modeling following the Fukushima accident are to be made available outside Japan to use in similar emergencies. Just as experience gained after the Chernobyl accident is utilized in Fukushima, we stand ready to apply elsewhere the knowledge obtained in Fukushima.

Collaborative Research Institutes

National University Corporation

Fukushima University

Fukushima University, as the only national university situated in the prefecture affected by the Fukushima Daiichi Nuclear Power Station accident, established Institute of Environmental Radioactivity (IER) for the purpose of contributing to the local community through the research activities of elucidating the transport mechanism of radionuclide in the environment and its impact on ecosystems. The IER, with its unique location close to the accident-affected areas, pursues research to better understand the long-term effects of radionuclides released into the environment in Japan's temperate and humid climate, in cooperation with other Japanese and international universities and research institutes. The IER shares the knowledge acquired through research activities both domestically and internationally, as well as broadly disseminates the expertise and information required by the affected municipalities.

Fukushima University

University of Tsukuba

HIROSHIMA UNIVERSITY

IER

NAGASAKI UNIVERSITY

TUMSAT Tokyo University of Marine Science and Technology

FUKUSHIMA MEDICAL UNIVERSITY

QST

Environmental Radioactivity Research by Collaborative Research Institutes

National University Corporation

University of Tsukuba

The University of Tsukuba (UoT) will continue the research launched immediately after the accident, including investigation of radionuclide transport in the environment of forest and land areas. As part of a joint project, UoT will participate in model experiments aiming to clarify the radionuclide transport in the rivers and oceans by using a 150 meter-long flume and a wave tank to evaluate the radionuclide behavior under controlled conditions that mimic the natural environment. Leveraging the analyzed data and the monitoring knowledge, through the collaboration with the IER as well as other domestic and international institutes, UoT will further promote the research of radionuclide environmental dynamics, focused on the rivers and forests; joint implementation of water analysis in compliance with international accuracy standards; joint usage of a database; and the sharing of techniques to evaluate radionuclide behavior in the environment.

National University Corporation

Hiroshima University

Hiroshima University, having the best-equipped research facility for amphibian biology affiliated with a graduate school, has been investigating radiation effects on animals and plants as well as experiment data management. Its research is focused on 1) morphological change of affected amphibians, 2) genetic analysis to study the effects of a genetic trait, 3) analysis of the impact for the next generation, and 4) wild species (tailed/tailless amphibian) which inhabit the areas around the Fukushima Daiichi Nuclear Power Plant. Hiroshima University intends to clarify the effects of acute exposure and of low-dose, long-term exposure and to establish an evaluation system of radiation impact. To investigate the effect of radionuclides released by the nuclear accident on the plant ecosystems, Hiroshima University conducts a field survey of moss plants in the Fukushima area and accumulates the survey data on radiation effects on the organisms in the environment.

National University Corporation

Nagasaki University

Utilizing the base set up in the Republic of Belarus, Nagasaki University (NU) has been evaluating the dynamics of environmental radioactivity and clarifying its impact in areas such as Chernobyl and Semipalatinsk nuclear test site, in collaboration with international institutions such as IAEA and WHO in Japan and overseas in the field of radiation health risk control. After the nuclear accident, NU set up a reconstruction promotion base in Kawauchi village, Fukushima Prefecture, and conducted radiation dose estimation based on the measurement of radiocaesium concentration in soil, water, and food, as well as evaluation of long-term dynamics of radiocaesium, especially in foods leveraging the research results. In particular, NU takes part in research on the dynamics of radionuclides based on the food chain through animals.

National University Corporation

Tokyo University of Marine Science and Technology

Tokyo University of Marine Science and Technology (TUMSAT), utilizing its unique resources in the TUMSAT Center for Marine Research and Operations, has established a framework for conducting radioecological surveys in coastal and offshore areas of Fukushima; the surveys are aimed at clarifying the radiocaesium dynamics of the marine ecosystem. With the continuous monitoring of the spatiotemporal change of radiocaesium in marine organisms and their environment, researchers are identifying the transfer pathway of radiocaesium into the food chain, which would affect the decrease rate of radioactivity in the living bodies of marine biota. TUMSAT has been conducting survey cruises of the university's own research and training vessels, in response to requests from domestic and overseas researchers and in cooperation with collaborative research institutes.

Public University Corporation

Fukushima Medical University

Fukushima Medical University has a university hospital serving as the center of the medical institution network in Fukushima Prefecture, including a disaster base hospital function. Since the Fukushima Daiichi nuclear accident, the university has also played a role as an institution not only to provide medical care for nuclear accidents, but also to support general healthcare in the affected areas. Subsequently, the University established the Fukushima Global Medical Science Center, which includes a department for estimation of radiation dose to the public. Measurement of environmental radiation for the dose estimation is included as a part of activities of the department.

