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Foreword

This annual report is the official record of activities at the National Institute for Environmental Studies (NIES) in Fiscal Year 2018 (FY2018: April 2018 to March 2019) which marks the third year of our Fourth NIES Five-Year Plan (FY 2016-FY2020).

NIES established its Fukushima Branch in the Research Building of Fukushima Prefectural Centre for Environmental Creation as a collaboration hub to conduct environmental emergency research in 2016 along with the seven research centers in Tsukuba Headquarters – the centers for global environment; material cycles and waste management; health and environmental risk; regional environment; environmental biology and ecosystems; social and environmental systems; and environmental measurement and analysis. In April 2017, Lake Biwa Branch Office was established located inside Lake Biwa Environmental Research Institute. The Center for Climate Change Adaptation was established in December 2018 to research and promote adaptation to climate change, whose mission includes collecting, analyzing, and providing scientific information regarding climate change adaptation to help plan and execute adapatation actions by local government and other agencies.

Each research center undertook basic research on various aspects of environmental issues whereas issue-driven research has been jointly carried out under five *Issue-Oriented Research Programs* - low carbon; sustainable material cycles; harmonization with nature; health and environmental safety; and environment-economy-society integration. Besides these research programs, three *Environmental Emergency Research Programs* - environmental recovery; environmental renovation; and environmental emergency management - have been undertaken in the aftermath of the Great East Japan Earthquake. Starting from the preceding five-year plan period, NIES also continued the activities to support and promote broad range of environmental research by updating and offering various type of tools and data: various type of monitoring activities; a greenhouse gas emissions inventory; environmental as well as biological specimen banking; reference laboratory functions; and various environmental databases.

Activities closely associated with NIES' research have been categorized as Research Project, which are to meet the increasing society's demands to make full use of research outcomes. These included observation of earth-level GHGs by Greenhouse Gases Observing Satellite (GOSAT) and a nation-wide birth cohort study by the Japan Environment and Children's Study (JECS), showing firm progress and generating achievements. In addition, several Collaboration Offices have been organized to serve as the primary promotion body of these projects and to facilitate smooth collaboration within and/or outside NIES.

The society's needs for environmental research such as analyzing and predicting climate change and its effects, designing adaptation measures for this, and achieving Sustainable Development Goals (SDGs) are steadily increasing. Here, challenge for NIES is to figure out how effectively we could give back and implement these research outcomes to the community. Thus, while focusing on its primary mission as a research institute, NIES will also strive to focus on activities that emphasize being in touch with the society and holding social dialogues.

NIES furthers advance and research networks domestically and globally, having research agreements with

more than 50 foreign institutes and universities, and 14 research projects conducted under the Science and Technology Cooperation Agreements between the governments. Furthermore, NIES contributes to various kinds of global initiatives including Intergovernmental Panel on Climate Change (IPCC), Global Climate and Health Alliance (GCHA), and Future Earth. To promote research collaborations in Asia, NIES together with National Institute of Environmental Research (NIER; Korea) and Chinese Research Academy of Environmental Sciences (CRAES; China) participated in the 15th Tripartite Presidents Meeting in Busan, Korea and exchanged views for future collaborations. NIES also held the 4th NIES International Forum to discuss with Asian research communities in Hanoi, Vietnam.

We hope that this report will help facilitate a greater understanding of our institute's activities, and we invite your full and frank feedback and opinion about these activities.

Watanabe, Chiho
President
October, 2019

Contents

During the 1950s and 1960s, Japan experienced serious environmental pollution problems accompanying rapid economic growth. The Environment Agency was established in 1971 as part of the Japanese government to develop measures to counteract serious problems associated with environmental pollution, such as Minamata disease, which was caused by poisoning from organic mercury in factory wastewater, and chronic bronchitis and asthma caused by sulfur oxides from factories in large industrial complexes. Understanding that research on environmental sciences was necessary and could address public needs, the Environment Agency established the National Institute for Environmental Studies (NIES) in Tsukuba Science City, about 50 km north of Tokyo, in 1974. It is now Japan's primary institute for comprehensive research in environmental science.

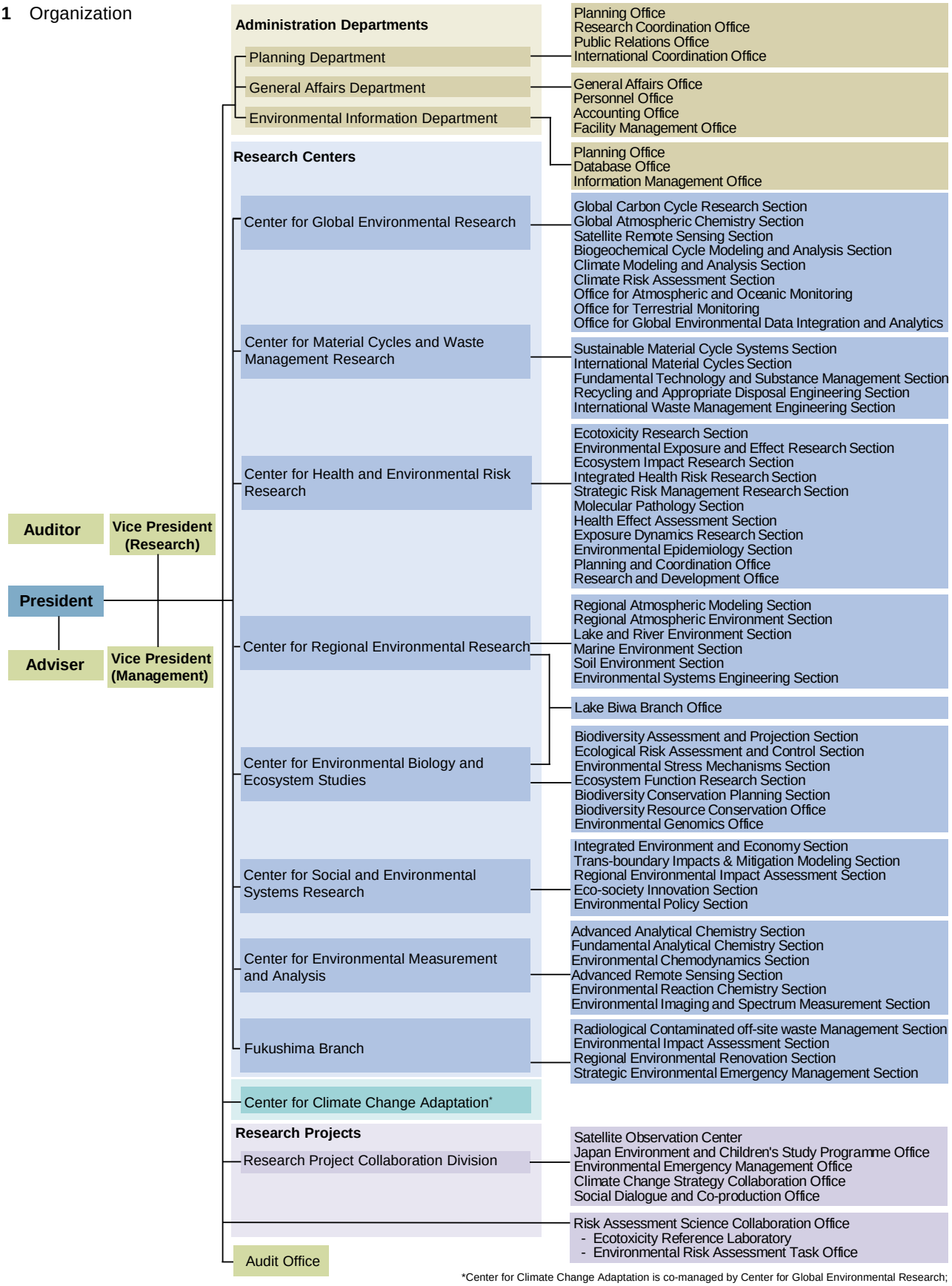
During the two decades following the establishment of NIES, rapid technological progress, structural changes in industry, and lifestyle changes, created additional issues for environmental science to confront. Moreover, global environmental problems such as climate change; depletion of the stratospheric ozone layer; acid deposition; destruction of tropical rain forests; desertification; and decreasing biodiversity, attracted greater concern worldwide. NIES subsequently underwent a major reorganization in 1990, including the establishment of the Center for Global Environmental Research, to enable it to conduct more intensive research on conservation of the natural environment and on global environmental changes and their effects.

January 2001 saw the transition of the Environment Agency into the Ministry of the Environment as part of structural changes within the Japanese government, and the establishment of a Waste Management Research Division at NIES. That year also marked the establishment of NIES as an Incorporated Administrative Agency, giving it a degree of independence from the national government. The change in the administrative status of the institute allows more prompt and flexible responses to societal demands. Concurrently, NIES prepared a five-year plan (2001–2005) in line with the objectives of the Ministry of the Environment.

Following the second five-year plan (2006-2010), the third five-year plan (2011–2015) was adopted in 2011. During the third five-year plan, research was carried out under eight fundamental fields of environmental research. Research activities to respond to and recover from the Great East Japan Earthquake have also been ongoing since the direct aftermath of the disaster. In March 2013, the five-year plan was revised following a directive of the Minister of the Environment and NIES relaunched as a National Research and Development Agency from April 2015.

April 2016 marked the beginning of the forth medium-and-long-term plan (2016-2020). NIES established five issue-oriented research programs for this plan's term, and has been pursuing them in an integrated manner that transcends individual fields. NIES has established Fukushima Branch, where it is running Environmental Emergency Research Programs. Also in April 2017, Lake Biwa Branch Office was established

Fig. 1 Organization



*Center for Climate Change Adaptation is co-managed by Center for Global Environmental Research; Center for Regional Environmental Research; Center for Environmental Biology and Ecosystem Studies; and Center for Social and Environmental Systems Research.

located in Lake Biwa Environmental Research Institute where developed research for water environmental protection is jointly conducted. In December 2018, the Center for Climate Change Adaptation was established to research and promote adaptation to climate change. Furthermore, to produce scientific findings on environmental protection, NIES has been carrying out research projects that include consolidating the institute's research foundation through basic research, data acquisition and analysis, preservation and provision of environmental samples, and other efforts.

NIES plays a central role in research networks too, for example GOSAT satellite observations and the Japan Environment and Children's Study (a large-scale environmental epidemiology survey). Also important among our tasks is actively disseminating environmental information in easy-to-understand formats, including the outcomes of our research efforts and projects.

As of April 1, 2019, there are 291 NIES permanent staff and 496 non-permanent researchers (Table 1; Figs. 2 to 5). The total budget for FY2018 was 17,298 million yen (Table 2).

Table 1
Numbers of permanent staff

Administration Departments	58
Research Centers	227
Executives and Advisers	6
Total	291

(As of April 1, 2019)

Table 2
Budget for the fourth five-year plan

(Unit: million yen)

Category		2016–2020 Budget (5 years)	Fiscal Year 2018 Budget
Revenue	Grants for Operating Costs	62,665	13,370
	Subsidies for Facilities	1,710	370
	Commissioned Work	17,786	3,557
	Total	82,162	17,298
Expenditure	Project Costs	44,399	9,568
	Facility Improvements	1,710	370
	Expenses for Commissioned Work	17,786	3,557
	Personnel Expenses	16,112	3,316
	General Administrative Expenses	2,154	487
	Total	82,162	17,298

Note: The budget for each annual work plan will be requested and decided for each fiscal year, based on the medium-and-long-term plan.

Administration Departments	:	58	
Research Centers	:	227	(4)
Executives and Advisers	:	6	
Total		291	(4)

Notes:
1. Data is as of April 1, 2019.

2. Figures in parentheses indicate number of non-Japanese.

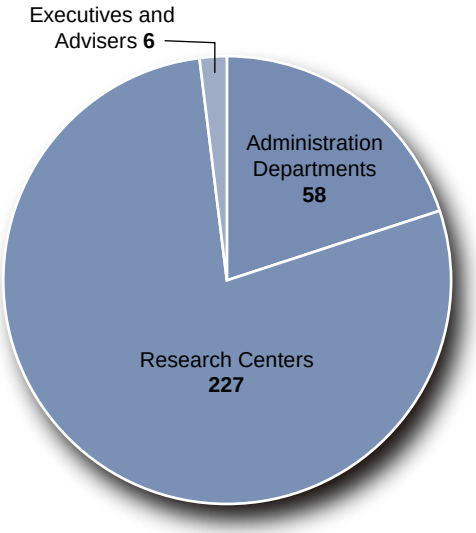


Fig. 2 Permanent staff breakdown

Basic Sciences (Physics, Chemistry, Biology)	:	89	41.98%
Engineering	:	64	30.19%
Agricultural Sciences	:	31	14.62%
Medical Sciences	:	9	4.25%
Economics	:	6	2.83%
Sciences	:	6	2.83%
Pharmaceutical Sciences	:	4	1.89%
Fisheries Sciences	:	1	0.47%
Law	:	1	0.47%
Veterinary Medicine	:	1	0.47%
Total		212	

Notes: Data is as of April 1, 2019.

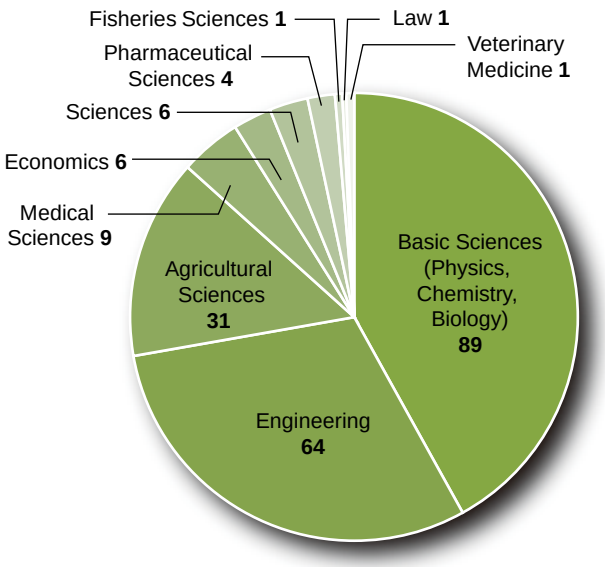


Fig. 3 Fields of expertise（Researchers holding doctorates（95.3%））

Senior Fellow	:	1	
Fellow	:	12	
Research Associate	:	86	(30)
Junior Research Associate	:	12	(5)
Research Assistant	:	25	(8)
Specialist	:	208	(6)
Assistant Staff	:	291	(1)
Senior Staff	:	6	
Senior Research Associate	:	8	
Total		649	(50)

Notes:
1. Data is as of April 1, 2019.

2. Figures in parentheses indicate number of non-Japanese.

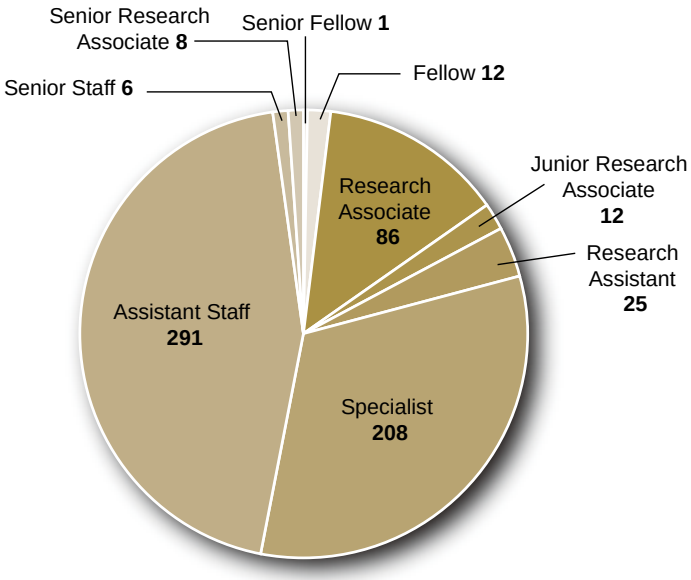


Fig. 4 Contract Staff Breakdown

Visiting Researcher	232	(8)
Research Student	42	(22)
Collaborative Researcher	78	(11)
Total	352	(41)

Notes:

1. Data is the total number accepted in FY2018.

2. Figures in parentheses indicate number of non-Japanese.

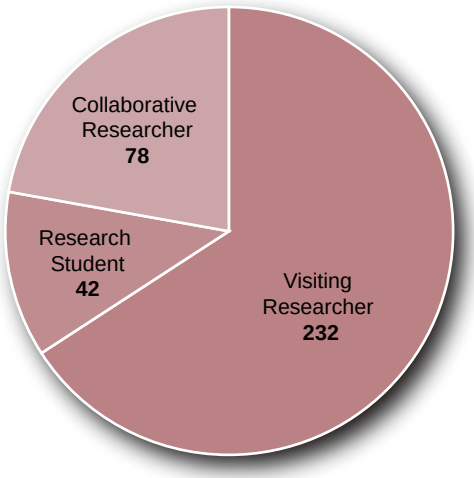


Fig. 5 Visiting and Collaborative Researchers and Research Students

Issue - Oriented Research Programs

Low-Carbon Research Program

The concept behind this program is to build a scientific foundation that society can use to tackle the goal of keeping the global mean surface temperature increase well below 2 °C, and preferably below 1.5 °C, relative to pre-industrial levels. In the program we will conduct observations, mainly in the Asia-Pacific region, to assess the balances of the greenhouse gases (GHGs) that cause global warming, as well as climate change impacts and control measures. To accomplish this, we will use surface and aerial observations, and data from observation satellites launched in 2009 and 2018, to develop a highly reliable three-dimensional global-scale GHG monitoring system. Furthermore, we will combine climate change projection models, impact assessment models, and integrated socioeconomic assessment models and use them to discuss the need for, and feasibility of, building a sustainable, low-carbon society along the path indicated by this comprehensive research program.

The program consists of three research projects: (1) Study of a multi-scale system for observing and evaluating GHG variation and mitigation; (2) Global-scale climate risk research based on integrated assessment of climate projections, impacts, and response options; and (3) Policy assessment research toward a global low-carbon society (Fig. 1). Each project and its research highlights are described below.

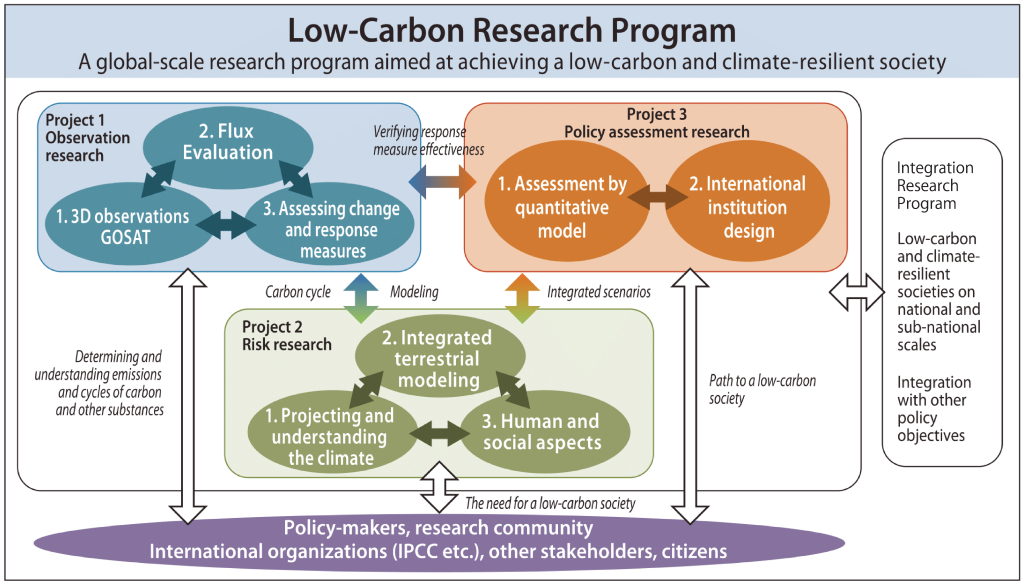


Fig. 1 Structure of the Low-Carbon Research Program. The three projects interact with each other and with society.

1. Study of a multi-scale system for observing and evaluating GHG variation and mitigation (Project 1)

This project aims to develop a multi-scale observation and analysis system for

estimating spatial and temporal variations in the atmospheric concentrations of GHGs and their surface fluxes, including those from anthropogenic and natural sources and sinks. The system is essential for analyzing a variety of climate change mitigation and adaptation policies and evaluating their effectiveness. The project comprises three sub-themes: (1) Evaluation of GHG budgets at different spatial scales, from global to local; (2) Estimation of oceanic and terrestrial GHG budgets and their upscaling; and (3) Assessment of climate change impacts and climate change mitigation policies.

In FY 2018, sub-theme 1 estimated global carbon sinks of the ocean and land biosphere by using time series of the atmospheric O_2/N_2 ratio and the CO_2 mole fraction of flask samples taken from ground stations and cargo ships sailing in the western Pacific. From the results, we estimated that the oceanic and land biotic carbon sinks were 2.3 ± 0.6 PgC year^{-1} and 2.0 ± 0.8 PgC year^{-1}, respectively, for the 14-year period from 2003 to 2016. The 5-year averaged ocean sinks showed an increasing trend during 2001–2014, whereas the land sinks showed an increasing trend for 2001–2009 and a decreasing trend during 2009–2014.

To examine the temporal and spatial distribution of ocean sinks in more detail, sub-theme 2 estimated the ocean surface partial pressure of CO_2 (pCO_2) in the global ocean (60°S–70°N) from 2001 to 2014 on the basis of an international pCO_2 database and bio-geophysical datasets. The pCO_2 trend distribution was then evaluated (Fig. 2). A high pCO_2 trend of about 2 to 3 µatm year^{-1} was apparent in the equatorial Pacific and in part of the subtropical Pacific, mainly due to the El Niño Southern Oscillation. On the other hand, a low pCO_2 trend (<2.0 µatm year^{-1}) was apparent in the high latitudes of the North Pacific (except in the Bering Sea), in the central subtropical Pacific, and in the high latitudes of the North Atlantic. The evaluated global mean pCO_2 trend (1.6 µatm year^{-1}) was lower than that of the atmosphere, suggesting that the lower oceanic pCO_2 trend was a main driver of increased oceanic CO_2 uptake in this period.

Finally, sub-theme 3 developed spatially explicit maps of anthropogenic GHG emissions at city to regional scales. First, a fine-mesh (1 km resolution) map of CO_2 emissions in Tokyo was developed, considering the characteristics of emission sectors such as industry, transportation, and residence. Second, we developed a moderate-mesh (0.5º resolution) map of N_2O emissions from natural and agricultural soils in East Asia in 1901–2015 by using a process-based ecosystem model. These emission maps are useful for interpreting observational data and improving inverse estimation in collaboration with sub-themes 1 and 2; they also will help facilitate future assessments in collaboration with project 2.

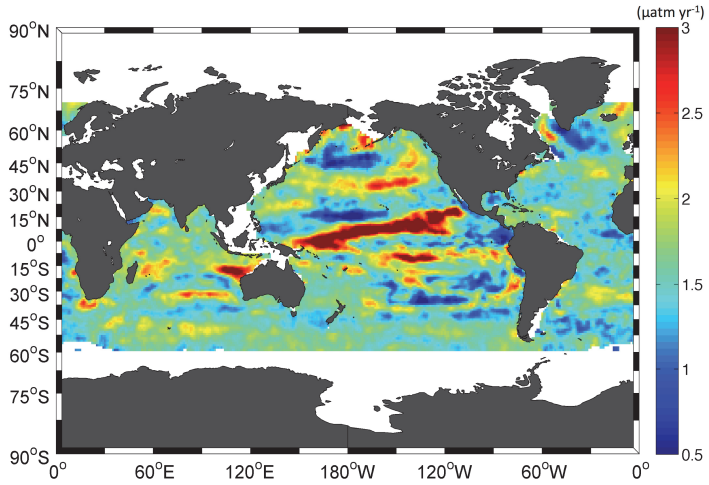


Fig. 2 Map of ocean pCO_2 trends from 2001 to 2014, based on an international pCO_2 database and bio-geophysical datasets

2. Global-scale climate risk research based on integrated assessment of climate projections, impacts, and response options (Project 2)

In this project, we are developing a comprehensive modeling approach in which models for climate projections, impact assessments, and assessments of response options at a global scale are used in an integrative manner. With this approach, we aim to describe synthetic scenarios of climate change risk. This project consists of three sub-themes: (1) Projection and interpretation of climate change; (2) Synthetic assessment of low-carbon scenarios based on an integrated terrestrial model; and (3) Assessment of climate impacts, adaptation, and mitigation from the human and social perspectives.

Sub-theme 1 contributes to the development of climate change risk scenarios by projecting the future climate and understanding past climate changes. This fiscal year, we discussed an oscillation in the zonal winds of the equatorial stratosphere known as the quasi-biennial oscillation (QBO). The QBO was disrupted in February 2016; this was unprecedented and was not predicted by forecast models. Our analysis revealed that two factors contributed to the disruption: a very strong El Niño and a very low Arctic sea ice concentration. We also contributed to studies that evaluated the climate change impacts that would be avoided by stabilizing global warming at 1.5 °C instead of 2 °C.

To examine the possibility of taking measures to promote synergy between the realization of negative emissions and the improvement of ecosystem services for achieving climate stabilization, in sub-theme 2, we started a comprehensive evaluation of sustainability considering the interaction between climate change and land uses. We also undertook a coupling of the Integrated Terrestrial Models and the Earth System Models. The results suggest that, without careful

consideration of land use for bioenergy crop production, the large-scale use of bio-energy with carbon capture and sequestration could negatively impact food, water, and the ecosystem services that support fundamental human sustainability.

In sub-theme 3, we conducted analyses of climate policies through the integrated utilization of climate impact models and mitigation assessment models. For example, we investigated the effectiveness and plausibility of shifting the working hours of various workers as an adaptation measure to climate change. Although such a time shift was shown to be effective to reduce the effect of heat stress, the required amount of the shift was beyond a realistic range unless stringent climate change mitigation was achieved. If society tries to avoid the economic impacts of climate change on outdoor labor only by changing working times, outdoor workers in many regions will need to start working well before dawn. The need for other climate change mitigation and adaptation measures (e.g., mechanization of work, body cooling) is also inevitable to minimize the impact of climate change.

To improve climate risk communication, we demonstrated in a holistic manner how climate change can generate various risks and how these risks are interconnected. From a literature survey, we identified 87 climate risks and 253 causal relationships among them and graphically drew the interconnected risks. An example is shown for the food sector in Figure 3. We found that changes in the climate system affect natural and socioeconomic systems; this ultimately influences human security, health, and well-being. The results indicate that climate change can trigger a cascade of impacts across sectors.

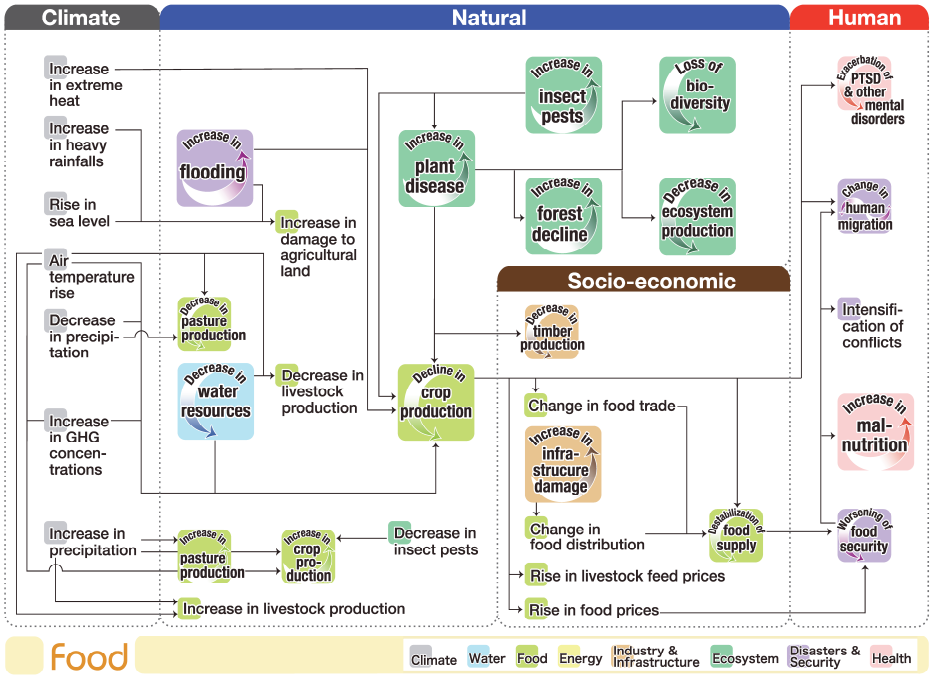


Fig. 3 Flowchart of climate risk interconnections related to the food sector. The climatic drivers are allocated in the far left column (gray). The risk terms of the sectors related to natural and socioeconomic systems are in the middle column (blue and brown). The risk terms related to human life are in the far right column (red).

3. Policy assessment research toward a global low-carbon society (Project 3)

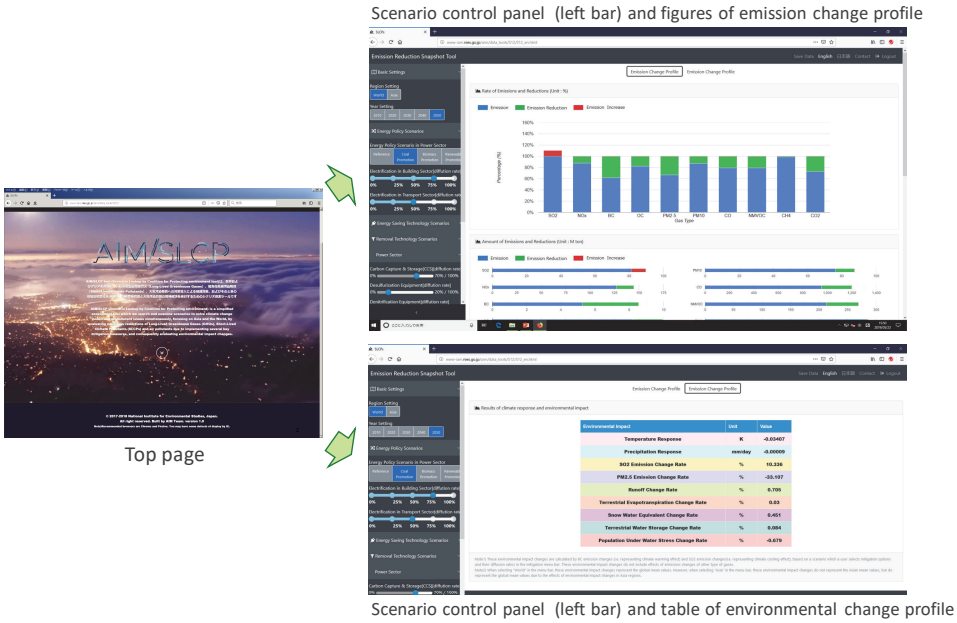
The aim of Project 3 is to provide scientific knowledge from the perspectives of modeling and analysis, scenario development, and negotiation processes, to achieve a global low-carbon society. National- and local-scale analyses toward a low-carbon society are being implemented in the Integration Research Program. Project 3 of the Low-Carbon Research Program consists of two sub-themes: (1) Assessment by using quantitative models; and (2) International institution design. The following are the main results obtained in FY 2018 in each sub-theme.

In sub-theme 1, we evaluated the synergies and trade-offs of various combinations of low-carbon measures and air pollutant control measures. We analyzed different features of emission projections of short-lived climate pollutants such as black carbon (BC) and CH_4 and of air pollutants such as SO_2, NO_x, $PM_{2.5}$, PM_{10}, CO, NMVOCs (non-methane volatile organic compounds), and NH_3 in global regions by using the AIM/Enduse [Global] model, while considering emissions pathways for achieving significant CO_2 reductions relevant to the 2 °C target. We found that different combinations of mitigation measures have large effects on diverse emission projections of air pollutants and short-lived climate pollutants, as well as on additional investment costs. At the same time, it is a complicated task for stakeholders to directly use the AIM/Enduse [Global] model to visualize various emission scenarios. We therefore developed a simplified tool for stakeholders to estimate future emissions scenarios globally and in Asia on the basis of an approximate simulation of the results provided by AIM/Enduse [Global]. This web tool is called AIM/SLCP (Scenario Lookup by Coalition for Protecting environment) and works on both PCs and tablets. It has simplified equations to represent the effects of major mitigation measures and to estimate future emissions and mitigations globally and in Asia. In addition, the simplified equations estimated by the climate model results are included in the tool, and users can therefore calculate the environmental impacts (e.g., temperature change, precipitation change, changes in population under water stress) from the global emissions profiles. The results can then be displayed by the tool. Figure 4 displays the home page (http://www-iam.nies.go.jp/aim/data_tools/S12/) and example screenshots of result figures and tables.

As part of sub-theme 2, we continued utilizing C-PPI (Climate change mitigation Policy Progression Indicator), a set of indicators developed in 2017, to examine countries' efforts to curb global GHG emissions towards the Paris Agreement's long-term target of 2 °C or 1.5 °C. We selected G20 countries because they are responsible for about 80% of global emissions. If all major policies implemented in some of the G20 countries were implemented in all the G20 member countries, total GHG emissions from G20 countries would likely be on track towards the 2 °C long-term goal. In addition, we studied one of the most controversial parameters in climate change modeling: discounting of future costs and benefits. Discounting is critical in determining the social cost of carbon and carbon pricing,

but distributive concerns are rarely reflected. Assuming a social welfare function that incorporates inequality aversion, we showed that the consumption discount rate could be decomposed into a growth effect and an intragenerational distribution effect. The framework could be extended to include population change and inequality in the environment. Taken together, numerical examples based on the RICE (Regional Integrated model of Climate and the Economy) model, which integrates economic activities, GHG emissions, and climate change and its impacts, suggest that distributional effects would turn non-negligibly negative. This may, in turn, lower the consumption discount rate by 1% to 3%.

Fig. 4 Website of AIM/SLCP (Scenario Lookup by Coalition for Protecting environment tool)

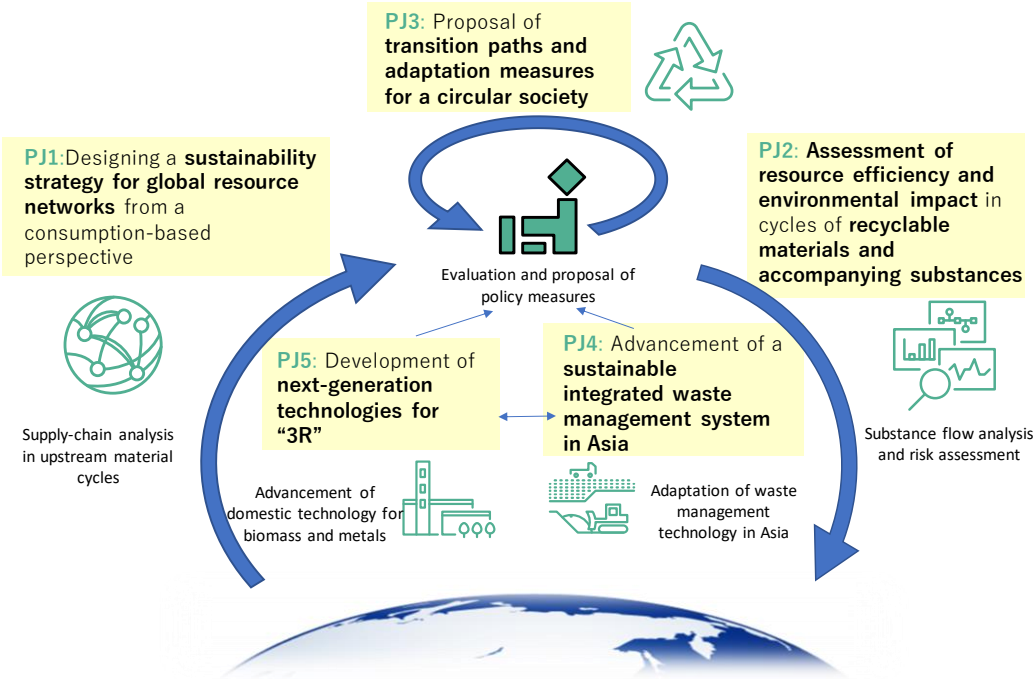


Sustainable Material Cycles Research Program

To help realize the future vision for an international material cycle strategy, this program will clarify supply chain structures and the factors that shape supply chains. Measures toward a sustainable material-cycle-based society will be proposed on the basis of an assessment of resource and environmental conservation and future social change.

The program will develop and evaluate measures for the advancement of sustainable, integrated waste management systems in Japan and the broader Asian region. It will also propose the fundamental technologies and social systems needed for waste prevention or minimization, reuse, and recycling in harmony with a low-carbon footprint society and other initiatives.

Fig. 1 The Sustainable Material Cycles Research Program



1. Designing a sustainability strategy for global resource networks from a consumption-based perspective (Research Project 1)

Economic growth is associated with a rapid rise in the use of natural resources within the economy. This project developed a methodology to detect the kernel structure of industrial supply chains formulated by using an input–output matrix.

By applying the detected kernel structure of Japanese supply-chain data (Fig. 2), we performed a structural decomposition analysis (SDA) of Japanese greenhouse gas (GHG) emissions in 1990, 1995, 2000 and 2005. The RAS-invariant decomposition that we developed was applied to Japanese linked input–output tables for the four 5-year periods studied. We analyzed the effect of the Leontief inverse on emission changes in terms of the specific effects of forward linkage, backward linkage, and kernel structure. Our SDA method completely solved the problem of parameter independence, and it had greater accuracy than conventional methods. For example, the method detected increased GHG emissions from backward linkages, but conventional methods incorrectly determined a decreased contribution from backward linkages. The results of the SDA confirmed that forward linkage and kernel structure contributed to a rise in GHG emissions, and that backward linkage also consistently increased emissions in the three periods.

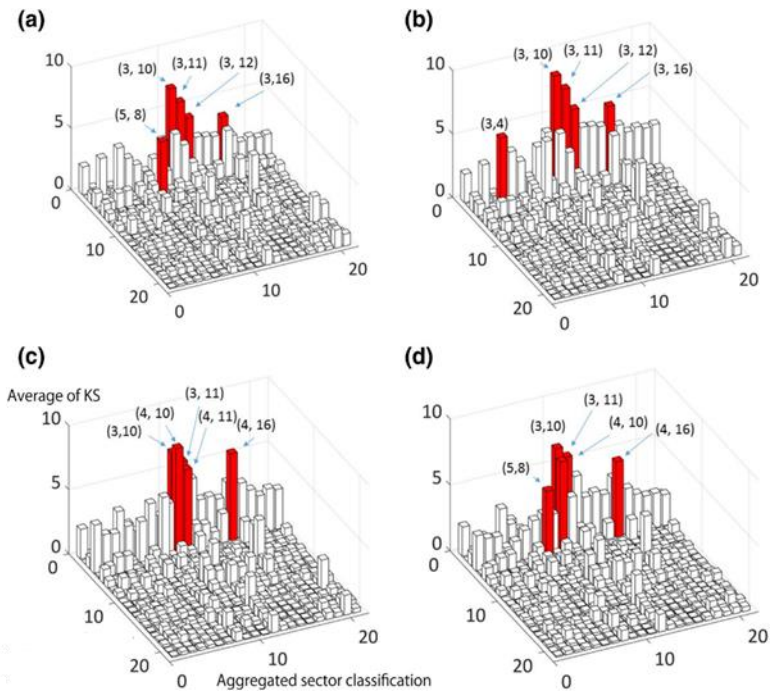


Fig. 2 Detected kernel structure matrices and their top five sectors in Japanese supply chains in 1990, 1995, 2000, and 2005 (Ryoko M., Nansai, K., Tsuda K. 2018. Role of linkage structures in supply chain for managing greenhouse gas emissions, *J. Econ. Struct.* 7:7)

2. Assessment of resource efficiency and environmental impact in the cycles of recyclable materials and accompanying substances (Research Project 2)

From the results of research conducted in 2017, we estimated the emission of 16

kinds of metals targeted by the Japanese Pollutant Release and Transfer Register system to the atmosphere from industrial waste incineration processes in Japan. Previous results showed that the metal content of incinerated waste and the emission factor differed by the type of waste predominantly processed and the type of exhaust-gas treatment system, so we considered these differences in our estimation. When emissions were estimated by using the median metal content values and the emission factor for each treatment system, we found that the estimated emissions ranged from a few percent to about half of the reported amounts from other emission sources. Although these estimates are preliminary, the results suggest that the amount of metals released by industrial waste incineration should not be ignored.

The total contents and bioaccessible concentrations of hazardous chemicals in dust generated during manual dismantling of waste electrical and electronic equipment (WEEE) were determined in artificial gastrointestinal fluids to estimate exposure via the dust ingestion pathway. Bioaccessible concentrations of heavy metals such as lead, cadmium, and zinc and of phosphorus-containing flame retardants such as TCEP (tris (2-chloroethyl)phosphate) and TCIPP (tris (1-chloro-2-propyl) phosphate) tended to be higher than those of brominated flame retardants such as PBDE (polybrominated diphenylether) and DBDPE (decabromodiphenyl ethane) in the gastric and intestinal phases and of dioxin-related compounds in the intestinal phase. The results should prove useful in determining feasible exposure levels of hazardous chemicals for workers at WEEE recycling sites. After conducting additional investigations of exposure to hazardous chemicals via dust inhalation and dermal contact pathways, we will be able to perform a risk assessment to indicate chemicals that should be controlled in the field of WEEE recycling.

We also analyzed trade statistics and reports related to the Basel Convention to better understand international trade, with the goal of promoting environmentally sound management of waste in Asia. Importations of electronic scrap and related precious metal scrap have been increasing in Japan since 2010, but the amounts arriving from non-OECD countries in Asia are limited. Because the generation of this type of scrap material is increasing in these countries, but their existing recycling facilities have insufficient capacity, Japan can contribute to environmentally sound management in Asia with increased imports. This could be achieved by simplifying regulatory procedures in a revised Basel Act and enforcing secured traceability in Japan.

3. Proposal of transition paths and adaptation measures for a circular society (Research Project 3)

We continued to develop a municipal waste model that simulates the different policies of municipalities by taking into account regional characteristics and calculates national-level policy outcomes. We then set up a policy package that included waste prevention and recycling and estimated its outcomes. The policy package reduced the amount of municipal waste generated and disposed of increased the recycling rate. A stronger policy will be needed if we are to meet the goals of a 4% waste reduction, a greater than 2% increase in the recycling rate, and a 8% reduction in final disposal to those in 2015 by 2030. We also estimated the outcomes of integrating waste incinerators that are not working at full capacity because of depopulation.

We also further developed a material flows/stock model for durables that separates Japan into nine regions and enables the analysis of future imbalances between supply and demand of nonmetallic minerals by decreased public construction. According to the analysis, the supply of recycled materials will exceed demand in five regions of Japan in 2030.

In light of the progress made in circular economy policies in the EU, we began a comparative analysis focusing on Austria, which has high levels of both waste material recycling and energy recovery in waste management as compared with other EU countries. We analyzed municipal waste management flows from 1990 to 2015. The material flow data indicated a shift from landfill to material use by 2000 and a subsequent shift from material recycling to energy recycling .

To tackle those waste management issues that are relevant in an aging society, we studied an ideal way to manage waste-collection points, which are currently managed by neighborhood associations. We interviewed officials from local municipalities and identified several problems with the current management of waste-collection points. These include rules violations and concentration of the management burden on community leaders because of a lack of local volunteers. We then began to categorize methods of managing waste-collection points by distributing a questionnaire survey and interviewing the chairpersons of neighborhood associations in Tsukuba.

To study recycling upgrades, we searched for information in major newspaper and magazine article databases in Japan by using relevant keywords. We collected 50 example case studies of recycling program upgrades. The case studies could be categorized into five types (material utilization, material recovery, social contribution, community revitalization, and natural decomposition). Examples included cases of the utilization of previously unused and discarded resources and the creation of social value (e.g., by employing disabled people).

4. Establishment of a robust, sustainable, and integrated waste management system for Asia (Research Project 4)

To establish a robust, sustainable, and integrated waste management system in Asia, including Japan, we are studying the development and adaptation of several technologies to suit Asia-specific situations. The technologies include mechanical–biological treatment systems, constructed wetlands for landfill leachate, landfills with reduced long-term pollution flux, systems that save or generate energy by using decentralized wastewater treatment, and *Johkasou* systems (small-scale wastewater treatment tanks). We are also developing and applying several tools for evaluating waste management in Asia. Below are some of the results we obtained in FY 2018.

As part of our research into the establishment of a watershed management system that uses energy-saving and decentralized treatment technology, we investigated and analyzed the characteristics of a decentralized treatment system in a rural area of China and helped to develop rural domestic wastewater treatment standards for China. We also investigated the energy potential of marine algae related from polluting coastal areas.

To establish a performance test and certification system for wastewater treatment facilities in Indonesia, we conducted several meetings with relevant stakeholders, including representatives from central or local governments, research institutions, non-governmental organizations, and manufacturers. With input from these stakeholder meetings, we drafted a performance-testing method for decentralized domestic wastewater treatment facilities in Indonesia. A trial of the testing method was conducted to confirm the availability of test equipment and the feasibility of the testing procedure (Fig. 3). Japanese wastewater treatment technologies were also tested under high temperature and with a typical Indonesian inflow pattern. The pilot test of a full-scale *Johkasou* system revealed greater treatment efficiencies and lower sludge generation under these typical Indonesian conditions; this should reduce both the initial capital outlay and the operating costs.

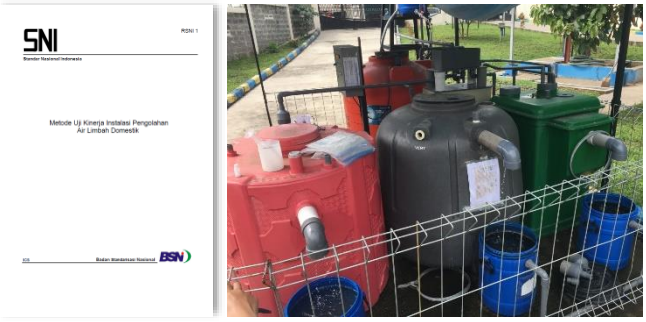


Fig. 3 Draft of the testing method that will be used as an Indonesian National Standard (left); and a trial of the testing method with local products in Indonesia (right)

5. Development of next-generation technologies for "3R" (Research Project 5)

To enhance the energy efficiency of an innovative on-site biogas system for skyscrapers, we investigated anaerobic co-digestion of food waste and grease trap waste in semi-continuous experiments. Despite the increased production of methane, a high mixture-ratio of grease trap waste to food waste inhibited microbial activity. The key substances in this inhibition were long-chain fatty acids (LCFAs); the accumulation of LCFAs eventually led to process failure. The results of a comparative study using two laboratory-scale anaerobic reactors at different temperatures (35 and 55 °C) suggested that mesophilic microbial consortia had greater tolerance to high lipid loading than did thermophilic consortia and thus contributed to high- loading rate operation of the reactor.

To understand the behavior of persistent organic pollutants (POPs) and phosphorus flame retardants (PFRs) in biogas plants and control their emission to the environment, we investigated the concentrations and flows of these compounds in each process in commercial biogas plants. The concentration of PFRs was much higher than that of PBDEs, some of which are POPs. Furthermore, PFRs were transferred not only to solid fermentation residue but also to wastewater, and their emission to wastewater was higher than that of PBDEs.

X-ray diffraction measurement and elemental composition analysis were performed on bottom ash, fly ash, fuel chips, and other materials collected at a wood biomass boiler power-generation facility to clarify their mineral composition and better understand elemental behavior in the facility. In addition, we began to analyze the elemental composition of each type of municipal solid waste (MSW) to be incinerated, including wood, paper, and plastics. These were estimated to contribute greatly to the heavy metals in incineration residues. An air-table sorting device was introduced to sort MSW bottom-ash particles according to size and density.

In a study of the appropriate treatment of wastes containing nanomaterials, we used a laboratory-scale combustion device to evaluate the degradation and emission of nanomaterials during combustion processes. Nanomaterials (TiO_2 and carbon nanotubes) were mixed into pulverized refuse-derived fuel at a ratio of 1% or 10% and then combusted in a tubular furnace at 750 or 850 °C. Flue gas and combustion residue were collected, and the concentrations of nanomaterials were quantified by using electron microscopy. We also started measuring the abundance of microplastics during waste recycling and waste treatment activities.

Harmonization with Nature Research Program

This program will shed light on the mechanisms by which the four major factors behind the biodiversity crisis (overexploitation/development, cropland abandonment, invasive alien species/pollution, and climate change) affect biodiversity. It will also assess and project the impacts of these factors and develop biodiversity conservation measures and adaptation strategies. Additionally, the program will assess the ecosystem functions and services generated by biodiversity and will propose strategies, such as watershed management in harmony with nature, for sustainably benefiting from ecosystems (Fig. 1).

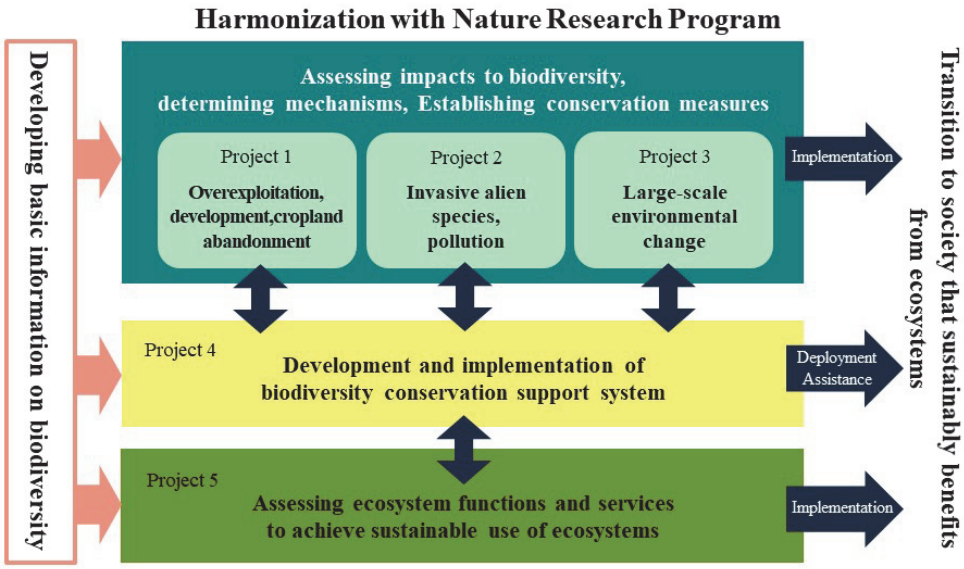


Fig. 1 Research framework of the Harmonization with Nature Research Program

1. Biodiversity assessment of impacts of large-scale human activities

1.1 Global effects of natural resource exploitation on biodiversity

The study aims to investigate if protected areas (PAs) mitigate deforestation and habitat loss of animals on a global scale. We first analyzed geospatial and temporal datasets of global forest cover and calculated global forest area change from 2000 to 2010. Then, we overlaid a world PA map (provided by the World Database on Protected Areas) on a forest area change map and compared the deforestation rate in PAs to that outside PAs in each country. We also overlaid distribution maps (provided by the International Union for Conservation of Nature) of forest-dwelling mammals, birds, reptiles and amphibians and assessed whether habitat loss (forest loss) was higher outside PAs than it was inside PAs for each species. Both the deforestation rate and habitat loss were higher outside

PAs globally. These results indicate that PAs are likely to be effective for maintaining both forest areas and forest species habitat on a global scale.

1.2 Effects of land-use abandonment on biodiversity

We examined aerial photographs of abandoned settlements (abandoned 7 to 45 years ago) and reconstructed vegetation growth after abandonment of 274 agricultural fields by digital stereoscopic analysis. We calculated digital surface models (DSMs) by using PhotoScan Professional (Agisoft LLC) from aerial photographs taken immediately before abandonment and in recent years. We determined vegetation height from the photos and calculated the difference between them. The difference in vegetation height from the more recent photo to the original ranged from –2.1 to +19.5 m. The results showed that average vegetation height increased with the number of years after abandonment, and the rate of increase at non-afforestation sites was much smaller than that at afforestation sites. Variation of vegetation height at non-afforestation sites was large, implying that succession to woody vegetation stagnated at some of the abandoned sites.

2. Ecological risk assessment of newly developed systemic insecticides

Ecological risk assessment has become an increasingly important issue in the conservation of biodiversity. We have promoted a methodology for assessing the field-level risk of agricultural pesticides—especially recently developed systemic insecticides such as neonicotinoides.

The ecological impacts of insecticides in aquatic areas around agricultural lands have long been ignored in Japan's regulation scheme for pesticides. In the current scheme, the predicted concentration of an insecticide in the main stream of a river is the only parameter considered, suggesting that the ecological impacts of insecticides on local biodiversity around agricultural fields are underestimated. To fill this knowledge gap, we measured insecticide concentrations in surface water and sediment in aquatic areas around paddy fields at 35 locations across Japan. Among the 18 insecticides considered, 15 were detected somewhere in Japan, and their concentrations were generally higher in the southwestern region (e.g. Hiroshima, Saga, and Kagoshima prefectures) (Fig. 2). Most insecticides accumulated at higher concentrations in sediment than in surface water, consistent with the findings of previous studies. We also detected insecticides applied to nursery boxes at high concentrations in surrounding aquatic areas, although such application is generally considered to have low environmental risks. In addition, derivatives of fipronil, which have toxicity similar to that of fipronil, were often detected in sediment at higher concentrations than that of fipronil itself. Concentrations of dinotefuran in water at two sampling points were higher than the 5% hazardous concentration (HC_5: the concentration in which 5% of species will be affected), indicating that there was a potential risk of acute toxicity to

aquatic organisms (Fig. 3). Our findings indicate that ecological risk assessments of insecticides and their derivatives should be expanded to include concentrations in sediment and water around paddy fields.

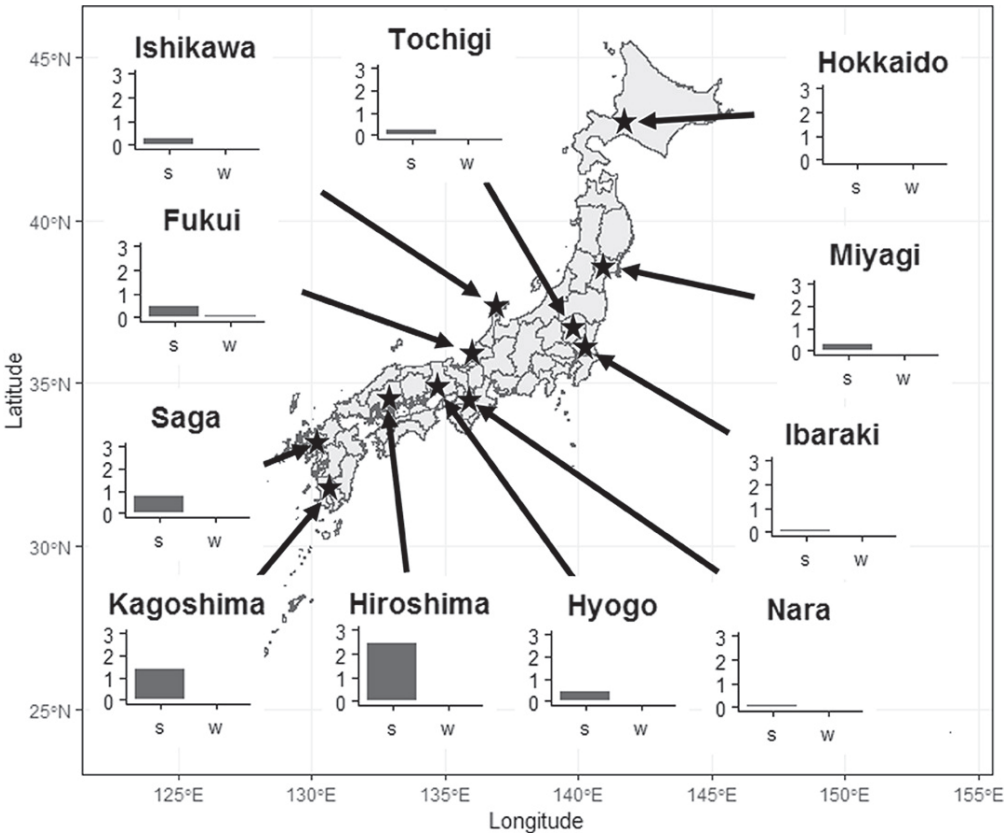


Fig. 2 Locations of 11 survey sites and the mean amounts (log+1 transformed) of pesticides detected in sediment (s; μg/kg) and water (w; μg/L) samples

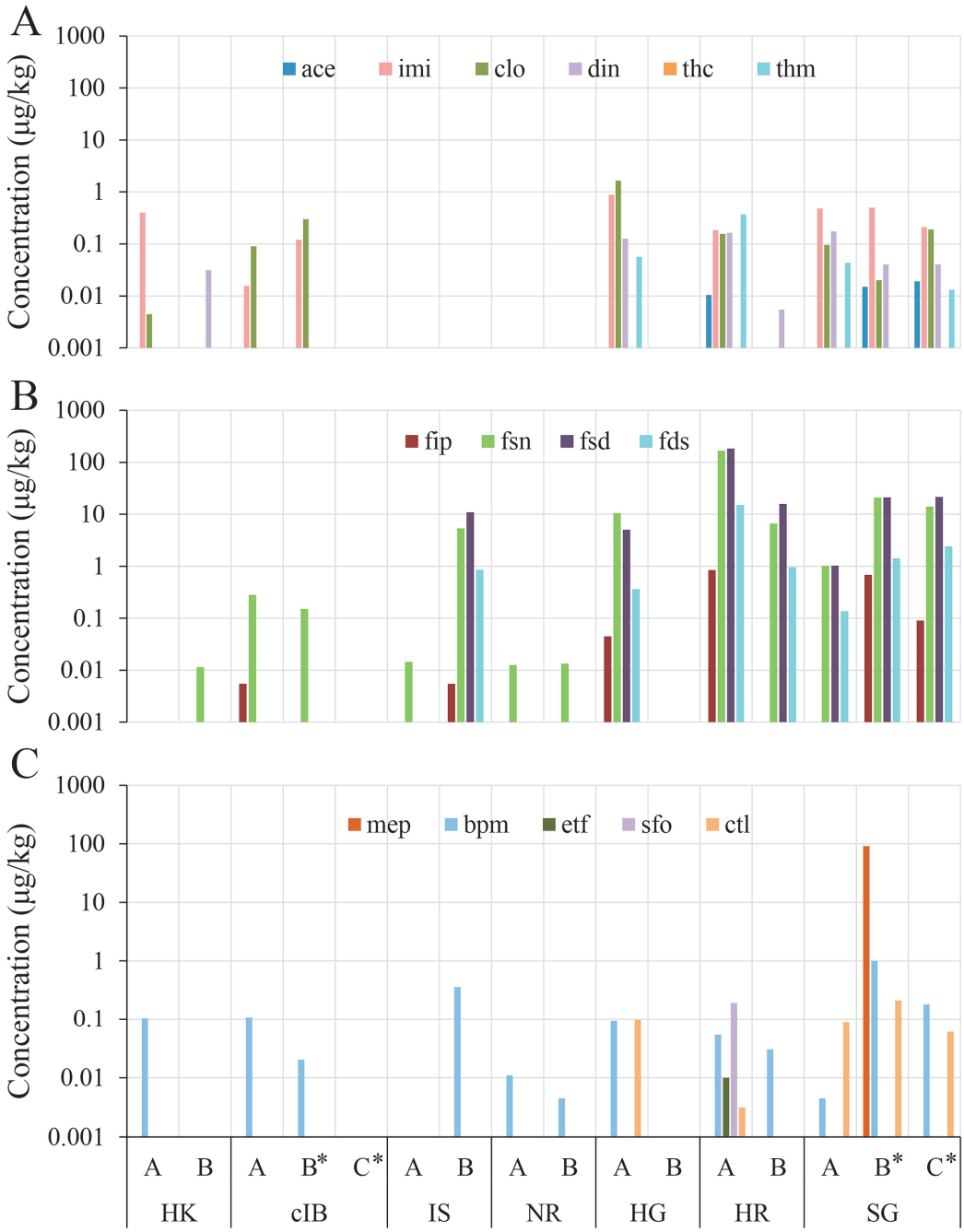


Fig. 3 Concentrations of residual insecticides detected in sediment samples: (A) neonicotinoids, (B) fipronil and derivatives, and (C) other insecticides. Hokkaido: HK; central Ibaraki: cIB; Ishikawa: IS; Nara: NR; Hyogo: HG; Hiroshima: HR; Saga: SG. Names of insecticides are abbreviated as follows: ace: acetamiprid; imi: imidacloprid; clo: clothianidin; din: dinotefuran; thc: thiacloprid; thm: thiamethoxam; fip: fipronil; fsn: fipronil sulfone; fsd: fipronil sulfide; fds: fipronil desulfinyl; mep: fenitrothion; bpm: fenobucarb; etf: etofenprox; sfo: silafluofen; ctl: chlorantraniliprole.

3. Ecological responses to large-scale environmental changes

This project aims to clarify ecosystem responses to human-induced global environmental changes such as climate change and atmospheric pollution.

In our study of the mechanisms of plant physiological responses to temperature, we conducted a cultivation experiment measuring leaf respiration traits under different growth temperatures in 12 ecotypes of *Arabidopsis thaliana*, which is naturally distributed over a wide range of longitude and latitude. The

measurements revealed that the pattern of leaf respiration acclimation to growth temperature differed among the ecotypes (Fig. 4). We also calculated a kinetics model and found that alternative oxidase (AOX) can be a key protein in determining different acclimation patterns.

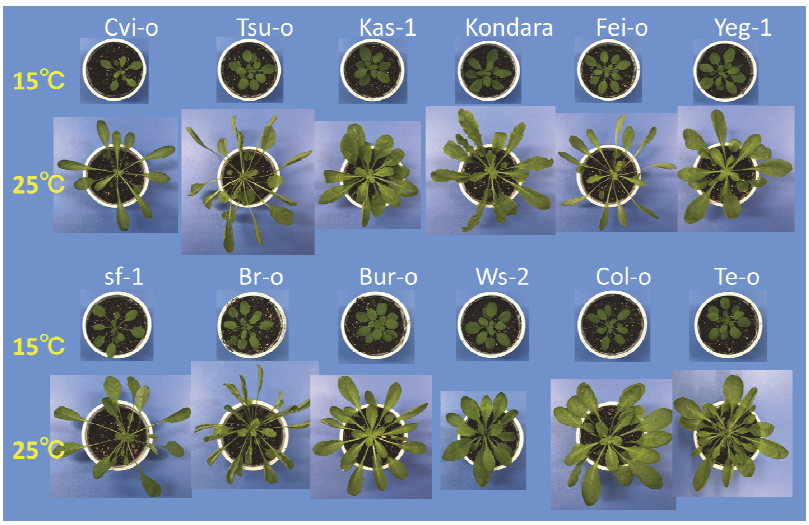


Fig. 4 Twelve ecotypes of *Arabidopsis thaliana* grown under different temperature conditions

In our study of the mechanisms of biotic responses to air pollutants, we continued genetic research on the responses of plants to an air pollutant, ozone (O_3), by using a model plant, *Arabidopsis thaliana*. We isolated an O_3-tolerant line from about 3000 *Arabidopsis* transgenic plant lines in which randomly selected full-length *Arabidopsis* cDNAs had been introduced and overexpressed under the CaMV 35S promoter (FOX lines) (Fig. 5). Determination of the DNA sequence of the introduced cDNA revealed an *Arabidopsis* gene (*X*) that may be responsible for the enhanced O_3 tolerance in this line. We then started to independently introduce and overexpress the cDNA encoding *X* in *Arabidopsis* plants to test this possibility.

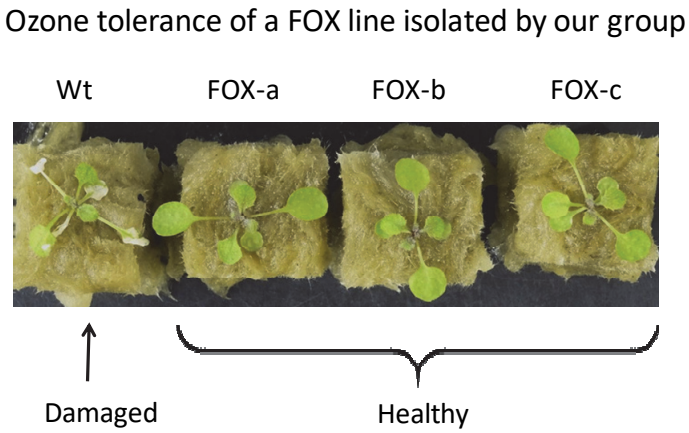


Fig. 5 Two-week-old seedlings of the wild type (Wt) and an ozone-tolerant FOX line (FOX-a, FOX-b, FOX-c) of *Arabidopsis thaliana*, ecotype Col-0, were exposed to ozone at 0.3 ppm under a photosynthetic photon flux density of 420 μmol m^{-2} s^{-1} for 4 h and photographed 1 day later.

In our study of Japanese coastal ecosystems, we revealed that predictions of coral bleaching and mortality were improved by a model including historical thermal stress with other thermal and environmental factors. Furthermore, we demonstrated that ocean current transport and fish herbivory, together with sea-temperature warming, have led to an ongoing community shift from macroalgae to corals along the Japanese coast—a process that is projected to be accelerated in the near future. To establish adaptation strategies, we also started to construct models including multiple environmental variables and hydrodynamic models with finer spatial resolution.

4. Integrated evaluation of biodiversity and development of tools for conservation planning

In this research project, we aim to contribute to the conservation of biodiversity and the sustainable use of ecosystem services through integrated conservation planning considering effectiveness, costs, and various related needs.

We applied the conservation planning tool "SecSel," which we developed for this project, to spatial conservation planning for plant species vulnerable to land-use abandonment. We performed the analysis in cooperation with the project described above in section 1.2, which evaluates the effect of land-use abandonment on biodiversity.

As a target of conservation, we selected 297 vascular plant species that are listed on the national Red List and for which abandonment of management is included as the cause of population decline. We used 10 × 10 km grids as the conservation unit of the analysis. We considered low human population density in each conservation unit as a management cost, because sustaining management is difficult in such units. Because the processes of site selection in SecSel include stochastic ones, we obtained different sets of conservation sites for different runs. The number of times a site was included in the conservation area in multiple runs indicates the irreplaceability of the site for achievement of the conservation target.

The results of the preliminary analysis showed that the options (flexibility) of conservation sites were narrower in the analysis that included human population density (Fig. 6B) than in the analysis that did not (Fig. 6A). On the other hand, the numbers of conservation units required to achieve the conservation target were similar between the two analyses, suggesting that the efficiency of conservation would not be reduced by the need to consider the costs associated with low population density. Many of the sites frequently included in the conservation area were not included in existing national conservation areas. This suggests that utilization of private conservation areas would be effective for conservation of the plant species vulnerable to land-use abandonment.