Quantum Medical Science Directorate of National Institutes for Quantum and Radiological Science and Technology

Quantum Medical Science Directorate of National Institute of Radiological Sciences utilizes its prior achievements and human resources related to radioecology to contribute to the advancement of research on dynamics of radionuclides in the environment and ecosystems, focusing on ecological functions such as biogeochemical cycles. It also participates in the research on the behavior of radionuclides in the environment based on their development of the world's most advanced isotope analysis technology for low activity concentrations of radionuclides (e.g., strontium and actinoid).

*In April 2019, National Institute of Radiological Sciences was merged into Quantum Medical Science Directorate of National Institutes for Quantum and Radiological Science and Technology.

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(As of April, 2023)

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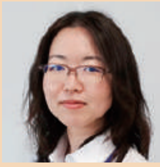

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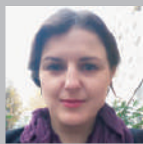

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Radiobiology

Alan CRESSWELL
Specially Appointed Researcher
Project Associate Professor (Sep. 2014 - May 2016)
Ph.D. (Nuclear Structure Physics)
【Research Interests】
Radiation Measurement Technology

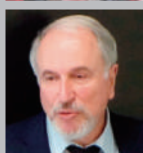
Kei OKUDA
Specially Appointed Researcher
Project Assistant Professor (Apr. 2014 - Mar. 2017)
Ph.D. (Agriculture)
【Research Interests】
Wildlife Management, Wildlife Ecology, Radioecology

AkiraWATANABE (Adjunct Researcher)
Project Professor (Aug.2013 - Mar.2018)
(Faculty of Symbiotic Systems Science)
Doctor of Science
【Research Interests】
Geophysics (Meteorology)

Tsugiko TAKASE
Specially Appointed Researcher
Project Associate Professor (Apr.2014 - Mar.2020)
Doctor of Science
【Research Interests】
Chemical Physics

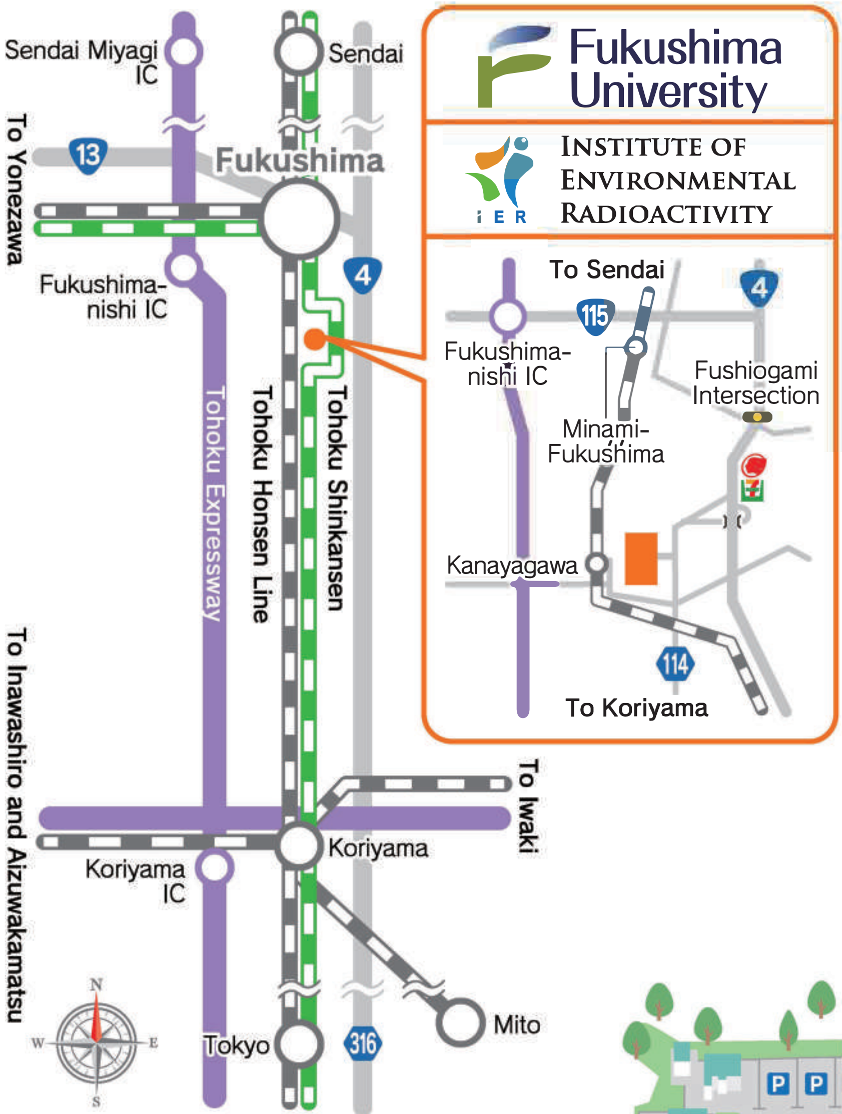
Michio AOYAMA
Specially Appointed Researcher
Professor (with Fixed Term) (Feb.2014 - Mar.2019)
Doctor of Science
【Research Interests】
Geochemistry, Oceanography, Environmental Radioactivity