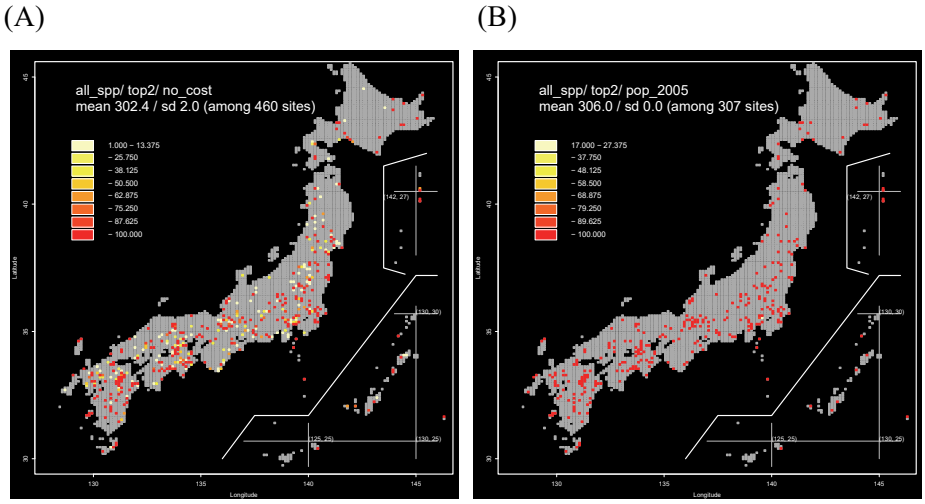


Fig. 6 Examples of conservation prioritization for plant species vulnerable to land-use abandonment. The results are (A) without and (B) with consideration of human population density as a conservation cost. Colors indicate the number of times a site was included in the conservation area in 100 runs, and a redder color indicates higher number of inclusion. In (B), almost all runs resulted in the same site set (most sites are selected 100 times in 100 runs).

5. Evaluation of ecosystem functions and services and their sustainable use

This research project evaluates ecosystem functions and services, taking into account land–sea connections at the watershed or island scale. The results will contribute to the better management of watersheds or islands on the basis of biodiversity conservation, enabling us all to enjoy the sustainable benefits of nature.

5.1 Interactions among multiple ecosystem services in the Lake Kasumigaura watershed

Wetlands can ameliorate the tradeoff between crop production and water quality services in agricultural landscapes and increase the likelihood of win–win outcomes. We defined the orthogonal residuals from the regression line relating the tradeoffs between these two conflicting services as the degree to which the tradeoff was mitigated (the “mitigation effectiveness score”). The more positive the residual was, the higher the mitigation effectiveness score and the greater the potential to mitigate the tradeoff. We measured nitrate concentrations as an indicator of water quality across 49 sub-watersheds of the Lake Kasumigaura watershed and quantified the mitigation effectiveness score from the tradeoff relationships between cropland area and nitrate concentrations. Despite the tradeoff between cropland area and water quality, some sub-watersheds were positive for both. We found that the mitigation effectiveness score was positively associated with wetland cover at all sampling times. Our findings suggested that maintaining and restoring wetlands might mitigate the tradeoff between crop production and water quality and thereby enhance the likelihood of win–win outcomes. Because the wetland area has decreased in the study watershed, flooding or ponding of abandoned rice fields may be an important alternative management option.

5.2 Sustainability of ecosystems on the Ogasawara Islands

We monitored freshwater ecosystems on Chichi-jima in the Ogasawara Islands, focusing on the process of recovery of freshwater ecosystems in the wake of a serious drought. The results indicated that flying insect species recovered quickly, whereas molluscan species did not. We observed that the numbers of two endemic species (a freshwater shrimp, *Paratya boninensis*, and a freshwater goby, *Rhinogobius ogasawaraensis*) largely increased after the serious drought, indicating that these are disturbance-dependent species. Environmental DNA (eDNA) analysis of freshwater detected 15 fish species or species groups covering all the main freshwater fish reported in previous studies. Because a survey employing eDNA is nondestructive and noninvasive, it was deemed to be effective for monitoring freshwater fish in the Ogasawara Islands. We have nearly finished constructing a DNA database for species that make up the freshwater ecosystems on Chichi-jima, and a genome analysis of an endemic bird species (the red-headed wood pigeon, *Columba janthina nitens*) is currently under way.

In addition, we conducted a questionnaire survey of demand for tourism in national parks in Japan. The results indicated that, for Ogasawara National Park, tourism demand in summer is higher than in other seasons and the ratio of repeat tourists is higher than that in most other national parks.

5.3 Ecosystem functions, services, and connectivity in basin ecosystems between rivers and the sea

We used otolith strontium isotope ratios ($^{87}Sr/^{86}Sr$) to test the hypotheses that a land-locked population of Sakhalin taimen (*Parahucho perryi*) above the impassable Hokushin Dam in Hokkaido retains the capacity for anadromy (migration from saltwater to freshwater as adults), and that some individuals out-migrate from the reservoir to the sea. The Sakhalin taimen is an endangered, iteroparous (with multiple reproductive cycles over its lifetime), and long-lived (lifespan >20 years) salmonid species; it inhabits Hokkaido and Far Eastern Russia.

We collected water samples at 31 sites and juvenile Sakhalin taimen at 11 sites throughout two river systems in northern Hokkaido. Five adult taimen captured in the sea were also obtained for otolith (ear bone) analysis. Otoliths were extracted from the fish samples, sectioned in the transverse plane, and polished to expose the primordium (the initial structure at the core of the otolith). Both water and otolith samples were assayed for $^{87}Sr/^{86}Sr$ ratios by using a multicollector inductively coupled mass spectrometer.

We quantified otolith isotopic signatures representing the maternal and natal freshwater origins of juvenile Sakhalin taimen by calculating the mean $^{87}Sr/^{86}Sr$

ratios in the otolith core and at the edge of the otolith, respectively. In the otoliths of the adults sampled, the mean $^{87}Sr/^{86}Sr$ ratios in a region 250 to 500 μm from the core were considered to represent the natal freshwater origins (Fig. 7).

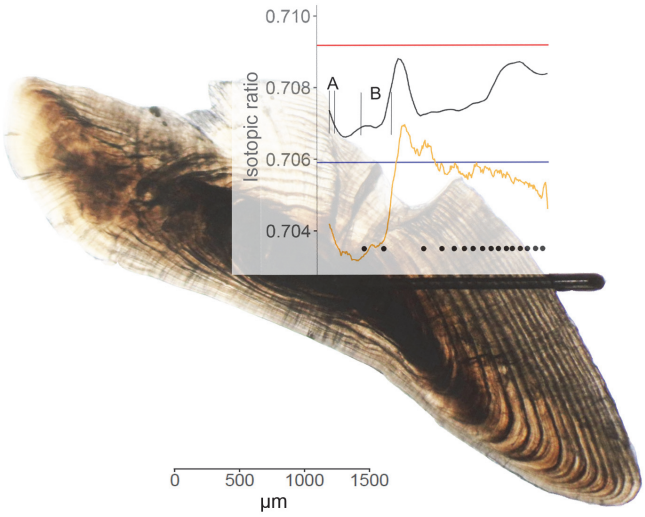


Fig. 7 An otolith core-to-edge $^{87}Sr/^{86}Sr$ profile of an adult Sakhalin taimen (black line), together with the ^{88}Sr signal intensity (orange line) superimposed on the image of an otolith sample. Mean isotopic ratios were calculated for (A) core and (B) natal freshwater regions for statistical analyses. The black dots on the bottom indicate annulus locations. Red and blue horizontal lines indicate the isotopic values of marine water and the Hokushin Reservoir, respectively.

Linear discriminant function analysis classified the juvenile Sakhalin taimen to their regions of origin with an overall accuracy of 88% based on their otolith Sr isotopic signatures. When the same classifier was applied to the adult taimen, we predicted with significantly high posterior probabilities (>0.95) that two individuals had originated from the reservoir.

Our otolith analyses verified that some individuals in the seemingly land-locked population of Sakhalin taimen still undertake anadromous migrations, nearly 40 years after dam construction. Our primary conservation concern is that emigration of the species from the reservoir will remove the genetic variations associated with anadromy from the semi-landlocked source population and will promote intense selection against anadromy in the remaining above-dam population. Whether the land-locked Sakhalin taimen can help sustain the metapopulation dynamics of the species at the watershed scale may depend on whether, and how soon, the disrupted migration pathway is restored.

Health and Environmental Safety Research Program

To ensure the establishment of a Safe and Secure Society, as described in the Fourth Basic Environment Plan of the Ministry of the Environment, we need to address current environmental concerns about chemical contamination and ensure that major environmental pollution events, such as the outbreak of Minamata disease in Japan, do not happen again. This is the basis for the establishment of all other sustainable goals in the Low-carbon, Sound material-cycle, and Natural symbiosis fields. The aim of this research program is to provide scientific support to establish a safe and secure society through new findings on hazards, analytical technologies, fate processes and models, and abatement technologies, as well as advanced risk assessment methodologies and management frameworks for environmental chemicals. To achieve this aim, the program is using a multi-faceted, systematic approach to gain new insights into health and environmental hazards and develop methods for assessing the health and environmental risks posed by environmental chemicals and abatement technologies for those risks. The program is examining the effects of chemicals on higher-order biological functions and multi- or transgenerational impacts. It is developing new systems for assessing the ecological impacts of chemical bioaccumulation, as well as advanced high-throughput chemical analyses, to give us a more comprehensive understanding of the dynamics of environmental chemicals. In addition, the program is examining the atmospheric processes and adverse health effects associated with exposure to PM2.5 and other air pollutants. It is developing advanced methods for conserving regional aquatic environments and for the global fate and risk management of mercury. The projects are described below (Fig. 1).

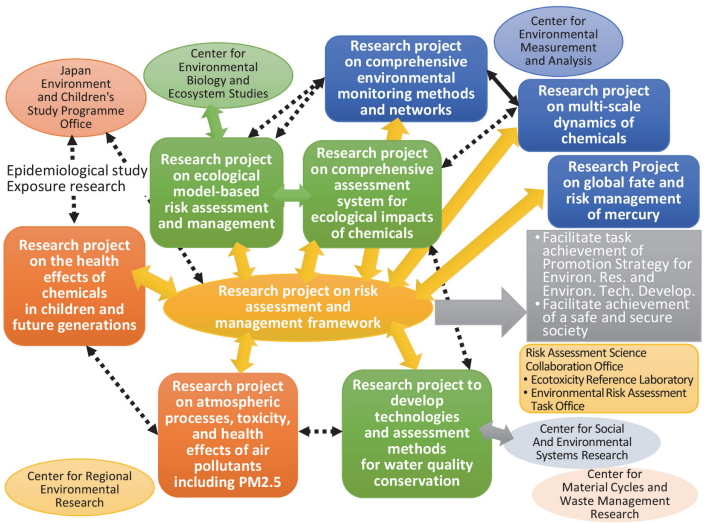


Fig. 1
The Health and Environmental Safety Research Program consists of nine research projects. The projects' outcomes are integrated to establish a general scientific basis for a safe and secure society.

1. Research project on the health effects of chemicals in children and future generations (Project 1)

To evaluate the health effects of chemicals in children and future generations, this

project is examining the risks caused by chemicals to higher-order biological functions and multi- or trans-generation by using animal models and cultured cells. Our main research outcomes this year were as follows.

We examined the effects of oral exposure to bisphenol A (BPA) on memory function and neuroimmune biomarkers by using an allergic asthmatic mouse model. Impairment of novel object recognition ability and upregulation of mRNA levels of N-methyl-D-aspartate receptor, tumor necrosis factor-α, ionized calcium-binding adapter molecule-1, cyclooxygenase-2, and heme oxygenase-1 in the hippocampus were observed in allergic asthmatic mice exposed to 9 μg/kg/day BPA. These findings show that BPA exposure may induce neuroinflammation, which triggers memory impairment in allergic asthmatic mice. We also started to study the effects of exposure to tris (2-butoxyethyl) phosphate, a flame retardant, in allergic asthmatic mice.

We elucidated the effect of a phosphorus flame retardant on sexual differentiation in the brain through its estrogenic action; the effects of diesel-exhaust-derived secondary organic aerosols on gene expression in the prefrontal area of the brain and social dominance behavior; and an inflection point for a behavioral toxicity phenotype caused by a dopaminergic chemical. We advanced studies for developing a novel behavior recording system with individual identification and for developing novel methods to evaluate the ability of chemicals to become distributed into the brain. We also contributed to the study of developmental toxicity in an avian embryo culture system and to research into developmental neurotoxicity using cultured neurons induced from mouse embryonic stem cells.

Epigenetic reprogramming hallmarked by changes in 5-methylcytosine (5mC) and its oxidized product, 5-hydroxymethylcytosine (5hmC) is important in early embryogenesis. We used a mice in-vitro fertilization system to investigate the effects of arsenic exposure on reprogramming in zygotes. We successfully quantified 5mC and 5hmC, which are abundant in female and male pronuclei, respectively, by immunostaining (Fig. 2). We also measured the distance between the male and female pronuclei as an indication of zygotic development. The results revealed that arsenic exposure right after fertilization induces a decrease in the 5hmC/5mC ratio in the male pronucleus without affecting the progression of development. These results suggest that there are yet-to-be-defined disrupting effects of arsenic exposure on embryogenesis.

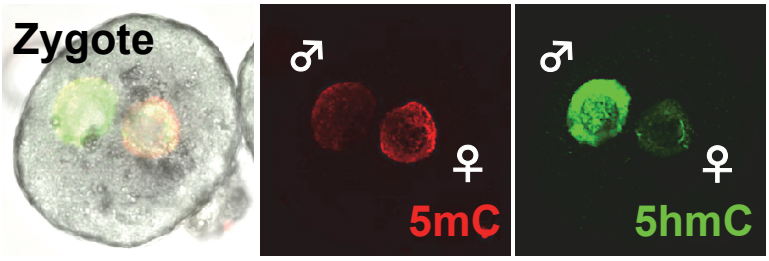


Fig. 2
Representative pictures of epigenetic marks (red: 5-methylcytosine, green: 5-hydroxymethylcytosine) in a zygote at the pronuclear stage. Left: merged image

2. Research project on comprehensive environmental monitoring methods and networks (Project 2)

The purpose of this project is to develop advanced comprehensive analytical methods and networks to monitor environmental chemicals that affect human health and the environment. This year—the middle year of the project—we conducted the following studies.

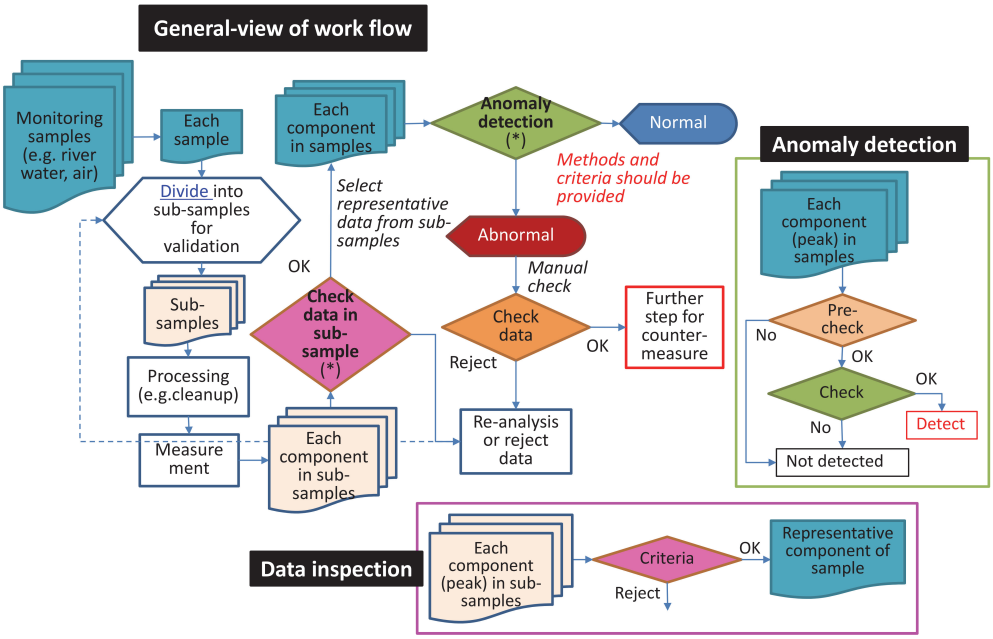
To develop a comprehensive target analysis method, we constructed an online analysis system for substances that show human estrogen receptor (hER)-binding activity. A mix of molecularly imprinted polymers (MIP) to selectively collect hER-binding-active substances was packed into a pressure-resistant chromatographic tube and used as a pre-concentration column. An environmental water sample was passed through the column; the analytes were eluted with acetonitrile, separated on a reverse phase system column, and analyzed by LC/QTofMS (liquid chromatography time-of-flight mass spectrometry). A switching valve was used at two points—one at the sample water bottle and the other on the water line to the MIP column—and an apparatus for automatically analyzing up to 12 samples was constructed by setting a program. A well-shaped peak was detected from a 10-mL sample of a standard 10-ppt aqueous solution. When the method was applied to 100 mL of sewage-treatment-plant drainage, 2,4-dihydroxybenzophenone (67 ppt), equol (1.8 ppt), estrone (1.3 ppt), bisphenol B (0.12 ppt), 2,4-dichloro-17beta-estradiol (1.6 ppt), and other compounds were detected. We are still evaluating the recovery rates and reproducibility. In addition, analysis of organic arsenic compounds was examined as a method for the speciation of organometallic compounds.

We designed a framework employing a statistical method to detect anomalies in individual chemical concentration trends in river water during non-target monitoring (Fig. 3). The variation of gas chromatogram retention times and mass spectra, and the intensity of those signals, is then evaluated for each individual component. To evaluate high-throughput annotation of chemicals after anomaly detection, about 54,000 peaks detected in the non-target screening were searched in an in-house database and a National Institute of Standards and Technology (NIST) library by using original software.

Furthermore, as a high-throughput method for detecting pollutants in air and water environments, we prepared a bioassay battery including eight types of human-cell-based *in vitro* bioassays, and we have been evaluating the usefulness of this battery by using reference compounds. We found that by using our bioassay battery we can detect 32 substances regulated under Japanese Law. The detection rates were as follows: cytotoxic agents (84%), compounds with Nrf2 activity (44%), compounds with p53 activity (13%), pregnane X-receptor agonists (13%), progesterone receptor antagonists (9.4%), aryl hydrocarbon receptor agonists (3.1%), and androgen receptor antagonists (3.1%). In addition, we

developed a novel method to detect the cytotoxicity and estrogen activity of environmental water samples by using morphological changes in MCF-7 cells.

Fig. 3
Framework flowchart of data inspections and anomaly detection in non-target environmental monitoring



3. Research project on ecological model-based risk assessment and management (Project 3)

Field surveys for ecological risk assessments for heavy metals are often conducted across several basins, and several survey sites are established for each basin to assure that there is a gradient in concentration of a target metal. In these cases, datasets can have confounding factors, which are common causes of both treatment and outcome variables. Confounding factors may lead to an association between two variables with no causal relationship. Identifying causal relationships is a critical issue in ecological risk assessments of heavy metals, because the impacts of management interventions (e.g., the effects of effluent standard setting) depend on those causal relationships.

To evaluate the effects of reduction in concentrations of three heavy metals (nickel, copper, and zinc) on the recovery of a benthic macroinvertebrate community, we first conducted literature surveys on ecological risk assessments for heavy metals, including both laboratory tests and field surveys in rivers. Next, we developed a causal diagram comprising Ephemeroptera, Plecoptera, and Trichoptera [EPT] richness (a biological indicator of heavy metal pollution), quality of river water (e.g., pH and concentrations of heavy metals), and physical characteristics of the river (e.g., riverbed sediment). By using the causal diagram and the backdoor criterion, which is a tool that enables us to determine a set of covariates for the identification of a targeted causal effect, we constructed a multiple regression model to evaluate the causal effects of three heavy metals on

the biological indicator. To construct the multiple regression model, we used a dataset of EPT richness and environmental factors collected in field surveys conducted at 45 sites in 14 basins across eight prefectures in Japan from November 2016 to January 2017. None of the causal effects of the three heavy metals on EPT richness was statistically significant. However, there were significant causal effects of flow velocity and dissolved organic carbon (DOC) on EPT richness; EPT richness increased as flow velocity increased and as DOC decreased. The high oxygen demand of EPT insects—especially Ephemeroptera—might be related to these causal effects.

As the next step, we will develop a framework for deriving optimal management measures for the conservation of communities of aquatic organisms. The framework will incorporate uncertainties in the causal effects of heavy metal concentrations.

4. Research project on comprehensive assessment system for ecological impacts of chemicals (Project 4)

Building on the concepts of adverse outcome pathways (AOPs) and AOP-based integrated approaches to testing and assessment (IATA), we continued to investigate *in silico* ecotoxicity prediction models such as quantitative structure-activity relationships (QSARs) and category approaches, as well as risk assessment factors for the purpose of chemical management under Japanese laws such as the Chemical Substances Control Law (CSCL). We continued to develop new test methods for evaluating chemical compounds by using various organisms including marine or estuarine algae and invertebrates, as well as benthic organisms. These tests were conducted by using reference chemicals to investigate the possibility of implementing them as part of a chemical management system such as the Agricultural Chemicals Control Act and the CSCL, and to establish water quality standards or effluent discharge limit. We also continued to work on developing and verifying new test methods to detect endocrine disrupting chemicals such as anti-androgens by using medaka (*Oryzias latipes*) and juvenile hormones by using *Daphnia*.

The results of fisheries-independent bottom-trawl surveys in Tokyo Bay in 2018 showed that the abundance of small- and mid-sized fishes (e.g., mantis shrimp and flatfishes) remained low, whereas that of large ones (e.g., Japanese sea bass and elasmobranchs) was still relatively high. Although the larval density of mantis shrimp in Tokyo Bay seemed high in 2018, extremely low population density was evident in juvenile mantis shrimp, suggesting that there is a low survival rate in their early life stages. Little or no recruitment of Kobelt's ark shell was observed in Tokyo Bay in 2018; this contributed to its continuing population decline in the bay. Multivariate analysis of the species composition and population densities of megabenthos in Tokyo Bay from 1977 to 2018 revealed that there were seven groups of period; the results implied that there were positive

or negative correlations between several environmental factors, such as water temperature, dissolved oxygen, and nutrients. We also found that the composition of bottom sediment in the central-eastern area of Tokyo Bay shifted from sandy to a muddy (i.e., silt and clay) in the mid-1990s. Further examination is needed to elucidate the possible adverse effects on the occurrence of hypoxia and the reproduction of megabenthos in Tokyo Bay.

Finally, we continued to investigate mixture toxicity by using both a component-based approach and a whole-mixture approach. For example, a mixture of six organic contaminants based on environmentally detected concentrations was investigated. Nonylphenol (NP), linear alkylbenzene sulfonate (LAS), two organophosphorus pesticides (malathion and chlorpyrifos), triclosan, and clarithromycin were selected as posing a relatively high risk for algae, daphnids, and fish, and short-term chronic toxicity tests were conducted at various multiples of the highest concentrations detected in the environment. The results of the mixture tests were compared with the concentration addition or independent action models. LAS was found to be predominant among the six selected compounds in fish testing, whereas triclosan predominated in toxicity testing on green algae. Antagonistic effects were found for fish and an alga (Fig. 4). Two of the organophosphorus pesticides were found to be additive in their effects on daphnids. CA stands for the concentration addition model while IA stands for the independent action model.

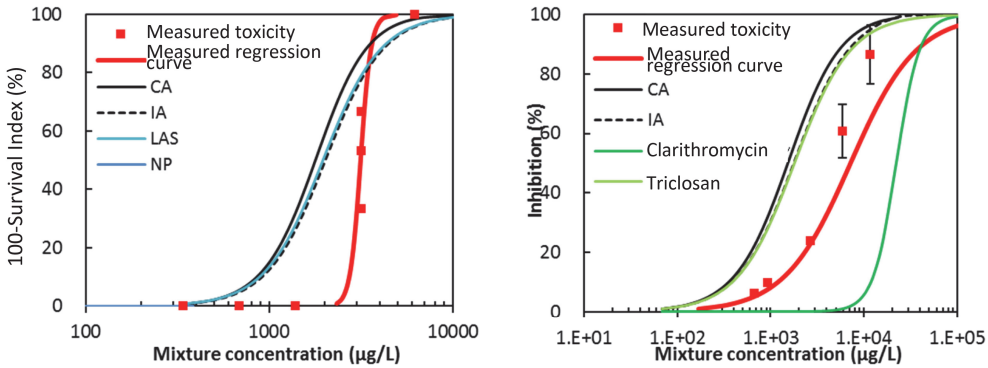


Fig. 4
Results of toxicity tests of a mixture of six contaminants in (a) fish (*Danio rerio*) in a short-term toxicity test on embryos and the sac fry stage; and (b) algal inhibition using green alga (*Raphidocelis subcapitata*)

5. Research project on multi-scale dynamics of chemicals (Project 5)

In this project, we are examining the dynamics of chemicals at various spatiotemporal scales by using state-of-the-art analytical techniques and constructing mathematical models to better understand and predict the concentrations and dynamics of environmental chemicals.

To evaluate the long-term impacts of atmospheric mercury (Hg) deposition in lake environments, vertical profiles of total Hg concentrations in water samples

from Lake Motosu near Mt. Fuji and Lake Mashu in Hokkaido were evaluated seasonally and historically. The Lake Motosu results indicated seasonal Hg variations in the surface water, and Lake Mashu showed an overall decrease in Hg concentrations in the last 30 years. These results suggest that atmospheric Hg deposition occurs seasonally, and that its impacts in Japan have declined since the 1980s.

We improved our global model for mercury (FATE-Hg) by implementing a new model for predicting spatial and temporal variations in the partitioning coefficient between seawater Hg and marine particle organic matter. We prepared a long-term inventory for Hg anthropogenic emission to the atmosphere and performed a 160-year (1850–2010) simulation by using our improved FATE-Hg model. Model validation showed that we were able to simulate the dissolved total mercury concentrations in the surface ocean (at 0 to 70 m depth) with maximum model data differences of one order of magnitude.

We are using GIS data on land-use and sewage collection areas to develop a prediction model for the daily concentration change of hydrogen peroxide (H_2O_2) in rivers. The model considers photo- and non-photo-reactions in rivers with dissolved organic matter emitted from various sources. We compared the modeled concentrations with observed ones from 24 to 25 August 2017 and corrected the model parameters. We also roughly considered the contributions of home use of H_2O_2 and direct deposition from the atmosphere (Fig. 5).

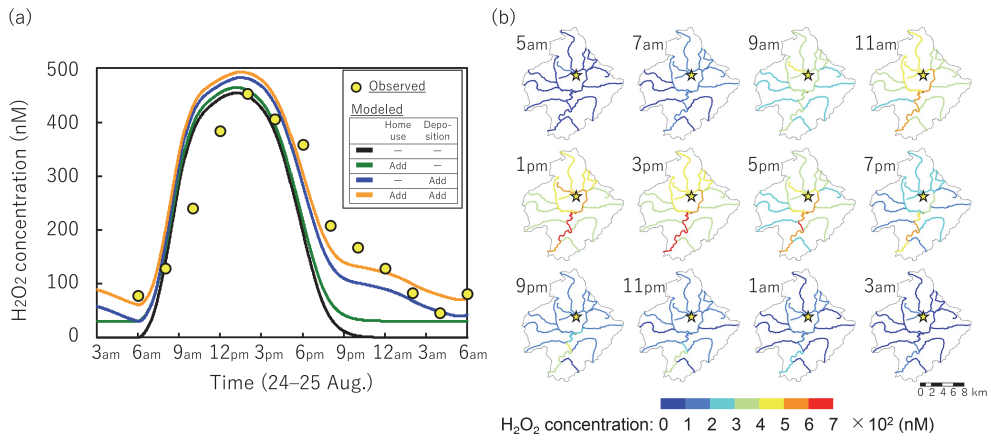


Fig. 5
(a) Observed H_2O_2 concentrations in river water at Rengeji Bridge, on the Kurose River in Hiroshima Prefecture, from 24 to 25 August 2017, and modeled ones under four scenarios with/without emission of H_2O_2 from home use and/or direct deposition from the atmosphere. (b) Time trend of H_2O_2 concentrations in the upstream region of the Kurose River from 24 to 25 August 2017 under a scenario without either the emission or the deposition of H_2O_2. Stars indicate location of Rengeji Bridge.

As part of a study of the indoor-scale dynamics of chemicals, we experimentally measured the transfer of phthalate and organophosphate additives from polymer fabric products to artificial dust attached to the surface of the products. The concentrations of the additives in the dust ranged from 1.2 to 12,000 μg/g after 1 week. We also worked on modeling the transfer processes of these additives and measuring the vapor pressures of alternative flame retardants.

6. Research project on atmospheric processes, toxicity, and health effects of air pollutants including PM2.5 (Project 6)

Rapid economic growth in East Asia has resulted in a marked increase in energy consumption, leading to increased emission of air pollutants. High concentrations of PM2.5 have been reported in Japan, and their adverse health effects are now of major public concern. To control air pollution, to collect evidence of its adverse health effects, and to construct alert systems for air pollution, we are developing an integrated air-quality modeling system and are conducting *in vitro* toxicity studies and epidemiological studies. In the third year of this project, we have obtained the following results.

To improve current emission models, we made a new emission inventory (NEI) with high spatial resolution for biogenic volatile organic compounds. We also made an NEI for the condensable particulate matter from stationary combustion sources. To improve the current simulation model, it is important to understand atmospheric processes. We introduced multiple-oxidation processes of semi-volatile organic compounds and oligomer formation processes based on laboratory experimental results obtained by using the NIES atmospheric chamber (Fig. 6). These additions have improved the reproducibility of organic aerosols in CMAQ simulations.

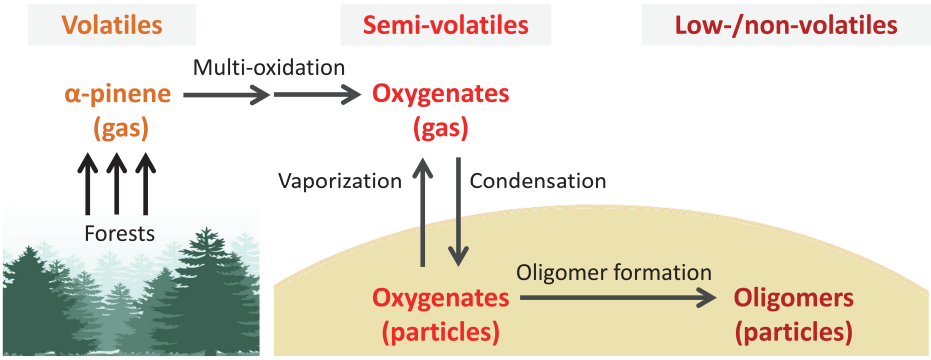


Fig. 6
Schematic mechanisms for multi-oxidation and oligomer formation

We prepared a reporter gene assay system to examine several types of biological responses to PM2.5. We exposed cells to extracts of PM2.5 and found that the water-soluble fraction contained antioxidant responsive element (ARE)-reactive chemicals, indicating that we may be able to screen for candidates of chemicals that have adverse effects.

We evaluated the association between non-accidental mortality and short-term exposure to PM2.5 for the fiscal years 2012–2014. A 10-μg/m^3 increase in average PM2.5 concentrations on the day of death and the previous day was associated with an increase of 1.3% (95% confidence interval, 0.9% to 1.6%) in total non-accidental mortality. The study revealed that short-term exposure to PM2.5 had adverse effects on total non-accidental, cardiovascular, and

respiratory mortality in Japan.

7. Research project to develop technologies and assessment methods for water quality conservation (Project 7)

In provincial cities domestically and in developing countries in the Asian region, the introduction of water-environment conservation technologies has been delayed because of economic constraints. The aim of this project is to develop technologies to conserve the water environment and evaluate the effectiveness of conservation projects so that water quality can be managed effectively.

This project comprises two sub-projects. The first is the development of appropriate wastewater treatment technologies. Reducing the energy and improving the effluent water quality of the treatment system promotes the dissemination of technology. This year, we conducted a performance evaluation of an aerobic trickling-filter system under fluctuating flow conditions (the flow rate of wastewater was increased in the morning and evening for 4 h each time) as a decentralized domestic wastewater treatment system in Bangkok, Thailand (Fig. 7). The aerobic trickling-filter system showed superior performance to the existing treatment system in terms of not only effluent water quality (concentrations of NH_4-N, *Escherichia coli*, and *Arcobacter*) but also power consumption (a 79% reduction).

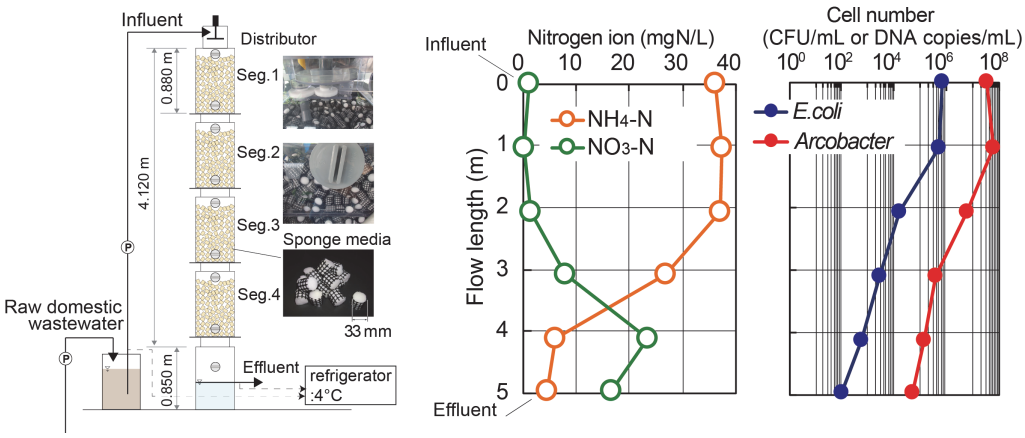


Fig. 7
Overview of the aerobic trickling-filter system for domestic wastewater treatment (left), and water quality profile along the flow length (middle and right)

In the second sub-project, we analyzed monitoring data on the water quality of canals in eight areas covered by sewerage systems (hereafter described as coverage areas) in Bangkok, Thailand to investigate the factors that disturb water quality improvement in some canals. We collected canal survey data compiled by the Water Quality Management Office, Bangkok Metropolitan Administration by month from 1996 to 2015, and we eliminated data from 111 monitoring sites located in the coverage areas. The annual average BOD (biochemical oxygen demand) concentration decreased gradually until 2009. It then began to increase in 2010 until the value in 2015 had recovered to the same level as in 1997. At the

same time, the concentration of total Kjeldahl nitrogen (TKN) also increased. The variation in ammonium nitrogen (NH_4-N) concentration was very similar to that of BOD. Furthermore, we conducted field surveys of some canals in which the BOD concentrations were high, and we found that high-rise residential buildings discharged poor-quality treated wastewater from on-site facilities (septic tanks) to those canals. These results imply that NH_4-N could be a determinant of the recent BOD increase in canals in the coverage areas. Investigation of wastewater released from high-rise buildings to canals is an important future task.

8. Research project on risk assessment and management framework (Project 8)

A sound management framework to manage the risks posed by environmental chemicals to human health and the environment can be established by integrating the social context, public concerns, and accumulated social and natural scientific knowledge. The aim of this inter-disciplinary project is to develop a robust framework for managing environmental chemicals that reflects both the social context and the latest outcomes of Projects 1 to 7. To achieve this aim, this project is developing risk assessment and management strategies that are acceptable to the public and incorporate the latest scientific information on the impacts of environmental chemicals on human health and the environment. Furthermore, the project is developing an ecological management framework based on the comprehensive characterization of ecotoxicity by using a newly developed system of testing protocols. It is also developing a system for the environmental management of coastal, oceanic, atmospheric, and aquatic pollution that will incorporate new technologies as they become available, and a management approach that incorporates comprehensive monitoring methodologies to assess new chemicals as they arise from technological development. Our aim is for Project 8 to summarize the scientific outcomes of all the other projects into the context of sound chemical management in our society.

This year we continued to study a new direction for incorporating the precautionary approach into chemical risk management on the basis of both the scientific and the social nature of chemicals. We re-evaluated several pollution incidents, including the one that caused Minamata disease, to explore how preliminary observations that may not be scientifically sufficient can be used to trigger precautionary actions. Time-series information on the scientific knowledge available at a given point in time, the level of public awareness, and the need for social or political decisions was compared and analyzed to determine appropriate management actions under different information conditions. Also, we began to evaluate the potential impact of the immunological effects of BPA on the basis of a new research outcome in Project 1. This year, we compiled and reviewed the elated literature, information on BPA production and usage, and management actions currently taken for this chemical.

9. Research project on the global fate and risk management of mercury (Project 9)

Establishment of a sound scientific basis to support the global management of mercury is essential for supporting the implementation of the Minamata Convention on Mercury. Project 9 aims to provide scientific information on the global fate of mercury in the environment, the material flows of mercury in the technosphere, and the combined health impacts of mercury and persistent organic pollutants.

Determination of methylmercury (MeHg) concentrations in plankton is important for evaluating MeHg contamination of the biosphere. An inter-laboratory study of MeHg concentrations in a plankton reference material (BCR-414) was conducted to obtain its MeHg reference value. The result was 0.186 ± 0.006 μg/g, with an analytical error that was smaller than previously reported values. Plankton samples were collected from different aquatic environments in Japan, and further analyses for MeHg will be conducted.

We implemented a new model for predicting spatial and temporal variations of the partitioning coefficient between seawater Hg and marine particle organic matter in our global model for mercury (FATE-Hg). We performed centurial-scale (1850–2010) simulations and evaluated modeled concentrations by using monitoring data compiled from recent cruises and from published sources (Fig. 8). The validation results showed that we are able to simulate the total dissolved mercury concentrations in the surface ocean, with maximum model data differences of one order of magnitude. On the other hand, we obtained poor results for methylated mercury concentrations.

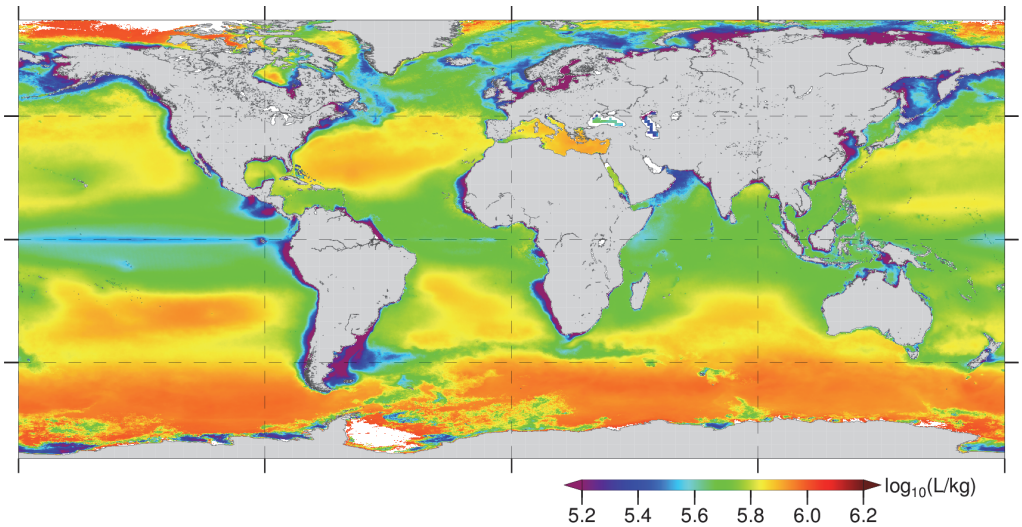


Fig. 8
Long-term (2002–2015) means of the modeled mean annual MMHg bioconcentration factor of phytoplankton in the euphotic zone

The effects of prenatal exposure to MeHg on birth outcomes and child development have long been an area of concern. The main route of MeHg

exposure in humans is the intake of fish and fish products. Polychlorinated biphenyls (PCBs) are also neurotoxic and can be ingested as contaminants in fish together with MeHg. Therefore, we investigated the effects of prenatal co-exposure to MeHg and PCBs on immune systems by using a mouse model. The hematological parameters were analyzed in offspring. We also reported that blood MeHg levels in Japan were four to five times those in the United States. Consequently, we are conducting a questionnaire survey of adult women (>20 years old) to assess knowledge with MeHg and POPs.

We evaluated the accuracy of Pollutant Release and Transfer Register (PRTR) reports of the amounts of chemicals released in terms of actual environmental mercury released to water from sewage treatment plants. To do so, we investigated the mercury concentration in effluent water of sewage treatment plants; this is used as a basis for calculating the PRTR reported release amounts. We conducted a questionnaire survey at approximately 60 sewage treatment plants, and the results revealed that the measured mercury concentration in the effluent was <0.0005 mg/L (1/10 of the effluent standard) at all of the investigated plants. Most of the plants calculated the PRTR reported mercury releases by assuming the mercury concentration to be 0.0005 mg/L or 0.00025 mg/L. Our analysis at three plants showed, however, that the concentration was actually much lower (<0.2 ng/L or 1/25,000 of the standard). This result suggested that the PRTR reported released amounts overestimated the actual mercury released to water from sewage treatment plants.

Environment-Economy-Society Integration Research Program

Starting with integration of the mitigation of, and adaptation to, climate change, this program develops multilayered models that quantitatively analyze solutions to environmental problems. These problems include those related to socioeconomic activities and the need for sustainable material cycles, harmonization with nature, and health and environmental safety, on a variety of scales from urban and regional to national and global. From the perspectives of environmental, economic, and societal sustainability, the program conducts quantitative and qualitative analyses pertaining to the future visions of stakeholders at each scale. It also designs and evaluates the international and local or urban policies needed to realize these intended future visions. The program will establish a system to support the implementation and realization of proposed policies, countermeasures, and innovative green technologies. Figure 1 illustrates the framework of the program and five aspects of the research integration. The program consists of three projects: Project 1 provides sustainable development scenarios for the world and Asian countries; Project 2 develops a local environmental sociologic integration roadmap focusing on climate change mitigation and adaptation; and Project 3 evaluates policies for an environmentally sustainable society.

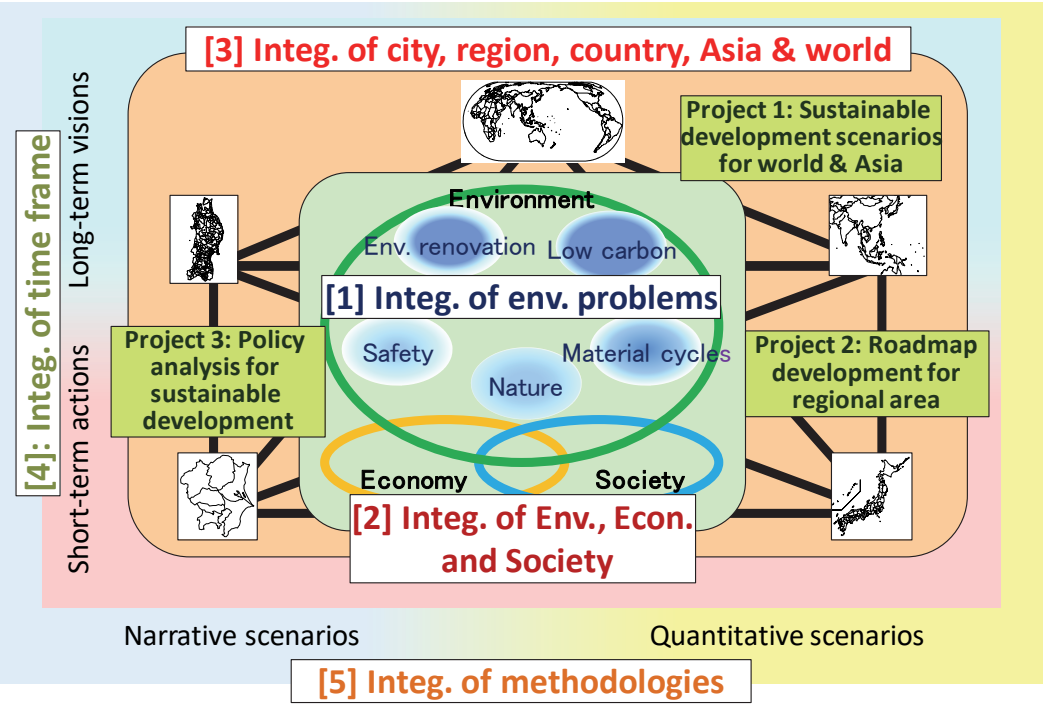


Fig. 1 Framework of the Environment-Economy-Society Integration Research Program. Shown are the three projects (PJs) and the five numbered aspects of the Program.

1. Sustainable development scenarios for the world and Asian countries

This project is developing integrated assessment models (IAMs) for analyzing sustainable development scenarios that pursue the simultaneous attainment of

multiple global or regional societal goals, such as a low carbon society, resource recycling, natural symbiosis, and safety from various risks. The project consists of two sub-themes. Sub-theme 1 provides global sustainable development scenarios, and sub-theme 2 provides national sustainable development scenarios for Asian countries. Sub-theme 1 also develops methodologies for downscaling of global socioeconomic scenarios and provides spatial socioeconomic scenarios with appropriate resolutions for supporting regional or national-scale analyses in the research program.

Information on global future gridded emissions and land-use scenarios is critical for many climate and global environmental modelling studies. In sub-theme 1, we generated those data by using an IAM (Fig. 2) and have made the data publicly available (http://www-iam.nies.go.jp/aim/data_tools/aimssp/aimssp_j.html). The dataset covers a full range and combinations of socioeconomic and climate mitigation levels, which are considered as a range of plausible futures in the climate research community. We also compared our data with existing gridded data to identify dataset characteristics.

In an analysis of sustainable development scenarios, we studied the extent to which climate policies in line with the 2 °C goal could have multi-sectoral consequences in China. Energy security (diversity and import dependency of total primary energy supply) and air quality (emissions of SO_2, NO_x, and black carbon) were shown to have co-benefits related to climate policies (synergies), whereas food security (food price, people at risk of hunger, and food trade dependency) and land resources (deforestation) were predicted to experience negative side effects (trade-offs). Near-term climate actions were shown to help reduce these trade-offs in the mid-term. A policy package that includes food and land subsidies also helped to achieve climate targets while avoiding the adverse side effects of the mitigation policies.

This year, we also analyzed the impacts of policies for attaining other development goals on climate policies. For example, policies to alleviate the pressure of bio-crops on the terrestrial environment can affect bioenergy potential and production costs. To understand the relationship between these quantitatively, we estimated the maximum bioenergy potential under environmental protection policies (biodiversity and soil protection) by using an IAM framework, which consists of a computable general equilibrium model (AIM/CGE) and a spatial land-use allocation model (AIM/PLUM). We found that the global bioenergy potential under no environmental protection policy was 245 EJ/year; 192 EJ/year could be produced under a bioenergy production cost of US$5/GJ. The corresponding values were 149 EJ/year and 110 EJ/year, respectively, under a full environmental policy.

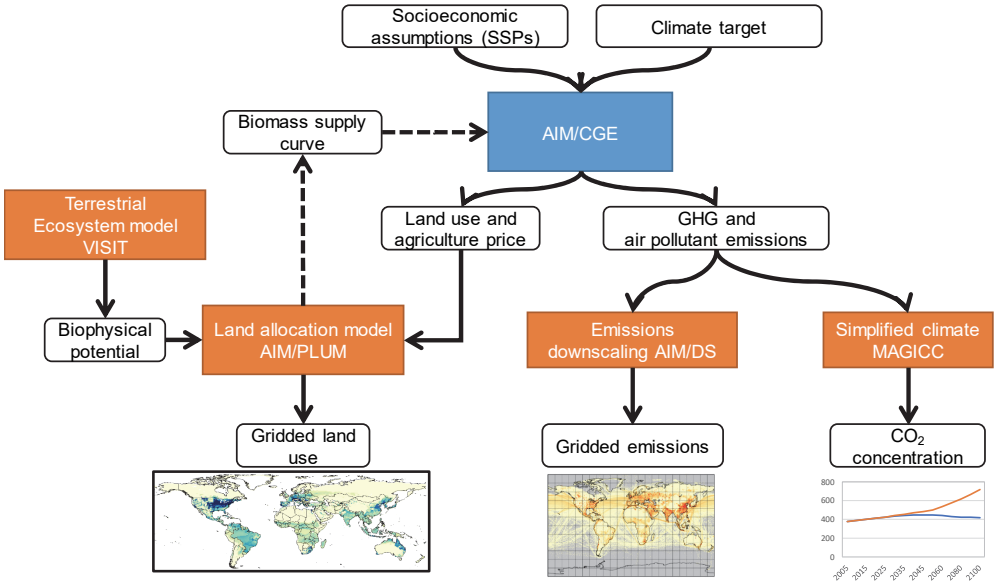


Fig. 2 Overview of the calculation method and flow used to create the datasets on global future gridded emissions and land-use scenarios

In sub-theme 2, we have improved our IAMs to assess GHG mitigation and sustainable development actions in Asian countries such as China, India, and Indonesia. A national CGE model for China was revised to assess the impacts of environmental policies in China. In addition to the features of traditional CGE models, the new model includes environmental satellite accounts that cover 18 kinds of major pollutants in China. It also builds separate pollution treatment sectors to describe the pollution treatment processes and reflect the policy impacts on production activities. The results show that a newly issued environmental tax would result in adverse effects on the economy. Heavily polluted sectors and energy-intensive sectors would suffer increased output losses, whereas clean energy sectors and service sectors would experience an increase in outputs. The low environmental tax plus low carbon tax scenario could reduce more CO_2 emissions than the high environmental tax scenario.

2. Research into a regional environmental sociologic integration roadmap focusing on climate change mitigation and adaptation

Sub-theme 1 is "Development of an Environmental Impact Assessment Model for Regions and Cities." As a leading research institute for "Research into the Development of Technologies for the Assessment of Climate Change Impacts," which is theme 3 of the Ministry of Education, Culture, Sports, Science, and Technology's Social Implementation Program on Climate Change Adaptation Technology (SI-CAT), we developed technologies to support local governments with the scientific knowledge they need for climate change impact assessment and examination of adaptation measures. Also, to develop an integrated assessment platform, we made a projection model of land-use change by using a cellular automaton. The model developed in the previous fiscal year lacked accuracy because of a lack of transition data for use as learning data. This year, we developed an improved model by adding a data augmentation method. Finally,

we confirmed that the new model's accuracy was improved with regards to land-use transition.

Sub-theme 2, "Development of an Integrated Evaluation Model of Economy, Society, and Technology for Countries, Regions, and Cities," is aimed at an integrated roadmap analysis focusing on mitigation. A total of 1724 municipalities in Japan were classified into about 50 types on the basis of their sectoral shares of CO_2 emissions. A regional low carbon scenario for 16 of these 50 types has been analyzed by using an improved regional low carbon scenario assessment model. In addition, a simplified assessment tool for a regional low carbon scenario was developed and applied to a city in the Kanto area. A series of workshops was organized to examine the potential of using the tool to encourage discussions among stakeholders, including local governments, businesses, and NGOs. Policy actions for promoting renewable energy were assessed by developing an assessment model of prefectural willingness to pay (WTP); the result clearly showed a positive relationship between household income and level of WTP. We also developed an electricity demand analysis model incorporating statistical methodology; the model can explain the level of electricity consumption by using a combination of time-dependent and spatial factors.

Sub-theme 3 is "Research into Social Implementation Support Measures and Society Monitoring for Sustainable Society Measures." Energy monitoring was continued in Indonesia and Fukushima Prefecture by using the system we developed for monitoring the electricity and fuel consumption of houses, offices, and factories. In addition, we applied a Markov-switching model, which determines the state of energy consumption, to the monitoring data and confirmed that energy consumption patterns were reproduced well. The colored areas show the monitored electricity consumptions and broken lines show the predicted electricity consumptions in Fig. 3. We proposed the use of a low-carbon heat supply system, called "Industrial Smart Energy Sharing," to promote de-carbonization in an industrial park. This system combined cogeneration of heat and electricity at a thermal power plant, high-efficiency use of heat produced at a waste incinerator, and efficient use of renewable energies for heat supply. The research results were used by several committees of the Ministry of the Environment. To promote the concept of smart energy sharing, a research group was established in collaboration with local governments and companies. With the cooperation of various companies, a technical proposal document was prepared and submitted to the government of Thailand, through the members of the National Strategy Committee, to contribute to their master plan on waste management.

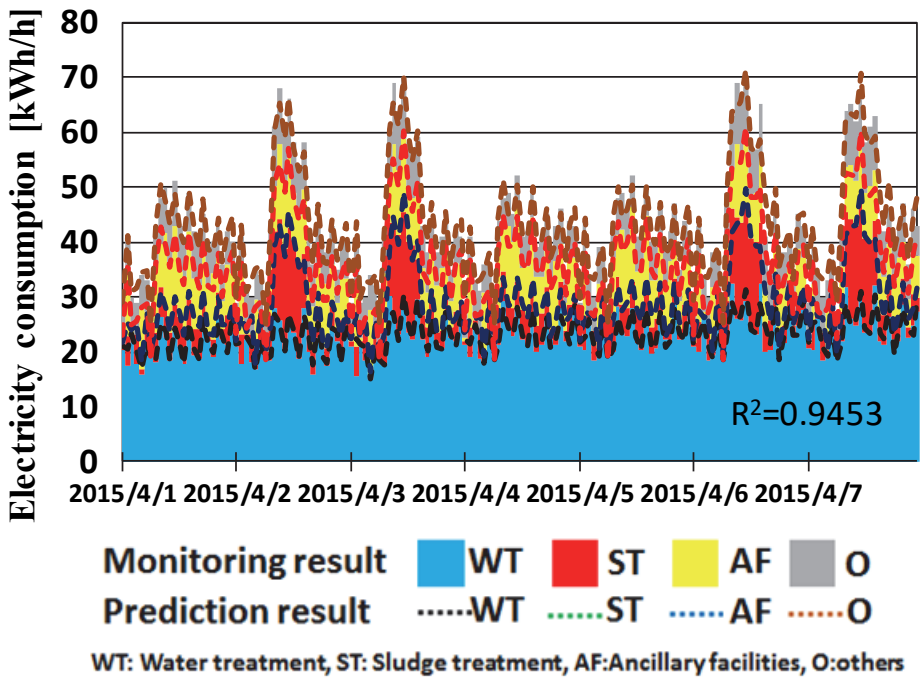


Fig. 3 Energy consumption prediction by using a Markov switching model in the case of a waste water treatment plant in Fukushima Prefecture

The three sub-themes are jointly conducting research to promote the transition toward a de-carbonized society, for example, by projecting future land-use patterns (sub-theme 1), evaluating environmental technologies accounting for local characteristics (sub-theme 2), and designing low-carbon systems and promoting the social implementation of such systems (sub-theme 3).

3. Evaluation of policies for an environmentally sustainable society

Project 3 aims to elucidate effective policy and planning for an environmentally sustainable society. In sub-theme 1, sustainable visions for various regions and lifestyles are designed and assessed, and the planning approaches and tools to accomplish these visions are developed. In sub-theme 2, national and regional laws and policies are evaluated and submitted from the perspective of their effectiveness and validity. Below are the main results for FY 2018.

To design sustainable regions and lifestyles, our estimations of the carbon emissions from household sectors and transport sectors in municipalities were revised by using survey data on household energy consumptions and statistical data at multiple scales. Per capita emissions are lower in municipalities where the ratio of collective housing is high. For example, per capita emissions were found to be high in suburban municipalities of Hokkaido, the Tohoku region, and the Chugoku region, where the ratio of household units with two or more households was high.

A well-known condition necessary for sustainable development is that inclusive

wealth must not decline, where "inclusive wealth" at least encompasses produced, human, and natural capital. An emerging class of produced capital that will substitute for conventional power plants and subsoil natural capital is renewable energy capital (REC), such as solar power plants and wind farms. We proposed a method for valuing REC as a class of produced capital. In doing so, we compared shadow prices on the basis of backward- and forward-looking perspectives that focus on past investments and future benefits, respectively. The forward-looking shadow price is based on the value of the fossil fuel that REC replaces, net of the operating costs of REC. Our numerical estimates for selected countries according to both approaches (see Fig. 4 for the forward-looking results) indicate that REC comes close to accounting for a share similar to that of natural capital in countries poorly endowed with natural capital (e.g., Belgium). It is imperative to closely monitor how REC will replace other capital assets, and to determine whether wealth including produced, human, natural capital along with REC is increasing or decreasing.

Reference:

Yamaguchi, R., Managi, S. (2019). Backward- and forward-looking shadow prices in inclusive wealth accounting: An example of renewable energy capital. *Ecol. Econ.* 156:337–349

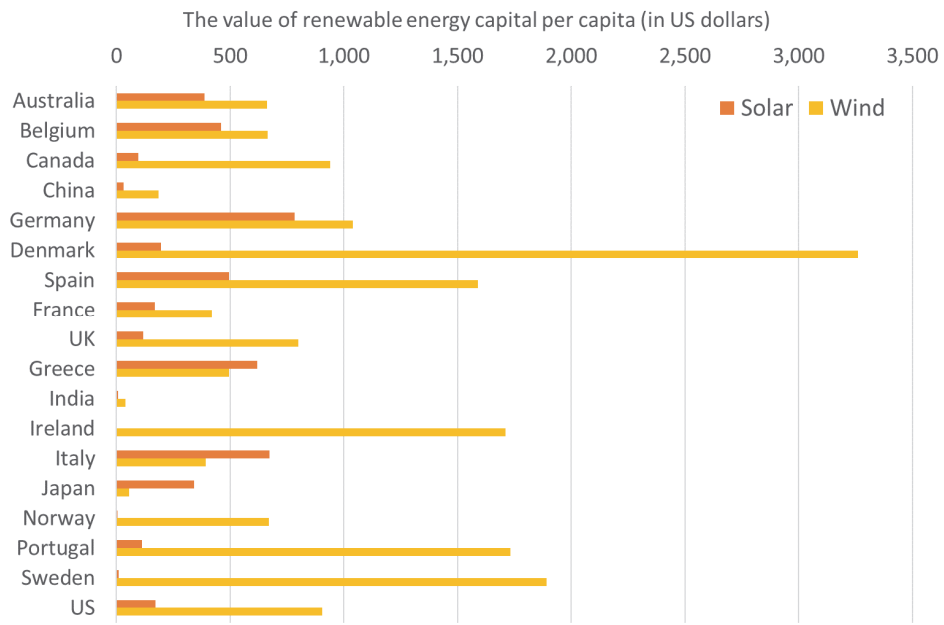


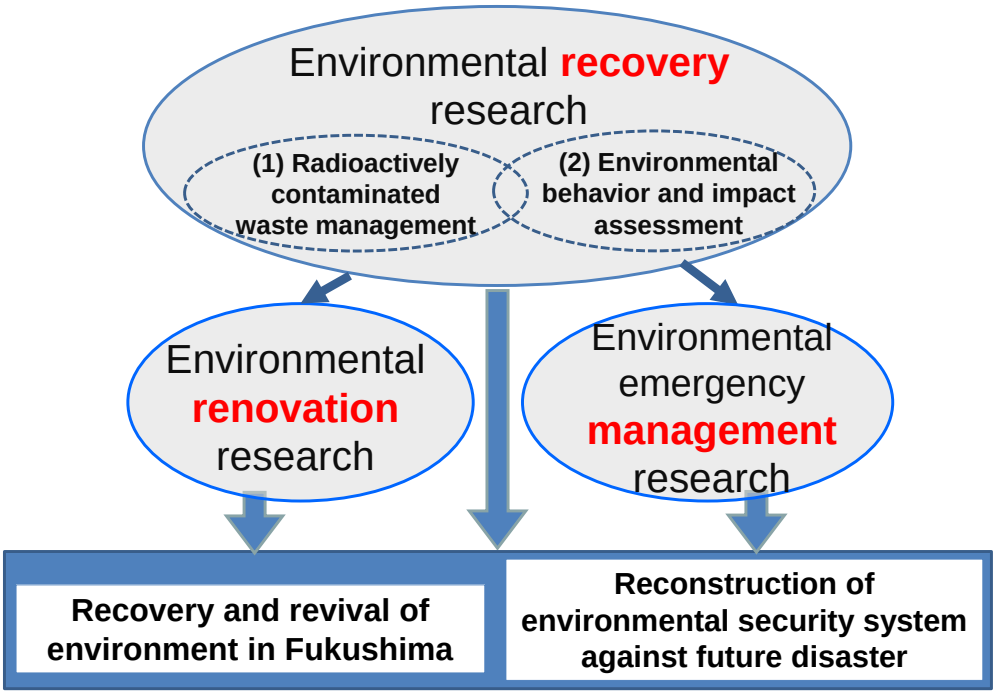
Fig. 4 The value of renewable energy capital per capita in selected countries (in US dollars), based on forward-looking shadow prices, 2014

Environmental Emergency Research Programs

Environmental Emergency Research Programs

Immediately after the Great East Japan Earthquake and the Fukushima Daiichi Nuclear Power Plant (FDNPP) accident, NIES undertook disaster-related environmental research. This research has helped in the environmental restoration and recovery of the devastated areas. By using the accumulated outcomes of this research, and with the NIES Fukushima Branch (which was established at the Fukushima Prefectural Centre for Environmental Creation in April 2016) as a research hub, this program conducts Environmental Recovery research, Environmental Renovation research, and Environmental Emergency Management research in collaboration with the government of Fukushima Prefecture, the Japan Atomic Energy Agency, other related institutions in Japan and abroad, stakeholders, and other entities. In addition to contributing to environmental recovery in the devastated areas, the Environmental Emergency Research Program delineates paths leading to environmental restoration and creation and is helping to create a disaster-resilient society on the basis of the lessons of the Great East Japan Earthquake and other major disasters. Below, we outline the major projects conducted under the three sub-programs.

Fig. 1 Outline of the Environmental Emergency Research Programs



1. Environmental Recovery Research Program

This program is conducting research and development for volume reduction and other technologies for the purposes of intermediate storage and final disposal of radioactively contaminated off-site waste; these are urgent tasks of the highest priority for the nation. The program will also carry out research and development for technological solutions to problems related to the treatment and disposal of designated wastes and other contaminated wastes. Additionally, it will conduct

studies from a long-term perspective on the environmental fate of radioactive substances remaining in forests, water bodies, and other environments. Furthermore, it will apply long-term environmental risk-management methods to secure a livelihood platform where people can live safely and free of concern, and it will implement an ecosystem assessment that will include ecosystem services.

1.1 Development of management systems for radioactively contaminated off-site wastes

The FDNPP accident resulted in serious radiocesium (r-Cs) contamination of solid wastes and soil in the surrounding area. We are performing various types of emergency response research into appropriate management of waste contaminated by radioactive substances (Fig. 2). We are also collaborating with central and local governments in the practical implementation of our research. Our research results are being reflected in various measures, including technical guidelines published by the Ministry of the Environment (MOE), discussions by an MOE panel, and implementation of the Act on Special Measures Concerning the Handling of Pollution by Radioactive Materials.

Our recent areas of interest are: 1) volume-reduction technologies for radioactively contaminated off-site wastes; 2) management and optimization of stocks and flows through recycling and disposal of radioactively contaminated off-site wastes; and 3) optimization and long-term management of processes in the final disposal of radioactively contaminated off-site wastes and interim storage of removed soil. Below are representative results of these studies in FY 2018.

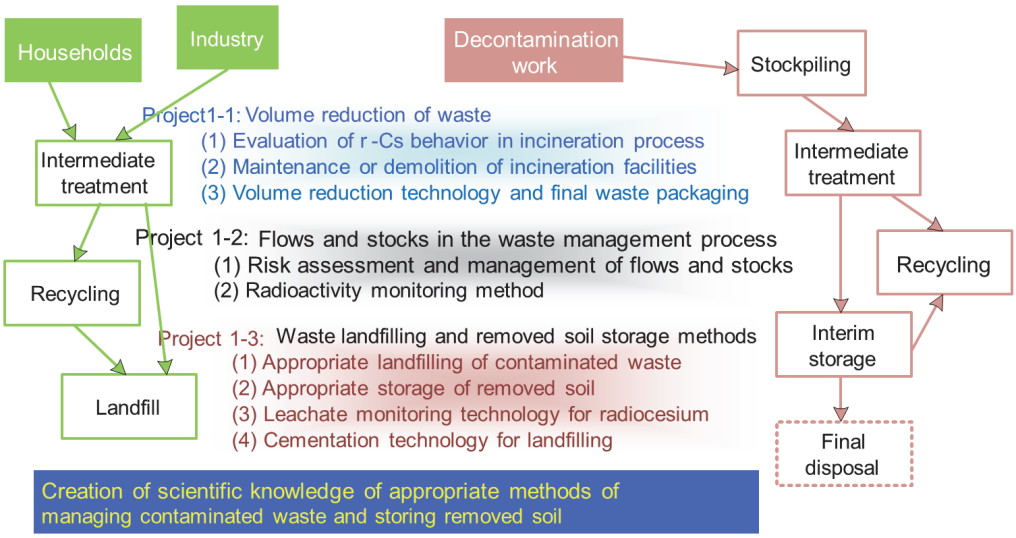


Fig. 2 Outline of the research project on the development of management systems for radioactively contaminated off-site waste

1.1.1 Volume-reduction technologies for radioactively contaminated off-site wastes

Direct melting and ash-melting process technologies, which we previously developed, have been employed as a thermal volume-reduction treatment for

decontamination waste and incineration residues such as bottom ash and fly ash in the Interim Storage Facility (ISF). To establish stable operation of the ash-melting treatment, a rapid and reliable elemental analysis method for the incineration residues is required. Therefore, we applied two types of x-ray fluorescence methods to determine the elemental composition of the residues and investigated the reliability of the methods. With both methods, it was difficult to quantify the content of Si—a key element during ash-melting treatment—in fly ash. We modified the sample preparation and quantification method in the elemental analysis, thus improving the reliability of the Si content.

We developed an incineration simulator to predict the behavior and chemical forms of r-Cs in three temporary incineration facilities dealing with decontamination waste. The simulator fairly represented not only the distribution of r-Cs between bottom ash and fly ash but also the leachability of r-Cs from both types of ash. Because two of the simulated incineration facilities are the same as a newly constructed incineration facility at the ISF, the simulator will be helpful for stable and safe operation of the new facility.

1.1.2 Management and optimization of material flows through recycling and disposal of radioactively contaminated off-site wastes

We surveyed the flows and stocks of r-Cs contained in by-products and industrial waste in Fukushima Prefecture by using official reports on industrial waste (for the mass flows) and field surveys (for the r-Cs concentrations). The r-Cs concentrations in by-products and industrial wastes could be estimated by using the waste types and areas of generation. We are also attempting to estimate changes in r-Cs concentrations with time by physical attenuation and weathering by monitoring buildings in the “difficult-to-return” zone. We are compiling the estimated flows and stocks of r-Cs in an input–output table. We also conducted case studies assessing the additional radiation exposure of workers during the treatment and recycling of waste and recyclable materials, such as sludge and wood waste, in areas of Fukushima Prefecture with low air dose rates. The case studies were conducted by using a Microsoft Excel-based calculation tool and a database, which we developed, of radiation exposure assessment cases. The results showed that the additional radiation exposure of workers was quite small compared with the background air dose rate. This finding was consistent with the radiation dose measured by personal dosimeter, so the developed tools are considered feasible and useful.