Thomas HINTON (currently Visiting Professor)
Professor (Mar. 2015 - Oct. 2018)
Ph.D. (Radiation Ecology)
【Research Interests】
Radioecology

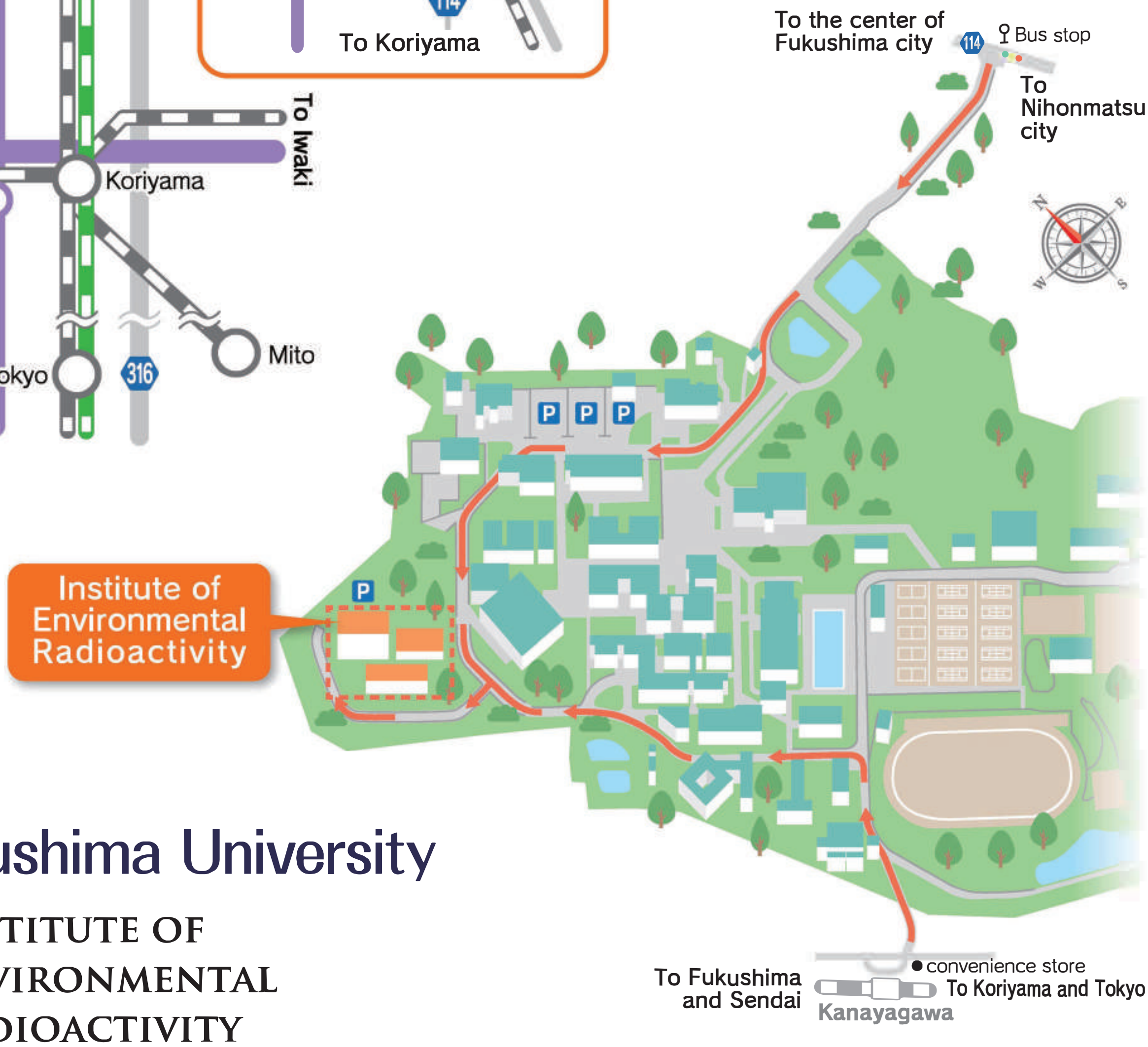


Mark ZHELEZNYAK (currently Visiting Professor)
Professor (Mar. 2015 - Mar. 2016)
Ph.D. (Fluid Mechanics)
【Research Interests】
Environmental Hydrology

Access



Campus Map



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