1.2 Analysis and prediction of the behavior of radioactive substances in multimedia environments

1.2.1 Comparison of 0.1 M stable CsCl and 1 M NH_4NO_3 as extraction reagents to evaluate ^{137}Cs mobility in soils

To evaluate the mobility and bioavailability of ^{137}Cs in soils, we compared the extraction of ^{137}Cs with stable Cs and ammonium solutions from

^{137}Cs-contaminated minerals and soils. The extraction yields of ^{137}Cs with stable Cs were significantly lower than those with ammonium for minerals with frayed edge sites, but such differences were not observed for minerals without frayed edge sites. The amount of ^{137}Cs extracted with stable Cs from soils was less than, or equal to, that extracted with ammonium. These results suggest that stable Cs extracted the ^{137}Cs from easily accessible sites. Plant-available ^{137}Cs was assessed by using kochia (*Bassia scoparia*) cultivated in pots of contaminated soil, and the results were evaluated for soil parameters, including extractable ^{137}Cs and K, as well as r-Cs intercept potential. The ratio of ^{137}Cs/K extracted with the stable Cs solution was found to be a potentially useful index for evaluating the easily mobile and bioavailable fraction of ^{137}Cs in soils.

1.2.2 Impact of clearcutting on r-Cs export from a Japanese forested catchment following the Fukushima nuclear accident

Changes in ^{137}Cs export over time following clearcutting were investigated in a Japanese forested catchment affected by the Fukushima nuclear accident. After 13% of the catchment area had been logged by clearcutting, export of annual suspended solids (SS) at the catchment outlet increased by 1.4 to 2.0 times, whereas ^{137}Cs export increased only slightly (up to 1.1 times), corresponding to 0.21% to 0.30% of the ^{137}Cs inventory in the catchment. The smaller increase in ^{137}Cs export was due to a rapid decrease in the activity concentration of ^{137}Cs following clearcutting. This decrease was likely caused by both natural attenuation and the presence of SS derived from sources with a low activity concentration in the clear-cut area. Monitoring of the sediment transport from hillslopes in small-scale experimental plots showed that the ^{137}Cs yield on a skid trail was 3.6 to 21 times greater than those in clear-cut and unlogged forest floors. This high level of ^{137}Cs transport was caused by greater soil erosion (up to two orders of magnitude greater) along the skid trail, despite the area having a lower activity concentration than those in the other plots. These results indicate that, although skid trails were involved in the rapid decrease in the activity concentration in SS, they were a potential source of the increased export of ^{137}Cs and SS. The net ^{137}Cs export increase by clearcutting (i.e. the export excluding the decrease accompanied by natural attenuation) was estimated to be only 0.092% of the inventory in the catchment for 2.5 years. These results imply that the impact of clearcutting on ^{137}Cs export was temporary in this catchment.

1.3 Research into impacts of radiation on wild organisms and ecosystem

Following the FDNPP accident, the dose rate of gamma (γ) radiation in species of the family Muridae in the forests of Iitate Village was estimated to be 3.9 mG/day over the first 30 days. According to the derived consideration reference levels determined by the International Commission on Radiological Protection (ICRP), this dose rate could affect the reproduction capabilities of these rodents. However, information on the dose rates in forest rodents after 2012 is limited. It is therefore important to know whether or not nuclear substances in the area are still affecting male and female fertility in Muridae. To understand the present fertility situation

of these rodents, we calculated the dose rate in large Japanese field mice (*Apodemus speciosus*) that were captured in the "difficult-to-return" zones of Fukushima Prefecture from 2012 to 2016. The daily external dose rate (mGy/day) was calculated on the basis of the ambient dose rate of γ radiation at ground level by using the following formula:

Daily external dose rate (mGy/day) = [Ambient dose rate at the trapping site (μSv/h) × 24 h] / [1.2 (conversion factor of ambient dose equivalent H×(10) for S-Cs 662) × 1 (radiation weighting factor of γ rays) × 1000]

The internal dose rate was calculated by using the EGS5 (Electron Gamma Shower Version 5) program (http://rcwww.kek.jp/research/egs/) and was based on the ^{137}Cs concentrations in the captured mice. The mean daily external dose rate ranged from 0.16 to 0.34 mGy/day, whereas the mean daily internal dose rate ranged from 0.04 to 0.21 mGy/day (Fig. 3). The total daily dose rate for the mice within the zones ranged from 0.20 to 0.55 mGy/day. Therefore, the present radiation exposure of field mice distributed within the trapping site should not be affecting their reproduction according to the ICRP reference level. However, because the total dose rate exceeded 0.1 mGy/day, a very low probability of the occurrence of certain effects is likely. We should therefore continue to evaluate the effects of gamma exposure on field mice within these zones.

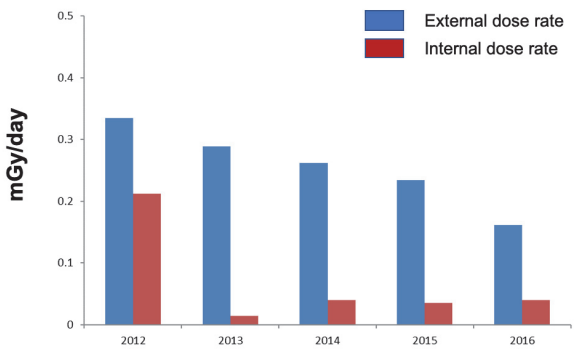


Fig. 3 Temporal changes in mean daily external and internal dose rates. The external dose rate was calculated on the basis of the ambient dose rate of γ radiation at ground level at the trapping site. The internal dose rate was estimated by using the ^{137}Cs concentrations in large Japanese field mice.

1.4 Ambient monitoring of radiation dose

We continued to measure r-Cs in particulate matter samples collected from two locations in Iitate Village, Fukushima Prefecture. Current atmospheric concentrations of r-Cs ranged from 0.01 to 0.1 mBq/m^3. We did not observe a short-lived elevation of r-Cs concentrations during a decontamination operation that resuspended soils into the air. We also optimized a portable imaging plate for quantitative measurement of radioactive material distribution in an indoor environment.

We collaborated with residents of Iitate Village to investigate their intake of hand-picked foods before the disaster. We also started a soil study in an area where edible plants grow to study any contamination by r-Cs and the mechanism

of its migration into those food items.

We used the results from an atmospheric transport and dispersion model for r-Cs and reconstruction of the temporal and spacial distribution of radioactive iodine immediately after the Fukushima accident to estimate the thyroid dose distribution in each municipality of Fukushima Prefecture by using the combination of an r-Cs inhalation model and a thyroid equivalent dose model. We also estimated the thyroid dose for 18 different evacuation scenarios. The tools we developed can be used to estimate chemical exposure through inhalation.

2. Environmental Renovation Research Program

This program is working with the staff of Shinchi, Mishima, and other municipalities in Fukushima Prefecture where reconstruction is under way to develop research theory and methods that will support the process of restoration and environmental re-creation in post-disaster regional environments. It also studies the use of these methods to support policymaking by local governments. Moreover, we are considering such items as global warming countermeasures and resource recycling strategies tailored to the characteristics of affected areas, and we are conducting practical research aimed at building regional environmental resource and energy systems and formulating quantitative eco-city policy targets and roadmaps for achieving those targets. Figure 4 presents the framework of our Environmental Renovation Research Program.

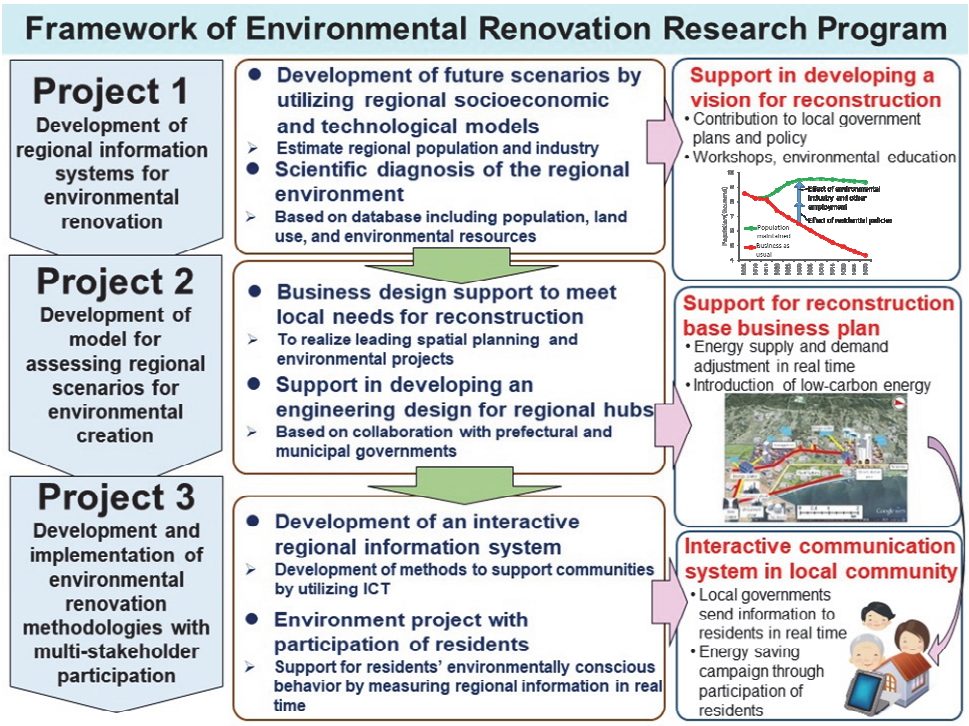


Fig. 4 Outline of the Environmental Renovation Research Program

2.1 Development of regional information systems for environmental renovation (Project 1)

An existing spatial regional database was enlarged with population information from the evacuation area (including where the evacuation order has been lifted) and information on the construction and operation of facilities such as public offices, schools, retail shops, and factories to determine the current status of recovery from the disaster. Land-use and future climate data were also added as a basis for climate change adaptation research. A framework was developed for thecollection of indicators for future research regarding Sustainable Development Goals (SDGs) and a Regional Circular and Ecological Sphere (RCES). Several outreach activities were conducted with the aid of a three-dimensional projection mapping system that was developed in 2017.

To develop regional integrated models, we created a corespondence table of 17 goals and targets composed of SDGs and variables in the models so that the goals can be considered in the analysis when using the model. An interactive methodology for local scenario development using this model was also developed and applied in Shinchi, where we launched the "Shinchi Future Vision Committee" with town officers, business leaders, and experts from the University of Tokyo. Two future sceanrios, BaU (business as usual) and SD (sustainable development), were developed through the committee's discussions.

We also began a collaborative study with Koriyama City, the most urbanized area of Fukushima Prefecture and the prefecture's geographic center. The city is strongly interested in incorporating SDGs in its policies, so we held a SDG seminar and a workshop with three sessions. We identified issues important to the city from the viewpoint of SDGs and developed solutions with the workshop participants.

Another study was initiated in Miharu in 2019. In this study, we clarified the policy process regarding radioactive wastes using policy documents and other local and community records. In 2018, we examined the collaboration between various stakeholders with regard to radioactive waste management.

2.2 Development of a model for assessing regional scenarios for environmental creation (Project 2)

Because of recent social and economic changes, the design of energy systems is increasingly being recognized as an important regional issue. In this study, we modeled the process of designing a distributed energy system from the perspective of mathematical optimization problems. To study the use of resources and energy throughout the region, it is necessary to focus on villages, which are the basic unit of organization in the region. This year, we developed "village clinical records," which summarize basic information on energy supply and demand in terms of settlements and the possibility of introducing energy systems

utilizing forest biomass resources. We proposed a basic framework for the data structure of the clinical records and collected information on villages which located in Mishima town, Fukushima Prefecture. We then prepared charts to convey the information to interested parties.

To create the clinical records, we first summarized basic information about each village. The building distribution for each purpose is displayed visually by using maps and photos, along with land-use conditions in the surrounding area. Next, we show the possession of energy-related equipment, such as heating, cooling, and hot-water-supply equipment. In addition, energy-saving equipment such as equipment related to biomass use and solar power generation are depicted. As part of the records, information on the actual energy consumption conditions in the village are also displayed. Finally, we present the results of our estimation of the effect of introducing an energy system centered on biomass to this area. In the next step, we will evaluate these village clinical records from the viewpoint of the accumulation and sharing of data and their effectiveness in the actual policy planning process.

In the quest to mitigate global warming, forest ecosystems that are well managed and efficiently utilized are effective systems for carbon sequestration. We used the effective carbon sequestration rate (ESR), which is a measure of the net sequestration rate in both ecological and social systems, to assess both production and manufacturing processes with the aim of promoting the use of woody biomass. In addition, we continued to examine the feasibility of installing small gasification systems for electricity and heat generation in western Fukushima Prefecture. ESR was found to have the highest value in an ideal consumption of woody biomass (i.e., in a cascade usage of wood material). These results are informative when planning a framework for the best combination of energy-use woody biomass and construction materials from the forest plantation stage to the combustion stage of wood materials. We also began a new assessment for the prevention of landslides and the protection of water resources and ecosystems by promoting the growth of woody biomass in areas that have been subjected to high-intensity ecosystem disturbances (e.g., logging).

2.3 Development and implementation of environmental renovation methodologies with multi-stakeholder participation (Project 3)

We continued power monitoring and data analysis by using a local information and communications technology (ICT) system with which we are promoting technology development and enhanced communication with local governments and residents. First, we analyzed the temperature sensitivity of power consumption in Shinchi by household attribute and the status of possession of space cooling, heating, and hot water equipment on the basis of the power consumption status of each household and the seasonal variation of temperatures. Next, to expand this analysis throughout Fukushima Prefecture, we estimated monthly and hourly temperature distributions by using simple meteorological

simulations. By combining the temperature distributions we obtained with the temperature sensitivity data, we were able to estimate monthly and hourly electricity demand in a detailed spatial distribution for Fukushima Prefecture. These results can be used when considering the introduction of a regional energy supply system and renewable energy.

We also analyzed the relationship between the method of information dissemination and energy-saving effects on the basis of the results of the sixth energy-saving campaign, which was run from November to December 2017 in Shinchi as a social demonstration experiment to improve energy-saving activities and to help revitalize the regional community. In addition to analyzing the results of this campaign, we analyzed the cumulative trends of the six energy-saving campaigns implemented so far. On the basis of these results, individual energy-saving reports were prepared and provided to participating households. To publicize the results of the demonstration experiments to local residents, we held an information session in the Shinchi Town Hall. Furthermore, these experiments led to the launch of a new project that proposes the introduction of automated demand-response control to improve demand and supply management of the regional energy supply system in the area around the JR (Japan Railways) Shinchi Station and the development of a consulting tool to expand the use of this system into other areas.

We also examined methods in which forest biomass could be used as an example that balances low carbon policy and community activation in the regional environment. This year, we conducted a questionnaire survey of households as consumers and business operators as sellers to clarify the amount of household wood-burning equipment being used and the demand for wood fuel from the perspective of both sales and consumption.

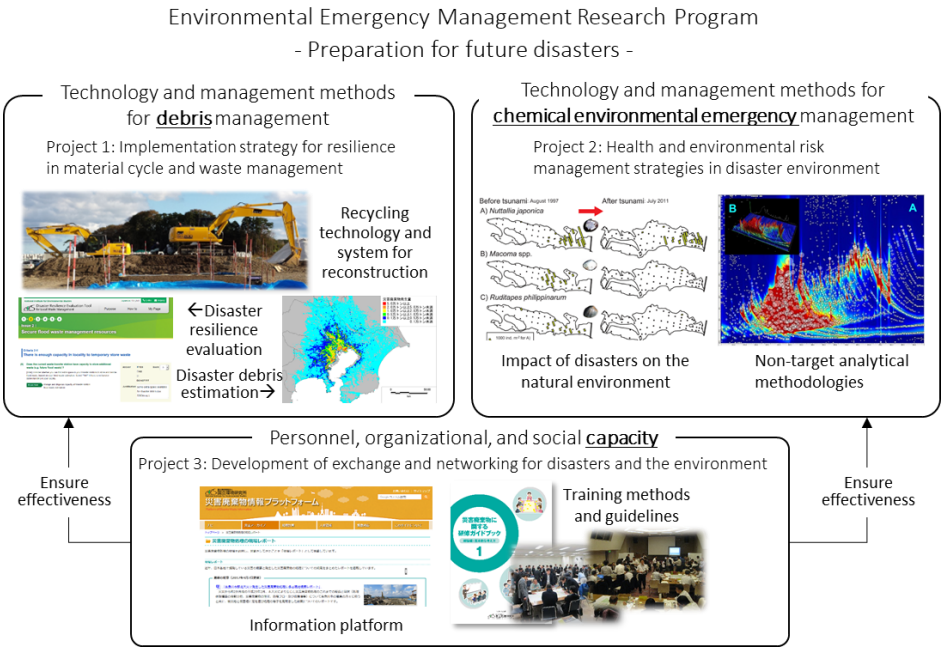
3. Environmental Emergency Management Research Program

Our Environmental Emergency Management Research Program (Fig. 5) aims to establish practical management systems and technologies for handling disaster waste during and after disasters. It also aims to develop a strategy for environmental and health-risk management in times of emergency to create more resilient social environmental systems and foster the communities within them.

This program will devise technologies and systems for integrated disaster waste management aimed at achieving smooth and appropriate management of these types of wastes. Additionally, to create a strategy to manage the environmental and health risks associated with disasters, the program will investigate approaches to setting risk management targets, focusing especially on chemical risks when disasters strike and methods and organizational arrangements for emergency environmental surveys. Furthermore, to build a research hub for an environmental emergency research network, the program will design and develop an information platform and capacity-development system for environmental emergencies. This

research will be pursued in collaboration with NIES's Environmental Emergency Management Office.

Fig. 5 Outline of the Environmental Emergency Management Research Program



3.1 Establishment of disaster-resilient waste management systems and strategies (Projects 1 and 3)

As part of our research into capacity development, we analyzed the effectiveness of a table-top exercise held last year in collaboration with the government of Hyogo Prefecture to develop participatory training methods for disaster waste management. We hypothesized that the table-top exercise, in which participants responded to various disaster waste management tasks assigned one after another in a hypothetical disaster situation, would enhance the capacity of waste management officers, particularly in terms of a) better perception of disaster waste situations, issues, and tasks; b) acquiring specific skills required to undertake tasks; and c) gaining the information management ability for waste management in emergency circumstances. The results of the pre- and post-tests and the evaluation of the participants' responses to the tasks under hypothetical settings were analyzed in an integrated manner to clarify their effectiveness. The results of the analysis showed that the table-top exercise was effective in terms of all three dimensions of effectiveness, but that provision of a lecture was a necessary condition to develop specific skills for disaster waste management. In terms of the design, it was suggested that about four tasks should be assigned per hour to ensure fruitful discussions and to enhance the effectiveness of the training.

We also conducted a questionnaire survey of officials from major cities and prefectures to clarify the current status of capacity development projects being undertaken in municipalities. The results showed that nearly 80% of the

prefectural governments currently have some kind of training program for disaster waste management; some of them have already adopted the table-top exercise method developed by NIES.

To support organizational management and capacity development, we initiated studies of public relations methodology with the aim of developing an online tool to support public relations undertaken by local governments about disaster waste management. Our research was conducted after the July 2018 Heavy Rain Disaster and suggested that, although information needs to be delivered to residents (victims) quickly after a disaster strikes, this is not an easy task unless the local government is prepared. This study was conducted in an integrated manner with the NIES Environmental Emergency Management Office, where the data used for the research were gathered and the study results were implemented.

3.2 Health and environmental risk management strategies in disaster environments (Project 2)

Health and environmental risk assessment and management of hazardous chemicals are currently general practices when such chemicals are used in normal environments. However, the risks posed by the accidental release of hazardous chemicals in disaster environments have not yet been sufficiently evaluated or managed.

This research project focuses on establishing a risk assessment and management methodology for the accidental release of hazardous chemicals in disaster environments. The project consists of several sub-projects, which are briefly summarized as follows: Project 2-1, setting target control levels for chemical contamination in disaster environments; Project 2-2-1, establishing comprehensive analytical technologies and emergency response teams for contaminant chemicals; Project 2-2-2, establishing non-target analytical methodologies and sampling technologies for emergency contamination; Project 2-3, clarifying the impacts of emergency contamination events on terrestrial ecosystems; Project 2-4, clarifying the long-term impacts of emergency contamination events on coastal ecosystems in the field; and Project 2-5, environmental epidemiology in emergency events. This fiscal year, we investigated information on chemical accidents in recent years and grouped the related accidents (Project 2-1); developed a rapid and comprehensive analytical screening method (Project 2-2-1); created a rapid sample-preparation method (Project 2-2-2); conducted monitoring and research on the mechanisms of groundwater contamination after the Kumamoto earthquake (Project 2-3); performed a field survey of the impact of a disaster on a coastal ecosystem (Project 2-4); and joined a workshop held on DR2 (Disaster Response Research) tools by the U.S. National Institutes of Health (Project 2-5). Through these achievements, the project aims to demonstrate comprehensive strategies for managing the health and environmental risks posed by hazardous chemicals in a variety of disaster environments.

Research Projects

Satellite Observation Center

The Center contributes to improved scientific understanding of the carbon cycle, more accurate prediction of the future climate, and climate-change-related policy-making by the Ministry of the Environment (MOE) through activities that use data from the Greenhouse Gases Observing Satellite (Ibuki/GOSAT, launched in 2009) and its successor (GOSAT-2, launched in 2018). Activities include developing and operating data-processing systems for GOSAT and GOSAT-2. These systems are being used to calculate the concentrations and fluxes of greenhouse gases (GHGs) and to verify, archive, or distribute GOSAT or GOSAT-2 products. The Center will also conduct a scientific review of the Earth observation satellites to succeed GOSAT-2, including GOSAT-3. GOSAT and GOSAT-2 projects are jointly promoted by MOE, the Japan Aerospace Exploration Agency (JAXA), and NIES.

Major achievements of the Satellite Observation Center in FY 2018 are as follows:

1. GOSAT

Operational data processing for GOSAT, which has been in space for more than 10 years, continued, and the generation, validation, and distribution of GOSAT data products, such as the concentrations and fluxes of carbon dioxide (CO_2) and methane (CH_4), were conducted. Concentration products up to February 2019, CO_2 flux products up to October 2015, and CH_4 flux products up to September 2015 are freely available from the data distribution website (GOSAT Data Archive Service, GDAS; https://data2.gosat.nies.go.jp). Maintenance and operation of GOSAT DHF (the GOSAT Data Handling Facility), which is the computer system needed for these activities, were also done. Since March 2019, GOSAT CO_2 concentration products have also been available from the World Data Centre for Greenhouse Gases, which is operated by the Japan Meteorological Agency under an agreement with the World Meteorological Organization.

2. GOSAT-2

In February 2019, the operational reception of GOSAT-2 Level 1 products from JAXA was started by using the GOSAT-2 Data Processing System (G2DPS), a dedicated data-processing system developed for GOSAT-2 over the past few years. Preliminary processing of several Level 2 products, such as columnar concentrations of atmospheric methane and carbon monoxide by the proxy method, was conducted, and the results were thoroughly examined to improve their quality. Meetings of the GOSAT-2 Science Team and its Calibration Working Group were held periodically.

3. GOSAT-3

A draft version of the long-term schedule of the GOSAT-3 Project was developed, and an FY 2019 budget was requested. Information on plans for foreign GHG observation satellite projects was gathered at international conferences and from websites, and discussions about GOSAT-3 with MOE and JAXA continued.

4. Collaboration with other organizations

The first Research Announcement on Greenhouse Gases Observing Satellite Series (GOSAT Series RA), which covers both GOSAT and GOSAT-2, was jointly issued by MOE, JAXA, and NIES in September 2018. Proposals submitted by November 2018 were evaluated by the GOSAT Series RA Selection and Evaluation Committee, and 37 joint research agreements were concluded in March 2019.

On the basis of an agreement concluded between NIES and SYKE (the Finnish Environment Institute) in FY 2017, a NIES researcher visited Finland to discuss in-situ measurement of solar-induced fluorescence in the forests of Finland.

In response to agreements concluded with NASA (the US National Aeronautics and Space Administration), ESA (the European Space Agency), CNES (the Centre National d'Etudes Spatiales), and DLR (Deutsches Zentrum für Luft- and Raumfahrt, the German Aerospace Center), several informal meetings were held to exchange technical information and discuss future collaboration. These meetings were held at large conferences such as the 14th International Workshop on Greenhouse Gas Measurements from Space in May 2018 and the American Geophysical Union's Fall meeting in December 2018.

5. Hosting of meetings

The 11th GOSAT Research Announcement (RA) Principal Investigators (PI) Meeting was held in Toronto, Canada, in May 2018. It was co-hosted by MOE and JAXA. Preparations for hosting the 15th International Workshop on Greenhouse Gas Measurements from Space (IWGGMS-15) and the first GOSAT Series RA PI Meeting in June 2019 in Sapporo, Japan, continued. IWGGMS-15's first circular was distributed in December, and its abstract submission site was opened in January 2019.

6. Participation in international events

To promote the use of GOSAT and GOSAT-2 data in Earth-science- and climate-change-related policy-making, the Satellite Observation Center participated in the following international events and conducted presentations, lectures, and exhibits:

- Land Cover/Land Use Changes (LC/LUC) and Impacts on Environment in South/Southeast Asia—International Regional Science Meeting (May, Manila,

Philippines)

- WGIA16 (16th Workshop on Greenhouse Gas Inventories in Asia), July, New Delhi, India)
- GEO Week 2018 (Group on Earth Observation 15th Plenary Session), October–November, Kyoto)
- UNFCCC COP24 (United Nations Framework Convention on Climate Change 24th session of the Conference of the Parties), December, Katowice, Poland.

Fig. 1 A side event titled "Satellite Observation of Greenhouse Gases: How are satellites contributing the Paris Agreement?" was held at the Japan Pavilion, UNFCCC COP24.

7. Press releases

Three press releases related to the Satellite Observation Center were issued in FY 2018:

1) “IBUKI-2 (GOSAT-2) Successful Launch and Completion of Critical Operations Phase” (October 2018)

Fig. 2 Launch of the H-IIA F-40 rocket carrying GOSAT-2 from JAXA Tanegashima Space Center on 29 October 2018

2) “Development of a plant CO_2 assimilation rate estimation method by using optical data that can be obtained by remote sensing observations” (November 2018)
3) “The WMO World Data Centre for Greenhouse Gases (WDCGG) begins provision of data from the Greenhouse Gases Observing Satellite (GOSAT)” (March 2019).

Japan Environment and Children's Study

The Japan Environment and Children's Study (JECS) is a large-scale birth cohort study that aims to investigate the impact of the environment on children's health and development. NIES serves as the JECS Programme Office, supporting the Regional Centers that conduct surveys in 15 study areas throughout Japan in cooperation with the Medical Support Centre situated in the National Center for Child Health and Development, which provides medical expertise.

1. Aim

The aim of JECS is to identify environmental factors that affect children's health to develop better environmental risk management policies. Specifically, JECS focuses on the effects of exposure to chemical substances during the fetal period or in early childhood. JECS gives priority to five major health domains: reproduction and pregnancy complications; congenital anomalies; neuropsychiatric/developmental disorders; allergy and immune system disorders; and metabolic and endocrine system dysfunction. The environment is defined broadly as the global or ambient environment (including chemical substances and physical conditions), the built environment, behaviors and habits, socioeconomic factors, family and community support, and genetic factors.

2. Study design and subjects

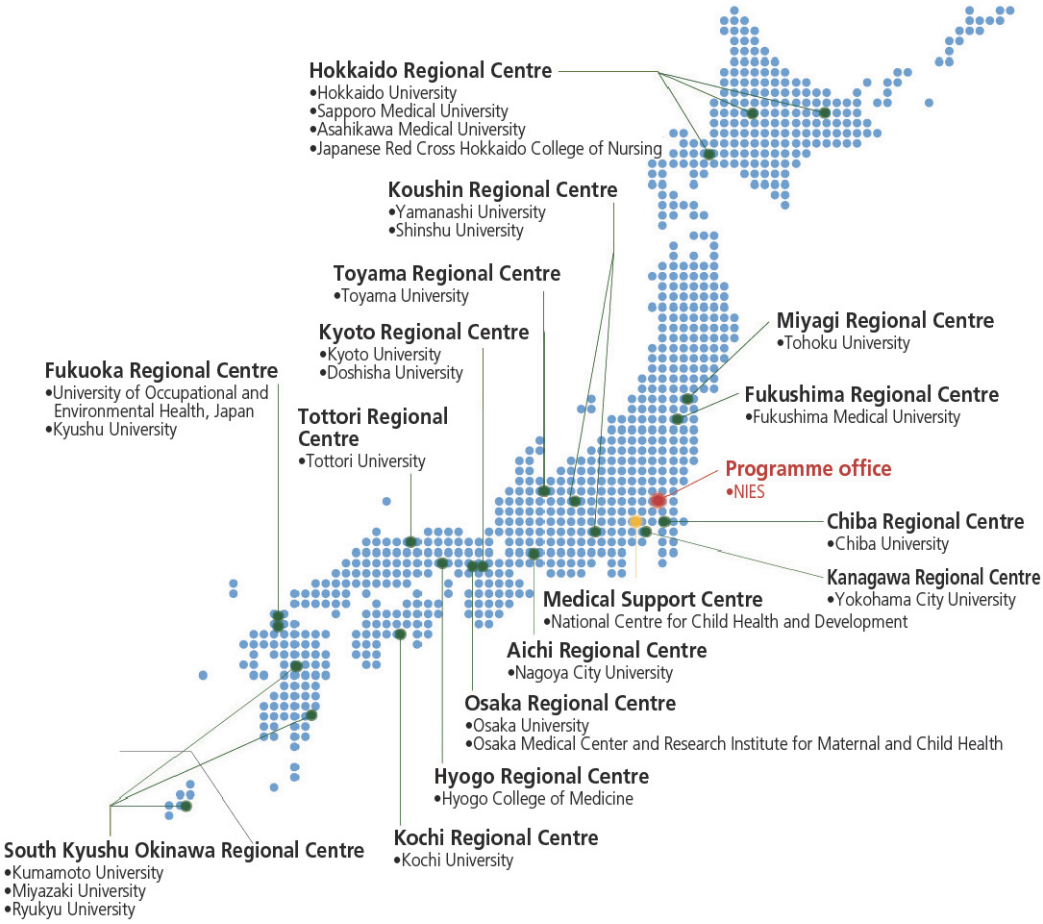
We started recruiting participants in January 2011, and recruitment continued until March 2014, by which time the number of participating mothers had reached 103,099. Recruited participants were pregnant women and their partners (when accessible). JECS began to collect data when the mothers were pregnant and plans to follow their children until they reach 13 years of age. For the Main Study, JECS acquires information about participant health and development and potentially relevant environmental factors by administering questionnaires twice a year. The Sub-Cohort Study, which involves 5000 children selected randomly among participants in the Main Study, is also being conducted to investigate environmental factors and outcome variables more thoroughly. It includes extensive assessment through home visits, ambient air measurements, psycho-developmental testing, and examinations by pediatricians.

3. JECS study organization and role of the Programme Office

For appropriate data collection and analysis, the Programme Office plays key roles, including developing standard operation procedures; accumulating the data collected by the 15 Regional Centers (Fig. 1); operating the data management system; maintaining a repository of biological and environmental specimens; performing exposure and environmental measurements, including chemical analyses of biological samples; and administering questionnaires. The Programme

Office also performs administrative tasks, provides administrative and technical support for Regional Centers, and is responsible for risk management and public communications. The Programme Office strives to play a leadership role in facilitating collaboration among the different research groups conducting environmental birth-cohort studies in both Japan and other parts of the world, working as a platform for information exchange among researchers.

Fig. 1 JECS organization



4. Study protocol

Details of the study protocols of JECS can be found in the following literature:

1. Kawamoto T, Nitta H, Murata K, et al. Rationale and study design of the Japan environment and children's study (JECS). *BMC Public Health*. 2014. 14:25. (doi:10.1186/1471- 2458-14-25)

2. Michikawa T, Nitta H, Nakayama SF, et al. Baseline Profile of Participants in the Japan Environment and Children's Study (JECS). *J Epidemiol.* 2018. 28(2):99–104. (doi:10.2188/jea.JE20170018)

5. Activity report in FY 2018

The children participating in the Main Study reached the ages of 4 to 8 years in FY 2018. We continued to administer questionnaires to participants to collect a wide range of information on the children's health and development and exposure to environmental factors. We completed analyses of 10,000 maternal urine samples for environmental phenols, 5000 maternal urine samples for organophosphate pesticide metabolites, and 3897 cord blood samples for metallic elements and inorganic and methyl mercury. As part of the Sub-Cohort study, 4537 four-year-old participants were tested developmentally and examined by a pediatrician, as well as having blood and urine samples collected and tested.

Risk Assessment Science Collaboration Office

The Risk Assessment Science Collaboration Office provides domestic leadership for the promotion of regulatory science with the aim of achieving a safe and secure society. The office consists of the Ecotoxicity Reference Laboratory and the Environmental Risk Assessment Task Office. The Laboratory conducts ecological toxicity research, international collaboration for the development of advanced testing methods, and standardization of test implementation. The Task Office conducts projects to assess environmental risks scientifically in collaboration with other organizations; it also constructs databases and disseminates knowledge and technical methodologies (Fig. 1).

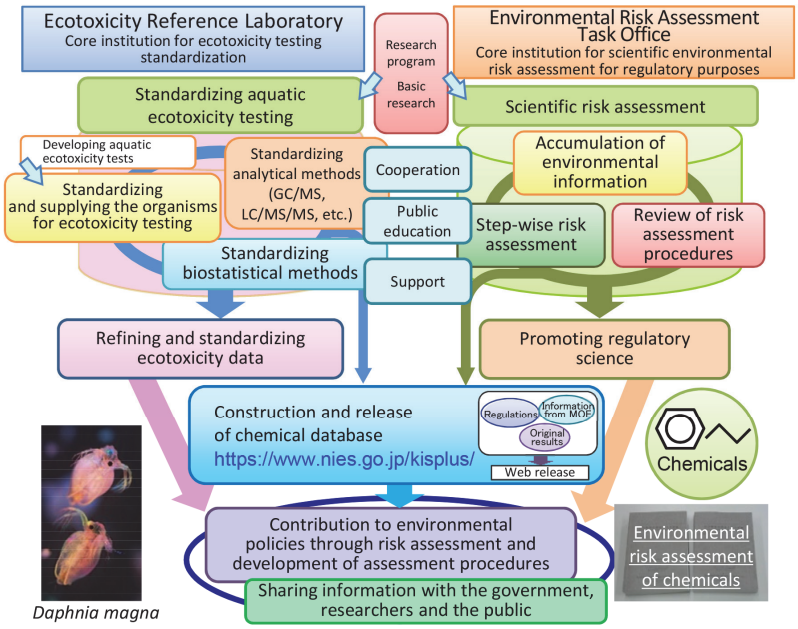


Fig. 1
The Ecotoxicity Reference Laboratory and Environmental Risk Assessment Task Office work in collaboration in regulatory risk assessment science through ecotoxicological testing, scientific risk assessment, and database development.

1. Ecotoxicity Reference Laboratory

As a leading reference laboratory for ecotoxicological research and testing, the Ecotoxicity Reference Laboratory helps realize a safe society by proactively promoting regulatory science. Two kinds of new ecotoxicity test methods, namely a method of detecting anti-androgens by using medaka (juvenile medaka anti-androgen screening assay: JMASA) and a simple method of detecting juvenile-hormone-like chemicals by using *Daphnia magna* (juvenile hormone activity screening assay: JHASA), were proposed by our laboratory in 2016 for the OECD (Organisation for Economic Co-operation and Development) and reported additionally at the meeting of the OECD's Validation Management Group for Ecotoxicity testing (VMG-eco) this year for approval next year. The two methods contribute to the EXTEND (Extended Tasks on Endocrine Disruption) 2016 project of the Ministry of the Environment (MOE), namely "Future correspondence regarding the endocrine-disrupting action of chemical substances."

Because the revision of a fish acute toxicity test (OECD Guideline for Testing of Chemicals, No. 203) is under discussion to change the endpoint from mortality to moribundity, the Laboratory conducted a validation study for individual fish identification (by using separation, visual implant elastomer tags, and pigment) to study the link between sublethal signs and outcome (survival or death) at the individual fish level.

To improve the ecological risk assessment of pesticides, we investigated the species sensitivity distribution for a few herbicides by using a green alga, a diatom, a cyanobacterium, a duckweed, and a submerged aquatic plant.

The Laboratory continuously supplies stable test organisms to personnel in Japan, both outside and inside NIES, for ecotoxicity testing. A duckweed species was added to the current list, which until now had included only fishes and invertebrates.

The Laboratory held two education seminars on ecotoxicity test techniques in FY 2018. The seminar covered a *Daphnia* reproduction test and a fish test at the embryo and sac fry stage. About 20 people from universities, local environmental laboratories, and private enterprise attended both of seminars.

In collaboration with universities, local environmental laboratories, and private enterprise, the Laboratory also promotes ecotoxicity testing and performs scientific risk assessments (Fig. 2).

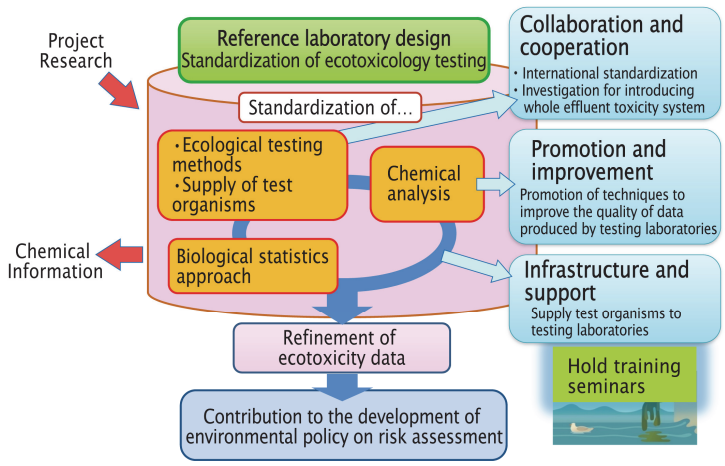


Fig. 2
The Ecotoxicity Reference Laboratory functions as a core organization for the standardization of ecotoxicity testing, both domestically and internationally

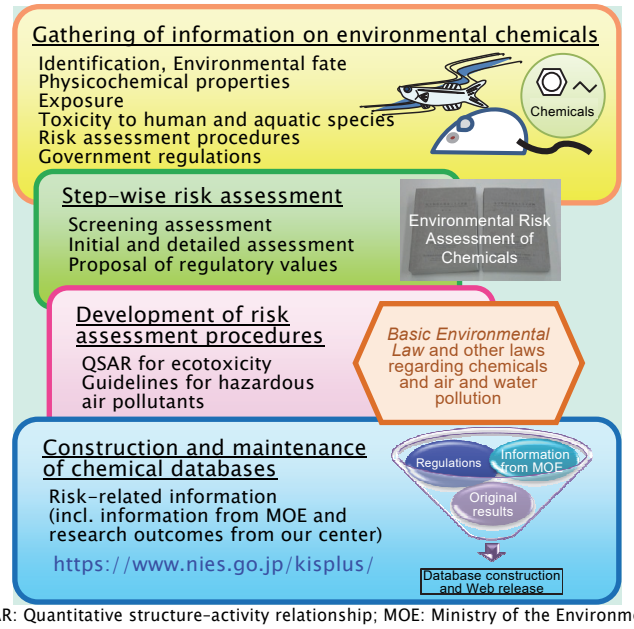
2. Environmental Risk Assessment Task Office

The Environmental Risk Assessment Task Office promotes research to support assessment and management of the risks posed by environmentally released anthropogenic chemicals. It also provides risk-related information to the government and the public. The Office collects a variety of information on the

chemicals and assesses their environmental risks to help with the risk assessment activities conducted under the laws enacted by MOE. Our activities are outlined in Figure 3.

Under the revised Chemical Substances Control Act, all chemical substances, which include existing chemicals but exclude chemicals subject to other laws (such as medicines and agrochemicals), must be screened to determine whether they need more detailed risk assessment (such as Risk Assessment I, II, and III under the Act). The Task Office supports the implementation of screening assessments and more detailed assessments. In FY 2018, as part of screening assessments, we evaluated the credibility of the classification of 51 chemicals in terms of the hazards they pose to the aquatic environment. We also collected and evaluated information on hazards to the aquatic environment of 11 chemicals under Risk Assessment I and 8 chemicals under Risk Assessment II. MOE publishes an "Initial Environmental Risk Assessment of Chemicals" every year. In FY 2018, the Task Office supported the initial ecological risk assessment of 17 chemicals. To support the standards for registration of agricultural chemicals on the basis of the Agricultural Chemicals Regulation Law, information on the toxicity to the aquatic environment of 29 substances was collected, and the credibility of the toxicity information was evaluated.

Fig. 3
Activities and research projects of the Environmental Risk Assessment Task Office



QSAR: Quantitative structure-activity relationship; MOE: Ministry of the Environment

We have been improving the Kashinhou Tool for Ecotoxicity (KATE) system for use in QSAR (quantitative structure–activity relationship) models. In January 2019, we released KATE 2017 on NET (https://kate.nies.go.jp/), which is the formal version of a beta version released in FY 2017 and a major update from KATE 2011 on NET. We have been continually updating our chemical substance databases and have renovated the related website, Webkis-Plus, in Japanese. Webkis-Plus contains information on about 10,000 substances, including their

physicochemical properties; laws and regulations related to environmental pollution; environmental concentrations from surveys performed by MOE; amounts of chemical substances manufactured and imported; volumes of agricultural chemicals shipped into each prefecture; Pollutant Release and Transfer Register information; the results of risk assessments performed by several organizations; and details about the analytical methods developed by MOE for environmental surveys in Japan.

Environmental Emergency Management Office

Through research collaboration with relevant organizations in Japan, this office implements projects aimed at supporting effective and efficient environmental emergency management by emergency response personnel. This includes building and operating institutional and information network systems that serve as a foundation for developing environmental emergency management strategies, training personnel to develop practical expertise in environmental emergency management, providing on-site support for disaster responses, setting up research hubs for environmental emergency management, and training researchers.

More specifically, this office is establishing a new platform for enabling domestic institutions to cooperate in collecting and organizing the experiences and lessons gained from tackling environmental issues caused by past disasters, and in efficiently and effectively organizing new knowledge derived from environmental emergency management research. The office will focus in particular on the smooth management and operation of the central government's Disaster Waste Treatment Support Network (D.Waste-Net), and on building emergency environment monitoring systems centered on regional environmental research institutions.

This year, we have especially made a great effort to establish a system of contributing to efficient and effective disaster-waste management. Below are the main results of our efforts.

1. Provision of on-site support for disaster responses in the July 2018 heavy rain disaster

The torrential rain that hit parts of Western Japan in July 2018 caused extensive damage in areas of Hiroshima, Okayama, and Ehime (Fig. 1). The amount of disaster waste in Okayama alone was estimated to be nearly 300,000 t.

Our office immediately sent an expert on site to investigate the situation in the city of Kurashiki, where the damage was most severe in Okayama Prefecture. The expert remained on site for a month to support the local government's disaster waste management responses. Our support was conducted in cooperation with the Ministry of the Environment under D.Waste-Net.

Examples of the support given were advice on:

a) how to separate many kinds of waste at a short-term waste storage site
b) how to make a plan for implementing disaster waste management
c) how to perform environmental monitoring for asbestos.

We also introduced an online system to support the on-site expert remotely from our office.

Fig. 1 Accumulation of disaster waste from the July 2018 heavy rain disaster

2. Supporting capacity development projects of local governments

Human resources are key to properly enhancing our potential to manage disaster waste in real, unexpected disaster situations. Our office provides practical support to local governments when they design training programs aimed at developing practical expertise for disaster waste management. This year we provided support to Miyazaki, Saitama, Mie, Kanagawa, Hyogo, Aichi, Tokyo, and Sakai. In addition, we published a guidebook explaining the concepts and design process of tabletop training exercises (Fig. 2); the book was developed from research undertaken under the Environmental Emergency Research Program.

Fig. 2 Examples of tabletop exercises from a guidebook created for a disaster waste management training program

3. Implementing a disaster waste information platform

We improved our online information platform on disaster waste management in response to demand from local government officers for information on preparation for temporary storage and management of temporary storage sites. A short video clip explaining the basics of managing temporary storage sites was prepared and released (Fig. 3). In addition, we updated our online database on disaster waste management plans prepared by local governments.

Other information updated on the platform included:

a) lessons and strategies learned from central and local government responses to past disasters

b) experiences and methods regarding capacity development for disaster waste management.

Fig. 3 Screen shots from a video clip about management of temporary storage sites

Social Dialogue and Co-production Office

1. About

To encourage dialogue between members of society and NIES about awareness of environmental problems and the current state of environmental research, the Social Dialogue and Co-production Office (DaC) has accumulated and analyzed our communication experiences to date and has developed new content for interacting with the public by using social media and other means. Furthermore, DaC has held events such as stakeholder meetings and science cafés on NIES activities. Through these communication opportunities, we get feedback from participants on NIES research activities. DaC will use these means to build a relationship of mutual trust between society members and environmental researchers (Fig. 1).

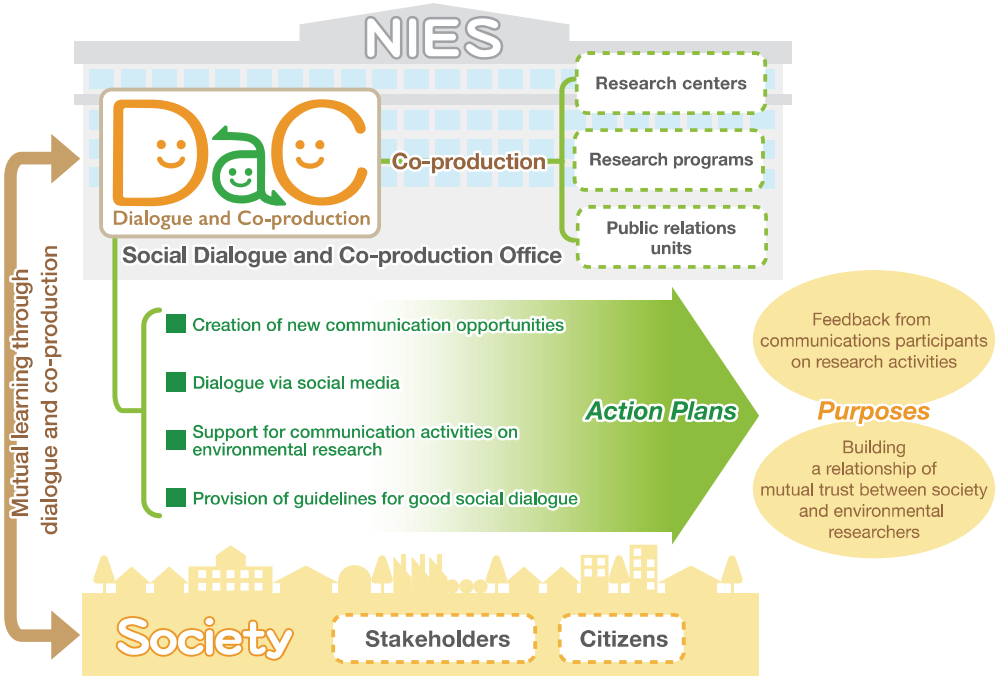


Fig. 1 Action plans and purposes of DaC. There are four activities that involve mutual learning between NIES and members of society. Through these activities, DaC can accomplish its purposes, namely to get feedback from society on NIES research activities and to build a relationship of mutual trust between society members and environmental researchers.

2. Major activities in FY 2018

2.1 Creation of new communication opportunities

DaC held interactive events such as science cafés (Fig. 2) to gain a better understanding of public reaction to environmental problems and NIES research activities.

Fig. 2 About 50 members of the public participated in science cafés and enjoyed talking with researchers at the Summer Open House.

2.2 Dialogue via social media

DaC has opened Twitter (Fig. 3) and Facebook sites to interact with many more members of the public on the Internet. By supplying timely information in response to social topics via social media, we can encourage a greater diversity of people to become interested in NIES's activities. DaC is also concentrating its efforts on enriching its online articles, which the public can read easily and which encourage people to think about environmental issues.

Fig. 3 Examples of Tweets. By contributing catchy topics or visuals, DaC attracts public interest in environmental issues.

2.3 Support for communications activities

DaC supported communication activities in other research centers or programs at NIES, such as a science café at the Fukushima Branch in July.

2.4 Provision of guidelines for good social dialogue

To create guidelines for good social dialogue, DaC holds a workshop every year to accumulate and analyze staff members' communication experiences at NIES. This year, staff discussed the communication gap between researchers and the public.

3. Future issues

DaC has been exploring how to evaluate the effectiveness of communications activities and mutual trust between members of society and NIES. For effective dialogue, it is important that we have a clear picture of communications counterparts and methods. It is also important to think about how we should obtain and use social feedback to improve NIES research activities.

Center for Climate Change Adaptation

Center for Climate Change Adaptation

Under the Climate Change Adaptation Act enforced in December 2018, NIES is the core information platform for climate change adaptation in Japan. It is tasked with collecting, organizing, analyzing, and providing information on the impacts of climate change and climate change adaptation, as well as supporting local governments and Local Climate Change Adaptation Centers (LCCACs) by providing technical advice for efforts on climate change adaptation (Fig. 1). NIES established the Center for Climate Change Adaptation (CCCA) in December 2018 and began to implement this new work.

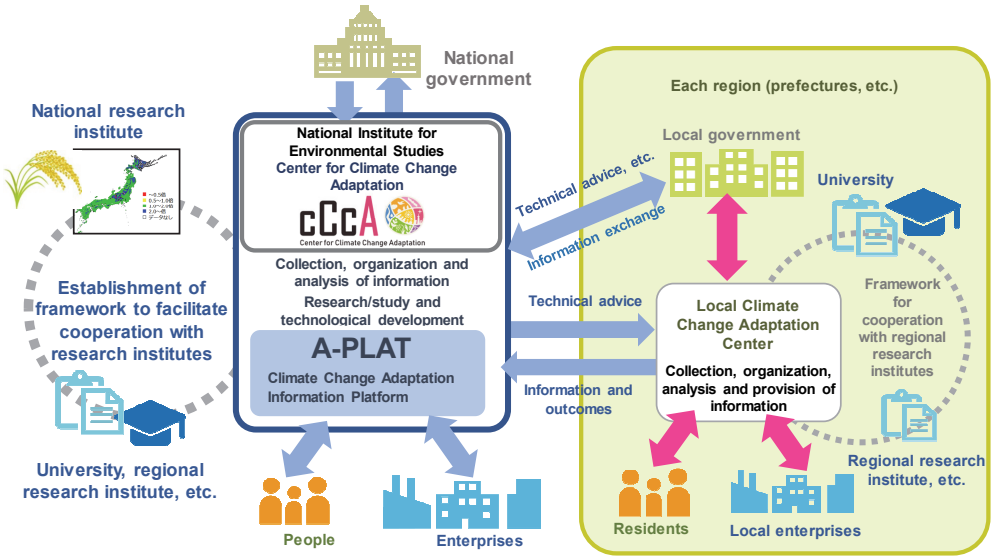


Fig. 1 Role of the Center for Climate Change Adaptation

1. Promotion of climate change adaptation

1.1Technical support for local public bodies

Questionnaires were distributed and discussion meetings were held with staff of local governments and LCCACs to identify their needs for technical help. On the basis of the needs that were identified, we considered our support strategies and expressed them as NIES support measures. They include providing technical advice, sending experts, building regional capacity, enhancing regional scientific knowledge, and constructing networks among regions; any of these measures can be applied, depending on the specific circumstances.

As support measures, we:

- gave lectures to approximately 1400 local government staff, regional company employees, and local residents at regional meetings and study sessions to provide knowledge related to climate change adaptation
- participated in meetings of examination committees of LCCACs and other regional groups to provide scientific advice

- helped promote regional climate change adaptation policies by providing scientific advice, figures, and tables to be used in Local Climate Change Adaptation Plans, brochures, and websites developed by local public bodies
- participated as advisors to the seven Climate Change Adaptation Regional Councils organized by the Regional Environment Office of the Ministry of the Environment (MOE) on the basis of the Climate Change Adaptation Act, and contributed to inter-regional cooperation with local governments.

In addition, the following projects were implemented to contribute to regional capacity building related to climate change:

- In December 2018, NIES, with MOE, organized the International Symposium Commemorating the Climate Change Adaptation Act. Local administrators, researchers, companies, and members of the public attended the symposium to deepen their understanding of domestic and international topics related to the impacts of climate change and its adaptation.
- A discussion meeting (Fig. 2) was held in December 2018 with the aim of sharing knowledge with local administrators to formulate regional climate change adaptation policies.
- The All-Japan Environmental Research Institutions Symposium was held in February 2019 with the theme of climate change adaptation, and related research was shared with regional environmental research institutes.

Fig. 2 Photos taken at the discussion meeting, December 2018

1.2 Collecting, organizing, analyzing, and providing information related to climate change adaptation

NIES operates the Climate Change Adaptation Information Platform (A-PLAT), a portal site for disseminating information on adaptation to the impacts of climate change. To disseminate more useful information on climate change adaptation to stakeholders such as governments, local public bodies, researchers, private companies, and individuals, we expanded the contents of A-PLAT and improved

the user experience (Fig. 3).

For the purpose of improving A-PLAT, we implemented the following tasks:

- By collaborating with the Japan Meteorological Agency, we included the outcomes of "Global Warming Projection Vol. 9" in the WebGIS (http://a-plat.nies.go.jp/webgis/index.html), and we created graphs of weather observation data that can be viewed by region.
- In line with the enforcement of the Climate Change Adaptation Act, in addition to posting related provisions such as the Climate Change Adaptation Plan and the Local Climate Change Adaptation Planning Manual, we established a new web page on Local Climate Change Adaptation Plans and LCCACs.
- Articles were added to introduce the topic of adaptation planning efforts and highlight examples of adaptation measures.
- An Adaptation Measures Database was created to introduce examples of adaptation measures for reference use by local governments.
- We added cases reports on for Adaptation Business and Climate Risk Management to introduce adaptation efforts by private companies.
- To educate the general public about adaptation, we created a webpage on current and future impacts of climate change and various adaptation measures.

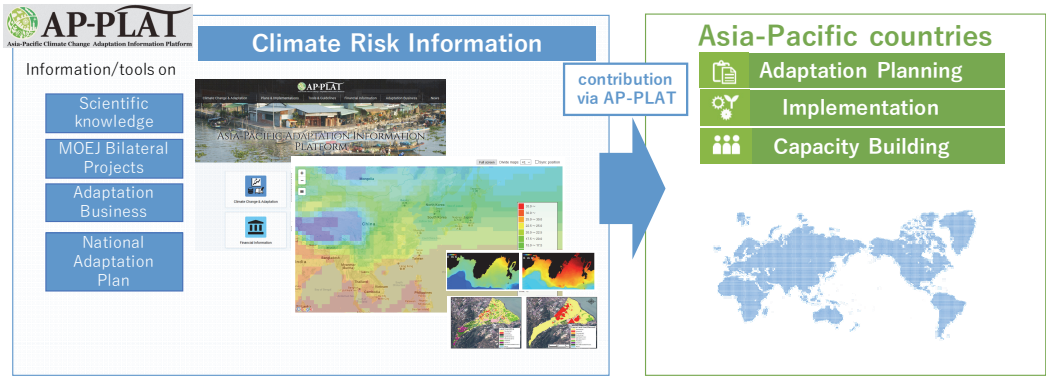
The number of page views for A-PLAT (Japanese pages) reached approximately 540,000 in 2018; the number has been increasing since the platform was launched. In addition, information on A-PLAT is being utilized in regional climate-change policy-making. For example, information provided in A-PLAT is quoted in many Local Climate Change Adaptation Plans, brochures, and websites formulated by local public bodies. In particular, 12 Local Climate Change Adaptation Plans and other plans related to adaptation that were formulated by prefectures and designated cities cited data and charts from A-PLAT in 2018.

Fig. 3 The home page of the A-PLAT website (http://www.adaptation-platform.nies.go.jp/)

1.3 International contributions to the development of an information platform for the Asia-Pacific region

In accordance with the Paris Agreement, to support adaptation planning for developing countries, we developed a prototype version of the "Asia-Pacific Adaptation Information Platform" (AP-PLAT). The platform was introduced at COP23 and included impact assessment data and information related to adaptation (Fig. 4). We aim to officially launch AP-PLAT by 2020. We presented an update of our activities to the UN Adaptation Committee at COP24 and at the Asia Pacific Adaptation Network.

To support the establishment of a platform that summarizes climate risk information in Asia-Pacific countries, we invited trainees from Indonesia and Thailand to NIES and delivered technical training in December 2018 to provide the requisite knowledge for establishing a platform. We also conducted other technical training in each of these countries in February 2019 to continue to promote adaptation planning. In addition, we exchanged information with relevant global platform organizations, including those from Asia-Pacific countries, in December 2018.



http://www.adaptation-platform.nies.go.jp/en/ap-plat/

Fig. 4 The outline of the AP-PLAT website (http://www.adaptation-platform.nies.go.jp/en/ap-plat/)

1.4 Contribution to climate change policy

We managed the "Study Team to Promote Climate Change Impact Observation and Monitoring" and the "Study Team to Collaborate and Promote Climate Change Projection and Impact Assessment," each of which comprises a group of experts contracted by MOE for relevant projects. The first study team produced a report titled "Direction of Strategic Observations and Monitoring for Climate Change Impacts," which described the direction of sectoral issues and solutions for climate change impacts, and the second produced "Future Approaches to the Link Between Climate Change Projections and Impact Assessment," which organized issues and approaches to impact assessment, respectively. These two reports were presented to the 19th Climate Change Impact Assessment

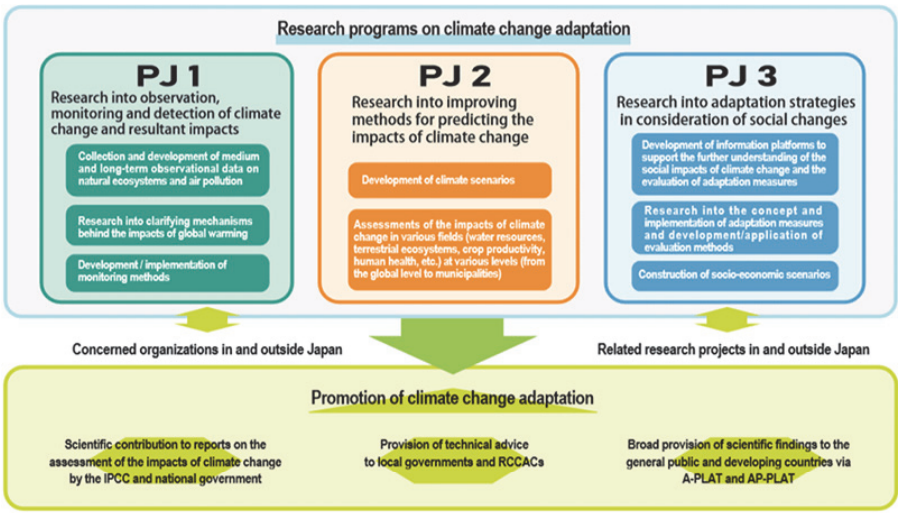
Subcommittee under a meeting of the Global Environment Committee of the Central Environment Council held in March 2019. The reports were used as references for climate change policy-making.

Center staff members participated in deliberative councils and investigative conferences such as the Assessment Subcommittees of the Central Environment Council, noted above, and helped to promote climate change policy.

2. Climate change impact and adaptation research

We consolidated research into climate change impacts and adaptation. We also organized research programs to advance climate change adaptation research and development in an integrated manner and support climate change adaptation activities by national and regional governments. The program consists of the three research projects, which are outlined in Figure 5 and discussed below.

Fig. 5 Structure of research projects



2.1 Observation, monitoring, and detection of climate change and resultant impacts (PJ1)

Project 1 has started collecting long-term monitoring data on ecosystems (terrestrial ecosystems, coastal-area/enclosed-sea ecosystems, marine ecosystems, coastal ecosystems, and lake/watershed ecosystems), as well as data on associated meteorological factors (e.g., air temperature, precipitation, wind velocity, and humidity) for the purpose of detecting and clarifying the effects of climate change on ecosystems.

For example, in the case of terrestrial and coastal ecosystems, surveys of published reports were conducted to list global warming impacts on ecosystems and to collect and digitize previously collected information on the distribution of plants and corals.

2.2 Enhancing methods for predicting the impacts of climate change (PJ2)

We worked on seven sub-projects to conduct climate change impact assessments at multiple scales (e.g. global, Asia-Pacific region, Japan, and local government) and across multiple sectors (e.g. water resources, ecosystems, crop yields, and human heath). To conduct cross-sectoral climate change impact assessments, we established common climate scenarios. On the basis of on an extensive survey of the availability and applicability of existing published climate scenarios, we determined two common climate scenarios, namely, the global scenario (for use in global and Asia-Pacific analyses) and the Japan scenario (for use in Japanese and local government analyses). We developed a data server to efficiently distribute the aforementioned scenarios to project members. We also designed another server to distribute them to a wider range of users.

2.3 Adaptation strategies in consideration of social changes (PJ3)

Project 3 consists of eight research themes with common ultimate objectives, namely (1) understanding the gaps that exist among adaptation planning, scientific knowledge, and adaptation implementation; and (2) exploring effective adaptation strategies for filling the gaps.

For example, in the research theme named “Development of socioeconomic scenarios for the analyses of climate change impacts and adaptation in Japan,” we are developing socioeconomic scenarios that include populations and land uses in Japan and can be applied, together with existing global socioeconomic scenarios, in integrated assessments of adaptation and mitigation policies. This year, we created narrative scenarios for Japan that were based on existing narrative global scenarios (SSPs: Shared Socioeconomic Pathways).

As another example, in the research theme, “Analyses of climate change adaptation options and management measures for nature reserves,” we evaluated policies for the simultaneous utilization and conservation of nature preserves such as national parks under a changing climate. We used the scientific findings of the study and experiences obtained in practical activities to publish a guide on adaptation for nature reserves.

Basis for Environmental Research

Center for Global Environmental Research

Global environmental change is an essential threat to a sustainable society and human life. Climate change, including global warming caused by increasing atmospheric greenhouse gas (GHG) concentrations, together with changes in the stratospheric ozone, is having serious impacts on all ecosystems and on humans. Considering the predicted impacts, it is urgent to take measures to conserve the global environment towards establishing a sustainable society with lower emissions of GHGs. We must adopt a long-term perspective and recognize the importance of mid- and long-term continuous research, because it requires a lot of time for the effects of climate change mitigation options to manifest.

The Center for Global Environmental Research (CGER) conducts strategic environmental monitoring across the atmospheric, oceanic, and terrestrial domains and distributes the resulting data through environmental databases to capture climate change and its impacts on society. CGER also implements proactive and predictive research on the global environment, develops new technologies, and conducts pioneering and fundamental research, especially in the field of climate change. CGER supports collaborative studies among domestic and international organizations, disseminates the scientific findings, and facilitates mutual understanding to raise public awareness of global environmental problems.

1. Large stimulatory effect of global warming on soil organic carbon decomposition in a Japanese forest

Globally, soils contain 3000 Gt of organic carbon (SOC). SOC is decomposed by soil microbiota and released to the atmosphere (by heterotrophic respiration) at a rate of 51 to 57 Gt C year^{-1}. This rate is more than five times of global fossil fuel emission. Heterotrophic respiration exponentially increases with increasing temperature; consequently, the carbon released to the atmosphere by increased heterotrophic respiration could cause positive feedback that further accelerates global warming. However, long-term observation data that verify the influence of global warming on heterotrophic respiration are limited. We have been conducting a soil warming experiment in a 70-year-old cool-temperate broad-leaved deciduous forest in Shirakami-Sanchi, in northern Honshu, since September 2011. We increased the soil temperature at a depth of 5 cm by about 2.5 °C using infrared carbon-filament heat lamps, and we continuously monitored CO_2 efflux from the soil surface, and related environmental parameters, with a multichannel automated chamber system. From a 5-year soil warming experiment between 2012 and 2016, we observed that annual effluxes ranged from 7.78 to 11.49 t C ha^{-1} for the control heterotrophic respiration and 8.76 to 15.25 t C ha^{-1} for heterotrophic respiration from the warmed soil. Heterotrophic respiration increased by 6.2 to 17.7% (annual average of 10.9%) per 1 °C soil temperature rise (Fig. 1). In addition, the inter-annual variation of the annual effect of soil warming on

heterotrophic respiration (warming effect) was closely related to the number of rainy days, suggesting the importance of a humid environment for a sustained stimulatory warming effect. We concluded that global warming will enhance SOC decomposition in the long term in cool-temperate forest ecosystems such as that in Shirakami-Sanchi. This result also suggested that abundant SOC and a humid environment were the primary factors contributing to the sustained and high level of the warming effect.

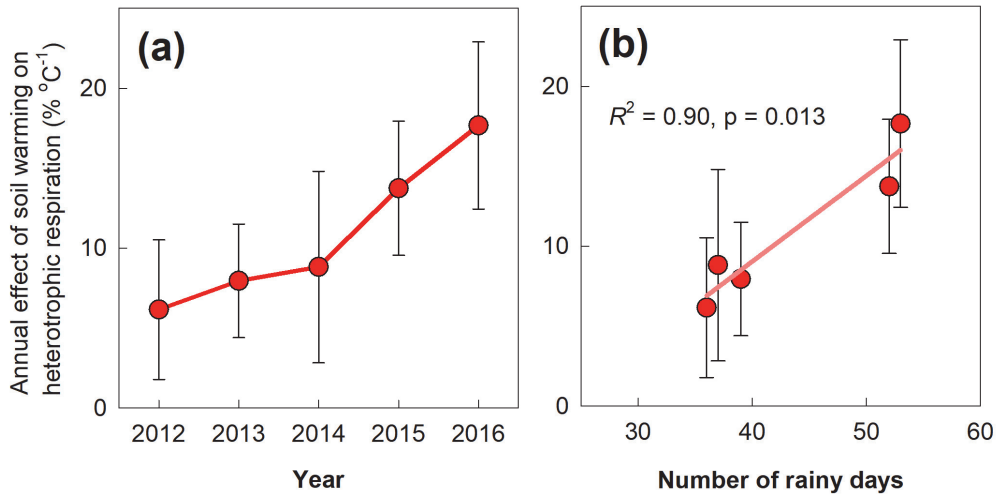


Fig. 1
(a) Annual effect of artificial soil warming on heterotrophic respiration per 1 °C; and (b) relationship between annual effect of warming on heterotrophic respiration and number of rainy days. Values are represented as mean ± SE.

Reference:
Teramoto M., Liang N., Ishida S., Zeng J. (2018). Long-term stimulatory warming effect on soil heterotrophic respiration in a cool-temperate broad-leaved deciduous forest in northern Japan. *J. Geophys. Res. Biogeosci.* 123:1161–1177. doi:10.1002/2018JG004432

2. Changes in tropospheric ozone in East Asia associated with changes in regional climate

Tropospheric ozone (O_3) is one of the most important trace gases in the atmosphere because of its great impacts on global warming and air quality. Over the past two decades, increases in anthropogenic emissions of nitrogen oxides (NO_X) in China (Fig. 2b), driven by the country's rapid socioeconomic development, have induced large increases in springtime tropospheric O_3 concentrations in downwind regions. However, observations at the Mt. Happo Observatory in Japan have shown that O_3 levels have unexpectedly decreased since 2008 (Fig. 2a), even though China's NO_x emissions have continued to increase. We found that the persistent La Niña-like wind pattern during 2008–2013 reduced the export of polluted air masses from East Asia to the western Pacific (Fig. 2c). This result indicates that, in addition to changes in emissions, changes in climate patterns play an important role in controlling decadal O_3 trends.

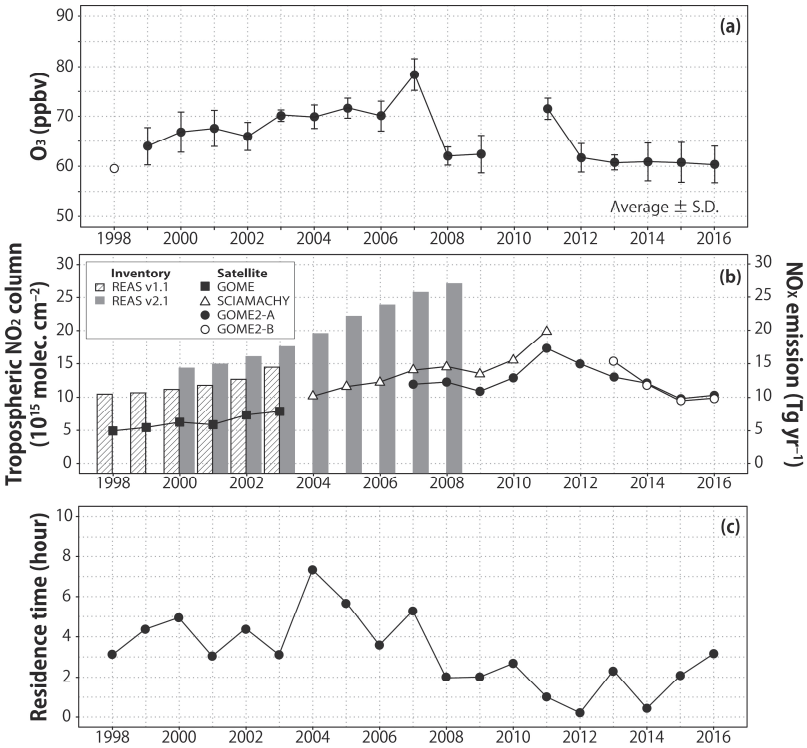


Fig. 2
(a) Time series of mean springtime tropospheric O_3 concentrations at Mt. Happo Observatory; (b) satellite-derived tropospheric NO_2 column data and NO_x emission data from emission inventories; and (c) area-averaged residence times of air mass trajectories, used as a measure of transport from China

Reference:
Okamoto, S., Tanimoto, H., Hirota, N., Ikeda, K., Akimoto, H. (2018) Decadal shifts in wind patterns reduced continental outflow and suppressed ozone trend in the 2010s in the lower troposphere over Japan. *J Geophys. Res. Atmos*. 123. doi:10.1029/2018JD029266

3. Analysis of the ozone-reduction event over the southern tip of South America in November 2009

A reduction in total ozone over the southern tip of South America lasting 3 weeks occurred in November 2009 and caused high levels of ultraviolet exposure there. Analyses of ERA-Interim reanalysis data and the total ozone observed by the Ozone Monitoring Instrument (OMI) on board NASA Aura satellite for 2009 indicated that the total-ozone-reduction event was caused by migration of the polar vortex toward the South American continent at the time of the vortex breakup in late spring. The vortex migration is associated with an enhanced wave flux from the troposphere in the west of the South American continent to the stratosphere over the southern part of the continent (Fig. 3). In November, a blocking event was diagnosed from the 500-hPa geopotential height over the west of the South American continent; this corresponds to the large positive deviation of geopotential height in the troposphere at about 120°W in Figure 3. These results suggest that there is a relationship between the long-lasting reduction in total ozone over the southern tip of South America and the blocking phenomenon in the troposphere of the Southern Hemisphere through wave propagation from

the blocking region.

Further analyses for November 1979−2015 indicated that there were three more low total ozone events in November 1994, 1997, and 2011, which were also associated with blocking in the troposphere. The analysis also indicated that the negative ozone anomaly in November 2009 was one of the largest anomalies in this 37-year period. These results suggest that diagnosing blocking in the troposphere may be useful for predicting low ozone events in November in South America as well as the numerical prediction of low ozone events and may increase the reliability of prediction.

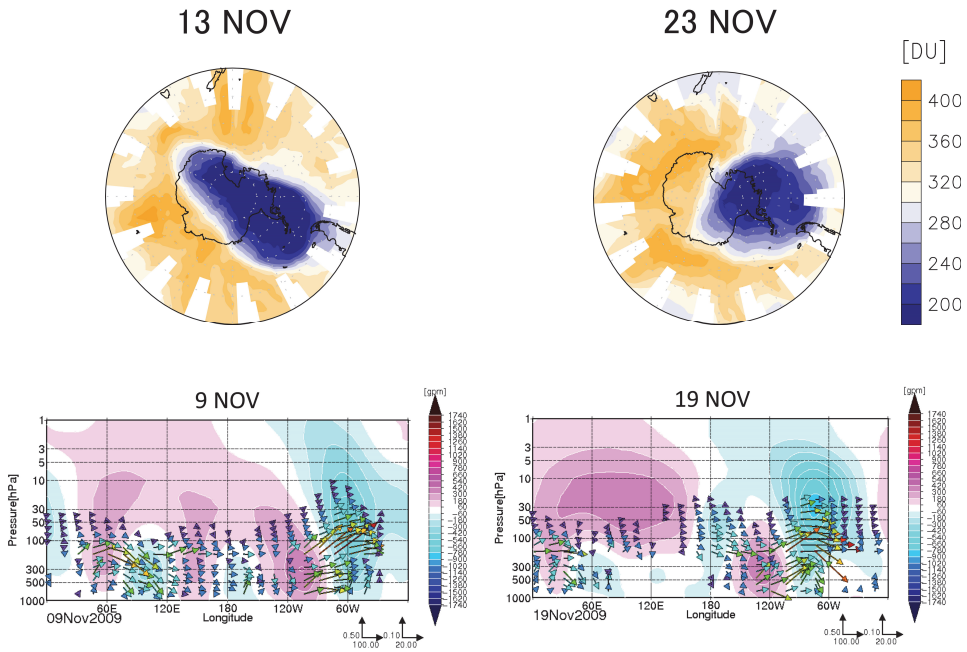


Fig. 3
(Upper panels) Total ozone distribution from the Ozone Monitoring Instrument in the Southern Hemisphere mid- and high latitudes on 13 (left) and 23 (right) November 2009. The values for total ozone are expressed in Dobson units (DU), indicated by color. The white areas with rough boundaries indicate missing data. The outer boundary of each panel is 30°S. (Lower panels) Wave activity flux (arrows) and geopotential height anomaly from the zonal mean (color) at 50−60°S on 9 and 19 November 2009. These dates are 4 days before the respective total ozone maps. Scales for the wave activity flux are presented at the bottom; the left scale is for pressure levels below 200 hPa (for the troposphere) and the right scale is for those above 200 hPa (for the upper troposphere and stratosphere). The length of the arrows is proportional to the flux, and the arrows are colored for conspicuousness, depending on the magnitude of the flux.

Reference:

Akiyoshi, H., Kadowaki, M., Nakamura, H., Sugita, T., Hirooka, T., Harada, Y., Mizuno, A. (2018). Analysis of the ozone reduction event over the southern tip of South America in November 2009. *J. Geophys. Res. Atmos.* 123:12523–12542. doi:10.1029/2017JD028096

Center for Material Cycles and Waste Management Research

The Center for Material Cycles and Waste Management Research conducts a variety of studies to establish a political and academic base in the fields of materials cycling and waste (Fig. 1). Currently our focus is the present state of, and mechanisms behind, the structure of material flows and the associated environmental burdens imposed by socioeconomic activities at local to international scales.

We intend to propose assessment methods and strategies for shifting to a sustainable, sound material-cycle society. We are also evaluating technologies and systems for treating and recycling waste and recyclable materials in Japan and other countries, and we are developing fundamental technologies for materials recycling and substance control in waste treatment and recycling processes.

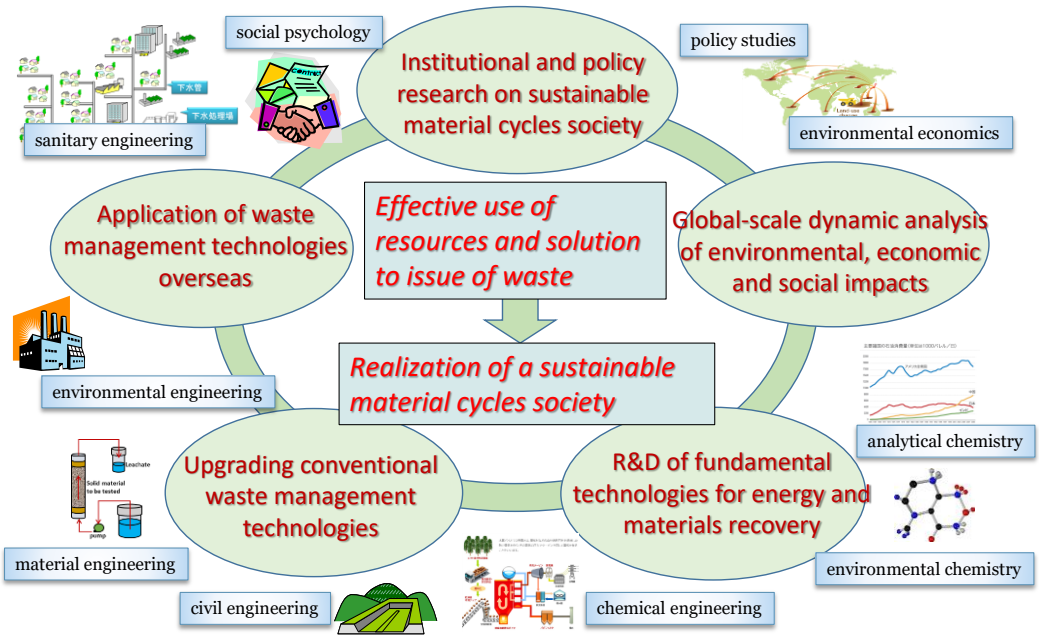


Fig. 1 Outline of fundamental research into material cycles and waste management

1. Institutional and policy research on systems and measures for shaping a sound material-cycle society

We published our results from a study of stakeholder perceptions of extended producer responsibility (EPR), which we have been analyzing for the last few years. We employed ordinal logit regression and showed that national government officers tended to think that EPR is borne by the beneficiary and disregard the "capability to bear" concept.

As part of our study of recycling systems for waste electrical and electronic equipment (WEEE) in Asia, we discovered several smuggling and improper disposal cases in Thailand that resulted from the import restrictions that were

implemented in China in January 2018. Several Southeast Asian countries have also begun to introduce import restrictions and raise awareness for building domestic collection and recycling systems. The newly proposed WEEE bill in Thailand stated that producers should bear physical responsibility, for collection and recovery of WEEE, instead of financial responsibility. The Thai system is similar to the WEEE recycling systems in use in India and Vietnam.

In our research on pro-environmental behaviors, we developed a psychological behavior model and analyzed factors that influence collaborative collective behaviors, rather than the individual behaviors that have been targeted in many existing studies. We revealed that fostering people's attitudes and sense of seriousness about environmental problems was not sufficient to promote their collective behavior as it relates to the introduction of a renewable energy system to a community. It was more important to provide learning opportunities to strengthen people's perceived importance of collective behaviors, responsibility for collective behaviors, and active interest in environmental problems. In another study, we analyzed the factors that influence disposal behaviors as they relate to clothing. The results revealed that experience with e-commerce promoted reuse behaviors such as selling used products to second-hand retailers.

Finally, we collaborated with external researchers and members of APRSCP (the Asia Pacific Roundtable for Sustainable Consumption and Production) and wrote a policy brief on Sustainable Consumption and Production, which is Goal 12 of the SDGs (Sustainable Development Goals). The policy brief was publicized at a side event of the United Nations High Level Political Forum, held in July, where progress on Goal 12 was reviewed.

2. Dynamic analysis of international material cycles and assessment of their environmental, economic, and social impacts

Product replacement programs promote the replacement of durable goods such as automobiles, home appliances, and houses with new energy-efficient products by using financial incentives such as subsidies. Many countries have implemented such programs to reduce environmental loads. These programs affect the point in time at which the decision to replace a product is made (and acted on) by consumers; this, in turn, influences the overall effectiveness of the program. Thus, to improve the policy design of these replacement programs, it is necessary to consider the mechanism of the consumer product replacement decision. We conducted two studies of the economic and environmental consequences of consumers' decisions on product replacements triggered by Japan's Home Appliance Eco-Point Program, an appliance replacement program that was in effect from May 2009 to March 2011.

In one study, we combined a dynamic discrete choice model for air-conditioner replacement decisions with an input-output model to evaluate the economic impact of the program. By focusing on air-conditioners produced from 1995 to 1999 and

replaced during the period from 2005 to 2013, we found that the Eco-Point program increased replacement probabilities by 1.5% to 1.9% in 2009. Moreover, the program produced an additional economic output of 31,337 million yen and a total added value of 21,259 million yen. However, the benefit–cost ratio, determined by dividing the increase in added value by the monetary value of the points awarded for appliance replacement, was only 0.68. Therefore, from a cost–benefit perspective, the program can be judged not to have been an effective policy measure.

In the other study, we examined the effects of the Eco-Point program on the timing of household air-conditioner replacements and the resulting impact on GHG emissions. The program reduced GHG emissions by 28,516 t CO_2eq, but the cost per ton of CO_2eq reduced was approximately US$978, which is quite high compared with the GHG emission-reduction costs of other programs. We again concluded that the Home Appliance Eco-Point Program as constituted in May 2009– March 2011 was not a cost-effective means to reduce GHG emissions and that appropriate policy coordination needs to be conducted to improve the cost-effectiveness of such programs in the future.

3. Developmental and survey research on various types of fundamental technologies required for resource recycling and materials management

We used synthetic epithelial lung fluid and artificial lysosomal fluid to develop chemical leaching tests to assess chemicals that are contained in products and can be inhaled. We then applied the tests to indoor dust and recycled materials from e-waste. In addition, we began to develop another leaching test to assess the intake of chemicals via dermal exposure.

As part of a continuous survey of the behavior of new persistent organic pollutants (POPs) in home appliance recycling facilities, we conducted a DecaBDE (decabromodiphenyl ether) sorting test for cathode ray tube TV cabinets on the basis of plastic markings. From a series of the incineration tests at commercial-scale incinerators, environmentally sound destruction of PBDEs (polybrominated diphenyl ethers) in auto shredder residues was demonstrated. In addition, we investigated POP emissions from landfills at six different facilities with different wastewater treatment systems. We also suggested a multimedia fate model (factory-fate model) and then used the model to predict the behavior of hexabromocyclododecanes (HBCDs) in waste recycling facilities. The model was able to represent the concentrations of HBCDs and suspended dust in the air at the facilities.

We developed an accurate mass measurement method to quantify short-chain chlorinated paraffins (SCCPs) in wastes precisely. We then quantified the concentrations of SCCPs in waste samples (refuse paper and plastic fuel, automobile shredder dust, and printed circuit boards).

We also developed a new method of measuring the air–water partition coefficient of a chemical by using a quartz crystal sensor. We evaluated the reliability of the method on the basis of the uncertainty of experimental data and comparison with published data.

4. Advancement of testing and evaluation management systems related to landfill disposal and the use of waste as construction materials

We established a method to determine whether the source of arsenic in soil is anthropogenic or geogenic by comparing the extraction ratio of the oxidized phase and the unoxidized phase. More than 30 types of marine sedimentary soil, volcanic ash soil, and anthropogenic soil were tested to confirm the effectiveness of this extraction method.

We organized an application scenario for using waste and by-products as construction materials. We then extracted environmental exposure conditions that are considered to have a large effect on harmful substance behavior to estimate long-term environmental impact. Also, we started to develop long-term stability tests of waste-based construction materials, including a dry-wet cycle test and a reductive environment test.

We used the pararell a batch test changing liquid-solid ratio to determine the adsorption and desorption parameters of materials that elute harmful substances. By using these parameters, we devised a method to perform advection analysis of materials that elute harmful substances.

To promote the effective use of recycled gypsum, we completed guidelines for quality control of recycled gypsum, including environmental safety when using civil engineering materials.

5. Fundamental research into the application of waste management technologies in Japan and overseas

We are studying fundamental technological issues associated with the improvement of waste management systems in Japan and Asia.
In FY 2018, our studies included the following.

- We analyzed the relationship between disposal costs and transportation distances of several items of industrial waste by using a database compiled from official reports on industrial waste management.

- A scheme for the appropriate management of wildlife was proposed, and a technical document for wild boar contaminated with radioactive cesium in Fukushima was published with the cooperation of the Fukushima Prefectural Centre for Environmental Creation.

- Whole gas emissions from a waste pile and landfill were measured by using an unmanned aerial vehicle to develop a field-monitoring methodology.

- Social factors to enable regionally appropriate waste management in Asia were extracted from a community-based interview survey.

- We confirmed that sulfur-oxidizing bacteria accelerated the deterioration of the products of sulfur polymer stabilization/solidification of elemental mercury.

- We successfully detected interactions among cationic substances, microbial cells, and extracellular polymers by using a newly designed monitoring system and found appropriate conditions for microbial film development in the treatment of saline wastewater.

6. Waste management research collaboration and research into practice projects with Asian countries

As part of our project for appropriate solid-waste management to reduce flood risk in tropical Asian urban areas by restoring drainage functions, we elucidated the mechanism of waste blockage of urban canal flows. We discovered that both density and dimension are important factors. The numerical models indicated that waste blockages increased the water level in canals. We also provided a tool for Bangkok residents to raise awareness of appropriate waste disposal behavior. This study will continue to its next phase, in which it will investigate how to prevent canal waste, which in turn becomes ocean waste.

As part of the activities of the committees for International Standard Organization/Technical Committee 297 (Waste management vehicles) and ISO/TC 300 (Solid recovered fuel), we continuously participate in the ISO technical committees to propose the development of new standards and reflect the Japanese and Asian context in ISO discussions.

A project called “Policy dialogue and network building of multi-stakeholders on integrated decentralized domestic wastewater management in ASEAN countries” was launched in July 2018 and will continue through July 2020 (Fig. 2). The project is currently conducting a fact-finding process in nine ASEAN countries.

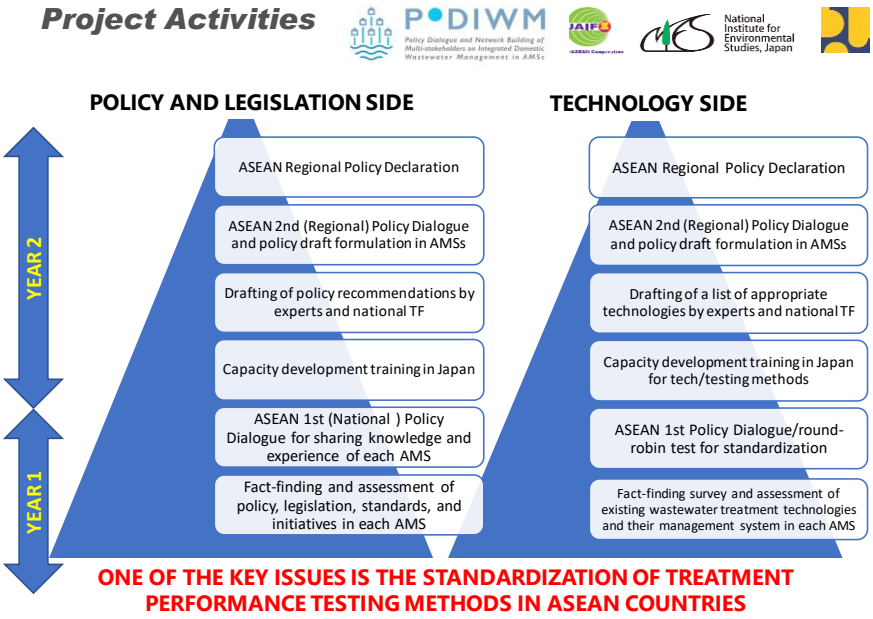


Fig. 2 Outline of activities in the "Policy dialogue and network building of multi-stakeholders on integrated decentralized domestic wastewater management in ASEAN countries" project (PoDIWM)

Center for Health and Environmental Risk Research

The Center for Health and Environmental Risk Research conducts research in the Environmental Risk Research Field and Environmental Health Research Field. The two research fields form the basis of two projects administered by the Risk Assessment Science Collaboration Office (RASCO) and the Japan Environment and Children's Study (JECS). The Center leads the Health and Environmental Safety Research Program with other research centers. Here, we report the current outcomes of research in the environmental risk and environmental health research fields.

1. Upgrade of ecotoxicity testing and development of a novel system to evaluate the ecotoxicological effects of chemicals

We continued to develop fish chronic toxicity prediction models by using QAAR (quantitative activity–activity relationship) and QSAAR (quantitative structure activity–activity relationship). QSAAR itself is based on *Daphnia* acute toxicity, chemical structure descriptors, and physicochemical properties. External validation of the model was performed based on the GLP-based reliable fish early life toxicity test results in Japanese medaka (*Oryzias latipes*). Successful prediction of chronic toxicity by using such models could efficiently accelerate the hazard and risk assessment of the chemicals. We also developed a hazard assessment scheme based on various ecotoxicity test results. The protocol used to establish the assessment scheme was based on the possibility of using alternative methods and information obtained about adverse outcome pathways. The sediment toxicity of selected hydrophobic organic chemicals was also investigated on the basis of uptake pathways in the amphipod species, *Hyalella azteca*. A *Daphnia* multi-generation test and the toxicities of mixtures of chemicals were examined to help standardize and upgrade risk assessment under the Chemical Substances Control Law (CSCL) and the Agricultural Chemicals Control Act. Various methods of preparing aquatic solutions of hydrophobic chemicals, such as passive dosing techniques, were compared in terms of toxicity testing and the maintenance of aqueous concentrations close to the aqueous solubility limit.

2. Fundamental study of integrated approaches to assessing chemical exposure and environmental effects

We are performing a comprehensive analysis of the relationship between chemical exposure and effects on humans and organisms by investigating PM2.5 and their carcinogen-related activities (i.e., DNA damage). To consider the effects of combined exposure, we verified the additivity of the activity of mixtures of typical DNA-damaging substances by mixing, for example, 4-nitroquinoline N-oxide (4NQO) and 1-nitropyrene, and 2-minoanthracene and benzo[a]pyrene. In many cases, additivity was recognized, including the case in which 4-NQO was

added to an actual PM2.5 extract. Furthermore, the DNA-damaging properties of atmospheric PM2.5 samples, PM2.5 from diesel emissions, and PM2.5 generated secondarily from volatile organic compounds were compared. The respective activity values (both per unit weight and per unit weight of organic carbon) differed greatly. In addition, the PM2.5 concentration distribution in the city of Yangon, in Myanmar, was investigated by using a pocket PM2.5 sensor connected to a smartphone. The actual contamination status was confirmed, and particularly high values (280 $\mu g/m^3$ or more) were detected in the vicinity of sources such as burning materials and road construction sites. In addition, an automated identification and quantification system (AIQS-GC), LC-QTof-MS, and GC-MS were used in a water quality analysis in Yangon. Receptor-binding active compounds, such as bisphenol A, nonylphenol, and chloropyrifos were detected.

3. Current status of the megabenthic community in coastal Fukushima Prefecture, Japan, in the wake of the Great East Japan Earthquake

To reveal the status of the megabenthic community structure after the 2011 Great East Japan Earthquake, tsunami, and nuclear disaster, we conducted fisheries-independent bottom-trawl surveys along the Fukushima coast from 2013 to 2017. Although substantial changes in biodiversity were not observed, total abundance and biomass fluctuated, primarily because of temporary increases in the abundance or biomass of small shrimp and squid or abundance or biomass variations in mid-sized fishes (i.e., puffers and flatfishes) and large elasmobranchs. A decrease in echinoderm abundance and biomass was observed in all areas. Extremely low crustacean abundance and biomass were evident in the central and southern offshore transects. Our results imply that no recognizable recovery was observed in the megabenthic community, and a failure of reproduction by megabenthic species might have been occurring in the Fukushima coastal area. Further research is required to reveal the factors causing these changes in the megabenthic communities.

4. Basic study for strategic risk management

We are studying the factors that are important for modeling the environmental fate and emissions of chemicals; assessing exposure to, and risks posed by, environmental chemicals; assessing the ecological impacts of environmental disturbances; and systematically managing the risks to health and the environment posed by environmental chemicals while taking into consideration the many risk factors.

This fiscal year we performed studies on modeling the global fate of mercury; the behavior of chemicals by using multimedia environmental fate models; the emission of additives from products; environmental monitoring and risk management during and after accidents and natural disasters; the bioaccumulation of chemicals in the aquatic environment; the impacts of chemicals on the

community structures of benthic animals in the field; and the management of wild mammals in cooperation with local governments. We utilized the results as the basis for research projects in Issue-Oriented Research Programs and for projects related to the strategic management of risks. In the chemical impacts study, we developed a mathematical model to assess the effects of metal mixtures on biological communities. We showed that non-additivity of the effects of the mixture components can be caused by a combination of metal speciation and binding of metals to biotic ligands and not by interactions among metals.

5. Fundamental study of integrated health-risk evaluation

This fundamental study aims to develop advanced toxicity evaluation methods and biomarkers of neurotoxicity, immunotoxicity, reproductive and developmental toxicity, genotoxicity, and inhalational toxicity on the basis of the physicochemical characteristics of harmful environmental substances such as nanomaterials, PM2.5, and metals.

We have made progress in developing an *in vitro* system for studying the neurodevelopmental toxicity of silver nanoparticles (AgNPs). Notably, that AgNPs induced autophagy concomitantly with cellular morphological changes and inhibition of cell migration in a culture system of rat fetal brain neural stem cells. These findings would be useful as a biomarker for evaluating AgNP toxicity.

6. Experimental evaluation of heatstroke

Heatstroke has been increasing in Japan, and it has been suggested that infants and the elderly are particularly vulnerable. In this study, we evaluated differences in the susceptibility to heat stress of mice of different ages. Juvenile (4 weeks old), adult (10 weeks old), and aged (15 months old) C57BL/6J mice were exposed to a heat (38°C) or control (23°C) environment, and then physiological and blood biochemical indicators were analyzed. Heat stress induced heat stroke; the levels of factors related to liver and renal dysfunction and of inflammatory cytokines were greater in the sera of males (especially aged males) than of females. In general, we found that aged male mice were most vulnerable to heat stress (Fig. 1). We are currently investigating the molecular mechanisms of susceptibility to heat stress (e.g., expression of heat shock proteins).

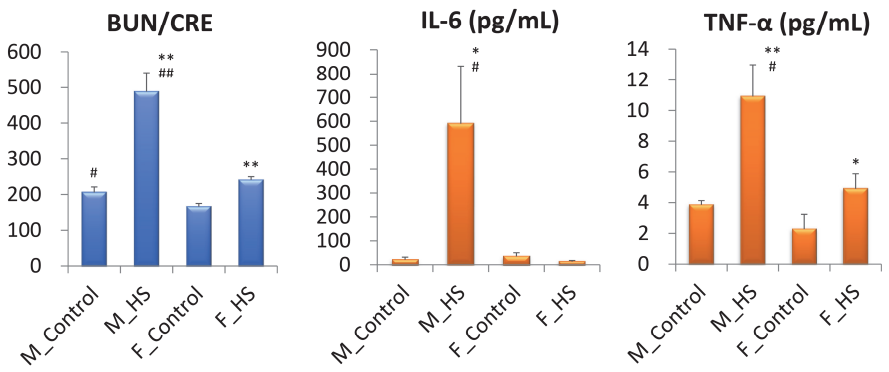


Fig. 1
Blood biochemical indicators in aged mice after heat stress.
Male and female aged mice were exposed to a heat environment for 3 h. After 2 h, a renal dysfunction indicator (BUN to CRE ratio) and inflammatory cytokine levels (IL-6, TNF-α) in serum were examined. Data were expressed as means ± SE for five or six animals per group.
**P* < 0.05, ***P* < 0.01, HS vs. Control; #*P* < 0.05, ##*P* < 0.01, Male vs. Female.
M, male; F, female; HS, heat stress; BUN, blood urea nitrogen; CRE, creatinine; IL, interleukin; TNF, tumor necrosis factor

7. Fundamental evaluation of the health impacts of environmental factors

This fundamental study aims to develop methodologies for evaluating the neuropathological and social behavioral effects of environmental factors. Its goal is to help identify health-threatening chemicals, reduce the adverse effects of environmental chemicals, and develop precautionary approaches to these threats.

This fiscal year, we found common behavioral traits between mice genetically engineered to show autism-like symptoms and mice developmentally exposed to chemicals. We observed that prenatal exposure to valproic acid, which induces autism, reduced the level of glutamic acid decarboxylase 67, a GABA synthesizing enzyme, in the hippocampus of both male and female offspring rats. We examined the effect of diphenylarsenic acid on dopamine neurotransmission in the mouse striatum by using a microdialysis–HPLC method. We investigated the toxic effects of airborne particles by using a culture system for a bronchial epithelium model made of human normal bronchial epithelium cells.

8. International harmonization of human biomonitoring

Human biomonitoring is a technique that is used widely to characterize our exposure to chemical substances. It employs measurements of biological samples, such as blood, urine, hair, and nails, collected from human subjects. The results of human biomonitoring have been used on a variety of occasions, including in policymaking and cohort studies. Especially for comparing international biomonitoring results or multiple cohort study data to increase statistical power in the analysis of chemical exposure and health outcomes, it is of great importance and of international interest to harmonize data from individual studies. We conducted an inter-laboratory test (a round-robin test) on the measurement of blood lead levels among four countries (China, France, Germany, and Japan) by using an in-house reference material or a commercially available reference material. This exercise proved that it was possible to post-harmonize existing biomonitoring data by using a reference material.

9. Adverse health effects of PM2.5 components

Few studies have examined the association between the chemical components of PM2.5 and health effects. This fiscal year, we conducted a case-crossover study to evaluate the association between continuously measured PM2.5 components and night-time primary care visits (PCVs) due to asthma attacks in a single city in Japan over a 21-month period. The subjects were 1251 children aged 0 to 14 years who received medical care for asthma at a municipal emergency clinic.

In the warmer months, PCVs were associated with the concentrations of water-soluble organic compounds (WSOCs) and hydrogen ions on the day before the PCVs, with odds ratios (ORs) of 1.33 (95% CI: 1.00 to 1.76) and 1.18 (95% CI: 1.02 to 1.36), respectively. In contrast, sulfate ion concentration showed a negative association with PCVs (OR = 0.85; 95% CI: 0.74 to 0.98). Going forward, sources of emission of WSOCs and hydrogen ion components should be evaluated, and emissions should be decreased.

Center for Regional Environmental Research

Human activities have a substantial impact on both human life and ecosystems through environmental media such as the atmosphere, water, and soil. To provide a sound scientific basis for minimizing the environmental impacts of human activities, the Center for Regional Environmental Research is investigating the mechanisms by which regional environmental issues develop at multiple scales (local, urban, and transboundary) in both Japan and Asia as a whole. Furthermore, we are studying solutions to these regional environmental issues and how to apply them to real-world issues and situations.

The center consists of six sections (Regional Atmospheric Modeling Section, Regional Atmospheric Environment Section, Lake and River Environment Section, Marine Environment Section, Soil Environment Section, and Regional Environmental Systems Section) and has one Principal Researcher.

In FY 2018, we implemented many research projects covering a wide range of regional environmental issues. Our main research projects were as follows:

- a study of the establishment of reference models to apportion sources and create effective strategies to suppress secondary air pollutants
- a study of processes causing the spread of hypoxia in lake bottoms
- a study of the reduction of CO_2 emissions from sewage treatment systems with a new power generation system utilizing fat, oil, and grease in wastewater
- a study of the development and verification of a simple measurement method of sediment oxygen demand in Lake Biwa.

Most of the projects are collaborations with other NIES centers. Additionally, there are two long-term monitoring programs: the Regional Atmospheric Monitoring Program and the GEMS (Global Environment Monitoring System)/Water Program, which is a collaboration with the Center for Environmental Biology and Ecosystem Studies.

Below, we briefly describe some of the important results of the Center's research in FY 2018.

1. Basic Research

1.1 Establishment of reference models to apportion sources and create effective strategies to suppress secondary air pollutants

$PM_{2.5}$ and ozone are secondary pollutants formed in the atmosphere via complex photochemical reactions, and they remain a concern in Japan. This study aimed to establish reference air-quality models that can be utilized to investigate air pollution caused by secondary pollutants and to evaluate source apportionments

and sensitivities to ambient pollutant concentrations. The aim of the study was met by conducting model inter-comparisons in which many modeling researchers participated. Although various emission inventories are already available, they contain many uncertainties. Our role was to develop and improve emission inventories, which are critical inputs to air-quality modeling.

Various improvements have been made to emission inventories by using the results of model inter-comparisons to obtain better model performance. One example is the inventory for biogenic volatile organic compounds (VOCs) emitted from vegetation. All of the models overestimated ambient ozone concentrations, suggesting the importance of improving the data on biogenic VOC emissions, which are major precursors of ozone. A new database was established by gathering detailed distributions and emission factors of vegetation specific to Japan. Biogenic VOC emissions estimated by using this new database contributed to better model performance in the estimation of ozone.

Another example is the emission inventory for large stationary sources. The model inter-comparison required information about the various types of facilities, much of which was missing in existing inventories. Such information would help better represent emission characteristics, which are critical for estimating the secondary aerosol formation embedded in models. Therefore, emission factors and energy consumption for the different facility types were derived by analyzing survey data for large stationary sources. Emission inventories for large stationary sources were then classified by facility type.

Data conversion tools have also been developed. They are required to convert emission inventories to formats required by models. The emission inventories and data conversion tools developed or improved in this study effectively contributed to model inter-comparisons. They clarified the optimal model configurations to obtain better model performance; they also helped to delineate the limitations of currently available models. Moreover, they indicated how to interpret the source apportionments and sensitivities evaluated by models when effective strategies to improve air quality are being considered.

1.2 Processes causing the spread of hypoxia at the bottom of lakes

Under high water temperatures, lake environments tend to become depleted in dissolved oxygen (DO), reflecting enhancement of the respiration rate in the water column and sediment. In the case of surface water that is rich in algal biomass and open to the atmosphere, depletion can be minimized through DO generation and diffusion during the daytime. In contrast, DO at lake bottoms generally continues to decrease during stratified periods when the bottom water does not mix with the oxygenated surface water. As part of an effort to conserve benthic aquatic organisms, lake-bottom DO concentration was introduced in 2016 as a new environmental quality standard for water pollution in Japan.

In 2018, we obtained temporal DO data at five lakes (Kojimako, Biwako, Kasumigaura, Naganuma, and Inawashiroko), with a frequency of one reading every 10 to 15 min. The data revealed periods of hypoxia in the bottom water and gave us information about the longevity and the start or disappearance dates of hypoxia. In addition, at least seven factors were identified as decreasing bottom water DO concentration. High water temperature was one of the most important factors, and wind speed was a secondary factor.

In Lake Naganuma, in Miyagi Prefecture, the DO concentration in bottom water was monitored at the point of 1m water depth. The DO concentration was less than 2 mg L^{-1} in summer (Fig. 1). This monitoring point was covered by lotus leaves, which suppressed DO levels by shading from sunlight and eliminating photosynthetic activity within the water column and by diminishing water-surface disruption by wind and waves. Even in summer, wind speeds greater than 4.5 m s^{-1} improved the DO concentration by up to 2 mg L^{-1} (Fig. 1). In September, the DO concentration began to recover after the water temperature dipped to below 23 °C.

Chronological data on lake-bottom DO tell us about the metabolic balance between production and respiration. From these analyses it may be possible to reveal the cause of the spread of hypoxia in these lakes.

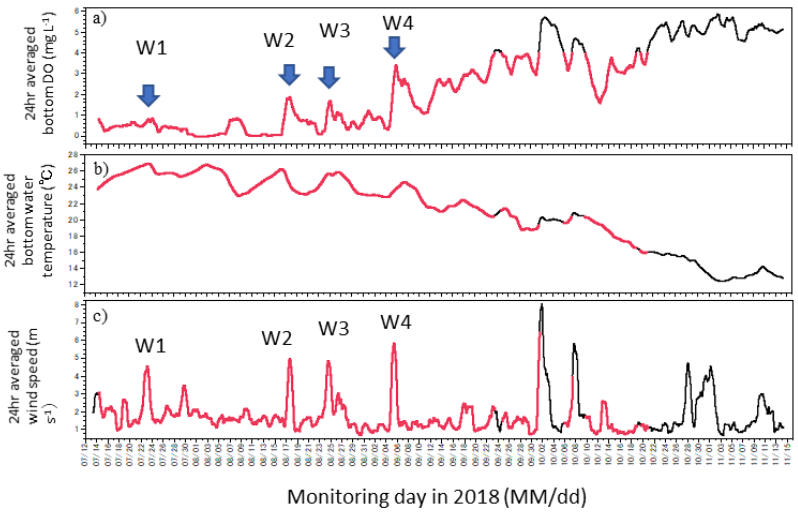


Fig. 1 Chronological data on bottom water dissolved oxygen (DO) (a), bottom water temperature (b), and wind speed (c) at Lake Naganuma. All data are 24-h moving averages. There were 4 windy days (W1–4) during the study period, with water temperature >23 °C; bottom water DO temporarily recovered on these same days.

1.3 Reduction of CO_2 emissions from sewage treatment systems with a new power generation system utilizing fat, oil, and grease in wastewater

Fat, oil, and grease (FOG) in wastewater discharged from communities often cause water pollution and declines in the performance of sewerage and sewage-treatment systems. FOG is thought to be a particularly important problem in urban areas, such as Tokyo, which have combined sewer overflow (CSO) in the rainy season. For example, oil balls, which probably originate in CSO, have been cast ashore at a seaside park in Tokyo Bay. The Japanese government has considered countermeasures to improve combined sewerage in urban areas and has set three goals: 1) reducing water pollutants, 2) ensuring sanitation, and 3) removing inert matter.

Reducing FOG in sewage falls under the third goal, and a grease trap (GT) is the most commonly used piece of equipment to remove FOG from wastewater. Restaurant owners in the Tokyo Metropolitan Area that discharge FOG are required to install GTs in their kitchens. GTs can easily remove FOG from wastewater, but the intercepted grease (IG) should constantly be collected and disposed of to maintain the GT's removal capacity. Because this collection process is high maintenance, more effective collection methods are needed.

An innovative urban biomass power-generation system called the FOG-green Power Generation System (FPGS) is being developed in Japan. Not only is FPGS a low-carbon technology, but also it is expected to reduce the amount of FOG flowing into sewage treatment systems, because an automatic collector can be used to collect a greater amount of IG from GTs and maximize the procurement of feedstock. Meanwhile, reducing the amount of water pollutants in the wastewater may reduce CO_2 emissions from sewage treatment plants (STPs) because of reduced energy requirements for treatment. This study therefore aimed to quantitatively evaluate the CO_2 emission reduction at STPs under a scenario in which automatic collectors were installed in restaurants in Tokyo as part of an FPGS.

Collectable IG from GTs with and without the collectors was estimated by using a bottom-up model that included the number of restaurants, the amounts of influent and effluent through the GT per restaurant, and the FOG concentration in the influent and effluent. The difference between the amounts of IG collected with and without the collector was defined as the reduction in FOG entering the treatment plant. On the basis of this result, the reduction in chemical oxygen demand (COD) inflow was estimated by using a standard conversion factor, and the reduction in CO_2 emission from the treatment plant was computed by multiplying the electric power consumption per unit of COD removal in an STP (provided by the Tokyo Metropolitan Government) by a CO_2 emission factor (provided by the Tokyo Electric Power Company).

We estimated that more than 31,000 t-FOG could be collected in the FPGS. This amount corresponds to 110,000 t-CO_2, a 15% CO_2 emission reduction at existing STPs, and an energy saving of 243 GWh in the Tokyo Metropolitan Area.

1.4 Development and verification of a simple method of measuring sediment oxygen demand in Lake Biwa

Increasing sediment oxygen demand (SOD) is one of the major factors that substantially decreases bottom-layer dissolved oxygen (DO) in lake environments. SOD is also closely related to nutrient release from sediment, because nutrient release likely increases as bottom-layer DO declines. Therefore, SOD can be a meaningful and useful parameter for evaluating the state of lake environments. However, SOD measurement is complicated and cumbersome, because many large-diameter sediment core samples must be collected and prepared for the measurement. In this study, we developed a simple method that could reliably and easily measure SOD in samples from lake environments (Fig. 2a).

Bottom sediment cores were collected by using an acrylic pipe (inner diameter: 11 cm; length: 50 cm) at several sites in the north and south basins of Lake Biwa. About 8 mL of undisturbed sediment core was transferred to a small glass vial (inner diameter: 12.8 mm; length: 125 mm) by using a 10-mL macro-pipette; the glass vial was used like a pipette tip (Fig. 2b). The vial was then filled with bottom-layer water filtered through a 0.2-μm membrane filter, and the ends of the vial were sealed with butyl rubber stoppers (Fig. 2c). Non-invasive optical oxygen sensor spots (PreSens, Regensburg, Germany) were attached to the inner surface of the glass vial (Fig. 2a, c). Temporal changes in DO in the glass vial were measured with a fluorescence oxygen meter (Fibox 4, PreSens) with a polymer optical fiber (Fig. 2d). It is important to note that this method does not account for the effects of environmental conditions such as benthos and water flow rates.

We found that the glass vial method was easy to use and measured SOD with a high degree of precision. The SOD in the north basin of Lake Biwa was lowest in summer but increased in winter, showing clear seasonal variation (Fig. 3). Because the bottom-water temperature remained almost constant at 7 °C all year, the difference in SOD between summer and winter may be related to differences in the degradation characteristics of surface sediments in summer and winter.

Fig. 2 Schematic diagram of the glass vial method for sediment oxygen demand (SOD) measurement. (a) Outline of the vial method; (b) transfer of the sediment to a glass vial, keeping the sediment structure as intact as possible; (c) sealed glass vials ready for SOD measurement; and (d) apparatus used for measuring dissolved oxygen (DO) inside the vial without opening and closing the vial

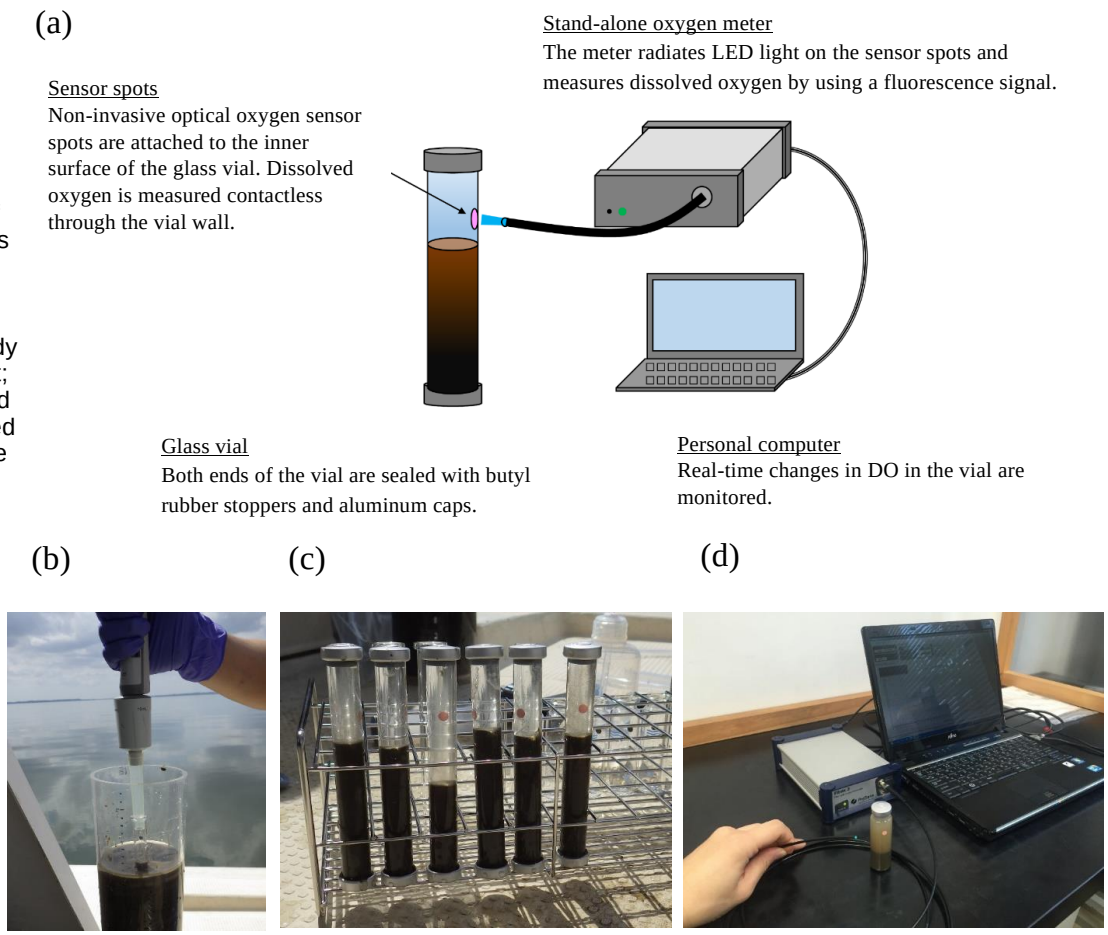
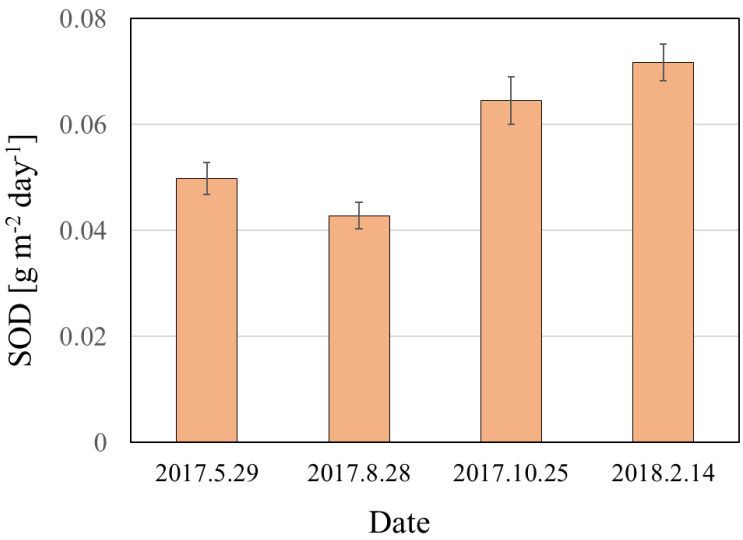


Fig. 3 Temporal changes in sediment oxygen demand (SOD) at a central site offshore in the north basin of Lake Biwa. Error bars show the standard deviations of SOD (n >3)



2. Long-term monitoring

2.1 Long-term monitoring of atmospheric pollutants at Cape Hedo, Okinawa, and Fukuejima, Nagasaki, to monitor air quality in East Asia

Long-term monitoring of atmospheric pollutants, including aerosols and gaseous species, has been conducted by our Center at Cape Hedo Atmosphere and Aerosol Monitoring Station (CHAAMS) on Okinawa Island and at Fukuejima (Fukue Island) Observatory in Nagasaki Prefecture, Kyushu, to observe changes in the atmospheric environment of the East Asian region. Observations of optical, physical, and chemical characteristics, including the scattering coefficient, chemical composition, mass concentration, and vertical distribution of aerosols, have been conducted since spring 2004 at CHAAMS and since autumn 2008 at Fukuejima.

Ultraviolet radiation (UV-A: wavelength 400 to 315 nm; UV-B: wavelength 315 to 280 nm) was monitored at CHAAMS during August 2012–March 2019. No interannual variability was found for either UV. The UV-B value at CHAAMS is slightly lower than that monitored at Hateruma Station, which is located at the south-west end of the Okinawa islands.

Isotopic compositions of gaseous elemental mercury (GEM) collected at CHAAMS from December 2017 to December 2018 were measured by using CV-MC-ICP-MS (cold vapor multicollector inductively coupled plasma mass spectrometry) to evaluate possible sources and transformation processes of atmospheric mercury. The 72-h integrated GEM samples showed large variations in both MDF (mass-dependent fractionation) of δ^{202}Hg (−2.15‰ to 0.41‰) and MIF (mass-independent fractionation) of Δ^{199}Hg (−0.32‰ to 0.00‰). δ^{202}Hg and Δ^{199}Hg were, respectively, negatively and positively correlated with atmospheric GEM concentrations, suggesting a mixing of background GEM and additional GEM (Fig. 4). We also found a seasonal trend in δ^{202}Hg and Δ^{199}Hg values (negative δ^{202}Hg and near-zero Δ^{199}Hg signatures in the summer samples, and near-zero δ^{202}Hg and negative δ^{202}Hg signatures in the winter/spring/fall samples; Fig. 5a and b), and positive correlations between the δ^{202}Hg values of GEM samples and carbon monoxide (CO) and $PM_{2.5}$ concentrations in summer (Fig. 5c and d). The Asian monsoon predominantly brings southerly winds to Okinawa in summer, as we further observed through back-trajectory calculations, suggesting that the summer GEM samples originate mainly from the south and southwest and are mixed with background air during transport. Further details are provided by Yamakawa et al. (2019).

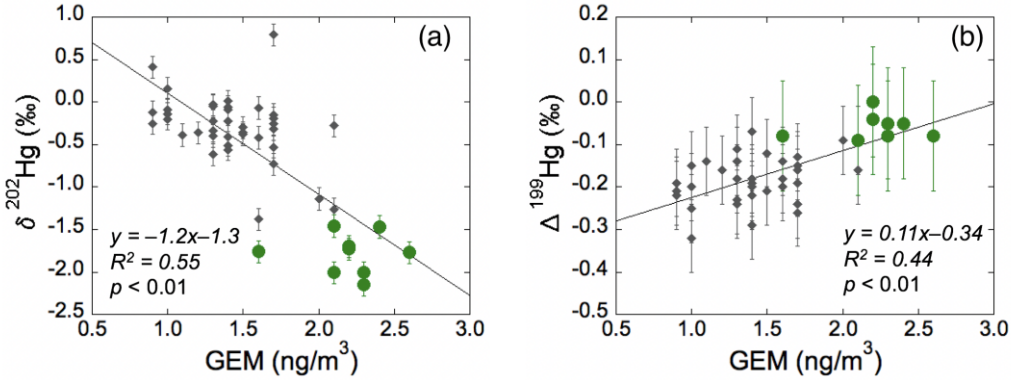


Fig. 4 Gaseous elemental mercury (GEM) concentration versus (a) δ^{202}Hg and (b) Δ^{199}Hg

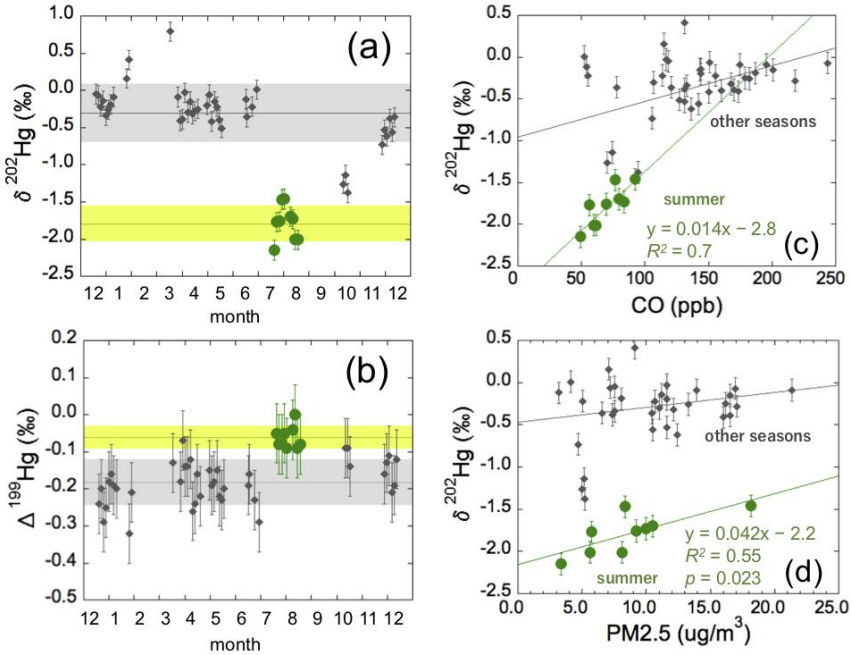


Fig. 5 Sampling date versus (a) δ^{202}Hg and (b) Δ^{199}Hg, and δ^{202}Hg versus (c) carbon monoxide (CO) and (d) $PM_{2.5}$

These types of long-term monitoring data contribute to our understanding of the current status and trends of atmospheric pollutants in the East Asian region and of trans-boundary pollution entering Japan. Some of these measurement data and a list of peer-reviewed papers are available to the public on the NIES web pages (http://www.nies.go.jp/asia/hedomisaki/home-e.html).

Reference:

Yamakawa, A., Takami, A., Takeda, Y., Kato, S., Kajii, Y. (2019). Emerging investigator series: investigation of mercury emission sources using Hg isotopic compositions of atmospheric mercury at the Cape Hedo Atmosphere and Aerosol Monitoring Station (CHAAMS), Japan. *Environ. Sci. Proc. Imp.*, 21, 809-818, doi:10.1039/c8em00590g

2.2 Long-term monitoring at Lake Kasumigaura

We have been monitoring Lake Kasumigaura, the second largest lake in Japan, monthly for nearly four decades in collaboration with the Center for Environmental Biology and Ecosystem Studies. This lake is registered as a core site of JaLTER (the Japan Long-Term Ecological Research Network). It is also part of the Monitoring Site 1000 project of the Ministry of the Environment and a trend-monitoring station of the United Nations Environment Programme's GEMS (Global Environment Monitoring System) Water Programme.

We measure selected environmental variables (water temperature, water depth, transparency, dissolved oxygen, pH, and light intensity in the water), water quality (electronic conductivity, chemical oxygen demand, chlorophyll a, suspended solids, particulate organic carbon, particulate organic nitrogen, particulate organic phosphorus, total phosphorus, dissolved total phosphorus, soluble reactive phosphorus, total nitrogen, dissolved total nitrogen, nitrate nitrogen, and ammonium nitrogen), plankton (bacteria, heterotrophic nanoflagellates, ciliates, picocyanobacteria, eukaryotic picoplankton, phytoplankton, rotifers, crustacean zooplankton, and mysids), benthos (chironomids and oligochaetes), and primary production. The database for this monitoring program has been released on the following website:
http://db.cger.nies.go.jp/gem/moni-e/inter/GEMS/database/kasumi/index.html.

This fiscal year, we focused on checking and revising the vast amounts of data obtained in this project (i.e., monthly data for more than 40 years). We were able to modify almost all of the invalid data and added explanatory remarks to the other invalid data. In addition, the data format was drastically changed to streamline data with explanatory remarks. In a regime-shift analysis conducted by using data from this project, a major regime shift was found in the early 1990s, and it was suggested that the timings of the shift differed between Lakes Nishiura and Kitaura. The history and the challenges of this project were introduced and discussed at the 17th World Lake Conference, held in Tsukuba.

We began to monitor dissolved metals (Fe, Mn, etc.) in the south basin of Lake Biwa and collected monthly data for 18 sampling points. Data loggers for dissolved oxygen, water temperature, and sediment temperature have been installed in the south basin and continuous data are being obtained.

Center for Environmental Biology and Ecosystem Studies

The Center for Environmental Biology and Ecosystem Studies (CEBES) performs various types of research aimed at understanding ecosystem composition and function and the relationships between these two factors, as well as the effects of human activity on biodiversity.

The center is responsible for leading the Biodiversity Research Program (one of the five Issue-Oriented Research Programs in the fourth NIES five-year plan), with the aim of helping to implement the Strategic Plan for Biodiversity 2011–2020, including the Aichi Biodiversity Targets of the Convention on Biological Diversity. Moreover, CEBES conducts long-term ecological monitoring, preserves biological resources, and establishes biodiversity databases. We have also studied the effects of the Great East Japan Earthquake on organisms and ecosystems. In 2017, we established the Lake Biwa Branch Office in cooperation with the Center for Regional Environmental Research.

CEBES considers commitment to national and international frameworks and policies to be an important task in the conservation of biodiversity and ecosystem services. During the third NIES five-year plan, four CEBES researchers were selected as experts and contributed as lead authors to the assessment reports of IPBES (the Inter-governmental Platform on Biodiversity and Ecosystem Services). We also responded to notifications from the Secretariat of the Convention on Biological Diversity, such as requests for peer review of documents. In addition, to lead and coordinate participation in these activities by the scientific community in Japan, CEBES set up the Secretariat of the Japanese Biodiversity Observation Network (J-BON) in 2014; its role is to act as an interface between the scientific community and other sectors.

1. Project for The Environmental Genomics Studies

NIES preserves highly endangered Japanese domestic species, such as Okinawa rail and white stork. Because of the restrictions of the Washington Convention, it is difficult to conduct whole-genome analyses of such species at overseas research institutes. Therefore, the analyses must be conducted, and the genome data released, by NIES. Whole-genome information on a wide range of wild species is required to analyze whether and how wildlife is affected by disasters such as the Fukushima Daiichi Nuclear Power Plant accident associated with the Great East Japan Earthquake. In this project, a draft analysis of the whole genome will be performed for highly endangered Japanese domestic species, species causing environmental problems, and indicator organisms widely distributed in Japan. By 2019, a whole-genome draft analysis of 15 endangered avian species and two mammals was completed. These data were released on the NIES homepage (http://www.nies.go.jp/genome/index.html). Figure 1 indicates the representative of species we have released.

In addition, using environmental DNA analysis methods, NIES plans to carry out a detailed food-chain analysis and distribution survey in lakes Kasumigaura and Biwa, and in the Ogasawara Islands. To achieve more reliable results, highly accurate DNA barcode data for species identification are essential, and we are acquiring the DNA barcodes of organisms distributed in these areas that are targeted for environmental research. To date, more than 250 DNA barcode sequences have been identified, and these are being used in other NIES research projects. Moreover, as part of this project, we have consolidated a platform for bioinformatic analyses and support for our research collaborators (Fig. 2).

Fig. 1 Okinawa rail (*Gallirallus okinawae,* left) and white stork (*Ciconia boyciana,* right)

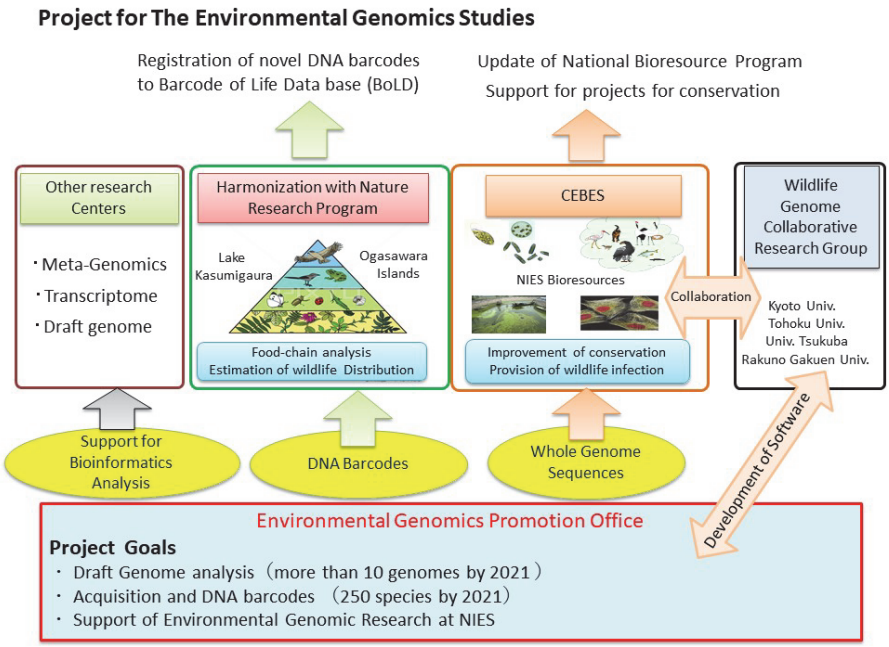


Fig. 2 Outline of Project for The Environmental Genomics Studies

2. Onboard bioassay to monitor seawater quality by using delayed fluorescence of microalgae

Seafloor mining to recover hydrothermal ores by using a mining support vessel can be designed well to minimize environmental impacts. However, there is a risk

of accidental spillage or leakage of both the recovered ores and mining wastewater to the ocean surface from the support vessel or during transfer of the ore from the support vessel to the transport ship. One of the environmental risks is the accidental release of environmental toxicants, such as toxic metals (derived from the ore and artificial chemicals used in the recovery process), into natural seawater, and the consequent adverse effects on the marine ecosystem. Hence, a scheme for constant monitoring of water quality, particularly the levels of toxic substances, should be introduced at each deep-sea mining site. The International Seabed Authority also recommends (in guideline ISBA/19/LTC/8) that a rapid assessment of ore and plume toxicity onboard the survey/support vessel, by using an approved assay, should be implemented during both the exploration and exploitation phases. In addition, the research highlights of the MIDAS project (Managing Impacts of Deep-seA reSource exploitation, http://www.eu-midas.net/) for policymakers and future regulations point out the requirement that using an ecotoxicological approach is important in environmental impact assessment

As part of the Next-generation Technology for Ocean Resources Exploration in the Cross Ministerial Strategic Innovation Promotion Program (SIP, 2014–2018), we first investigated the leaching potential of metals from various sulfide minerals collected from hydrothermal chimneys (Fig. 3a) and mounds. We found that substantial amounts of Zn, Cu, and Pb were rapidly released from the minerals in oxygenated seawater at higher temperatures (around 20 °C), namely in areas with almost identical conditions to the ocean surface. Moreover, these metals affected the photosynthetic activity of marine phytoplankton. Second, on the basis of our results, we developed a novel bioassay using a specific marine microalgal strain, *Cyanobium* sp. (Fig. 3b), as an onboard seawater monitoring system that can detect unexpected pollution at seafloor mining sites. We confirmed that a delayed fluorescence (DF)-based bioassay produced results matching those of a standard growth inhibition assay, which takes more than 72 h using 500 mL culture vessels. The DF-based bioassay (Fig. 3c) enables rapid handling (less than 24 h) of smaller sample volumes (less than 50 mL); this method could therefore contribute to onboard monitoring for seawater quality in deep-sea mining areas.

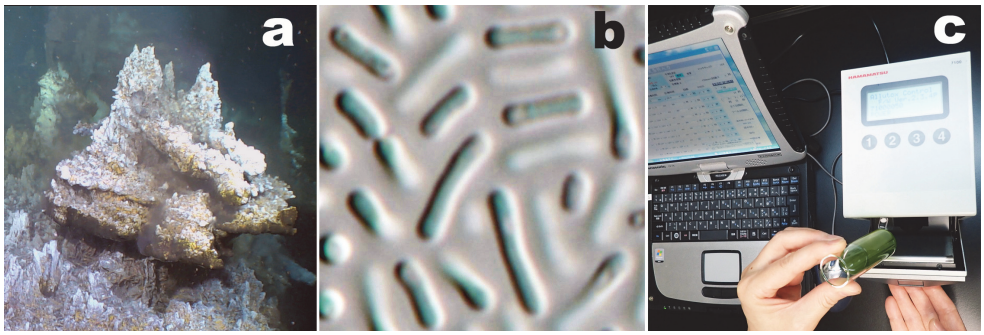


Fig. 3
(a) A hydrothermal chimney in the Okinawa Trough;
(b) a test strain (NIES-981, *Cyanobium* sp.) for on-board bioassay; and
(c) apparatus for measuring delayed fluorescence

3. Economic analysis of ecosystems

We conducted a stated preference survey to determine the economic value of vulnerable coastal ecosystems. The results showed that the public were willing to pay for the conservation of each ecosystem. Further analyses are needed to project economic values considering ecosystem changes under climate change.

Center for Social and Environmental Systems Research

The Center for Social and Environmental Systems Research targets linkages between human activities and the natural environment to identify the relationships among socioeconomic systems and environmental issues. The work of the Center results in important academic findings as well as policy recommendations for environmental issues, covering a broad area, from global environmental issues to local sustainable cities and regions.

The Center consists of five research sections:

1. The **Integrated Environment and Economy Section** analyzes the structure of causes and effects of various environmental problems, considering the inter-relationships among multiple sectors (such as household, government, and enterprise) and multiple scales (including world, country, and city), and explores solutions to these problems.
2. The **Trans-boundary Impacts and Mitigation Modeling Section** develops and utilizes analytical models to quantify the impacts of various environmental changes at transboundary and national scales—including the impact of climate change—and to examine measures for mitigating these changes.
3. The **Regional Environmental Impact Assessment Section** investigates solutions for environmental problems by developing methods and models to assess various environmental impacts at country, local, and city levels.
4. Through social transition research for innovative technological and social systems, the **Eco-society Innovation Section** conducts system design, evaluation, and support for the implementation of environmentally friendly technologies and policies to foster the transition to a sustainable environmental society.
5. The **Environmental Policy Section** aims to elucidate pathways to sustainable social systems by assessing the effectiveness of environmental laws and policies and analyzing the roles and activities of multiple stakeholders.

Researchers at the Center are involved in at least one of two major research programs, namely the Environment-Economy-Society Integration Research Program and the Low-Carbon Research Program. Basic research that supports these project-oriented programs, together with any other research activities, is categorized as part of our Center's research sections. In FY 2018, the third year of the fourth mid-term plan of NIES, our goal was to extend our research activities to cover a variety of research projects regarded as "seeds" for future studies. Included were those related to data collection for model development, data collection as a foundation for future studies, and outreach-related activities. Some of our outputs are described below.

1. Municipal Solid Waste Generation and CH_4 emissions from landfill sites in Asia

In any country undergoing rapid economic development, the amount of municipal solid waste (MSW) generated increases and methods of waste disposal such as landfill, incineration, and recycling are subject to debate. MSW generation and landfill area have risen owing to economic growth in Asia, and it is important for policymakers to understand future potential MSW generation as they consider appropriate countermeasures for MSW landfill. From the perspective of National Greenhouse Gas Inventories, MSW landfills are a source of methane (CH_4) emissions and MSW incineration is a source of CO_2 emissions. Both are anthropogenic GHGs, and in general, appropriate measures for reducing CH_4 emissions derived from MSW landfill have not been taken in Asian developing countries. Therefore, this study developed appropriate methods to estimate future MSW generation in Asian countries considering their socioeconomic development. It also estimated the increase in CH_4 emissions from landfill sites in Asia and analyzed the effects of the shift from landfill to incineration and its impacts on net reduction of GHG emissions by 2050 in Asia.

We estimated future MSW generation in Asian countries by using three different correlation functions between per capita GDP growth and per capita MSW generation growth: low growth (up to Japan level), mid growth (up to EU level), and high growth (up to US level). Figure 1a shows the uncertainty ranges of CH_4 emissions from landfills in the reference scenarios by using the different growth levels of GDP per capita given in the five shared socioeconomic pathways (SSP1 to SSP5). CH_4 emissions from landfills in the reference scenarios range widely, from 566 to 1010 Mt CO_2eq. Currently, many Asian developing countries lag behind in implementing MSW countermeasures, and most MSW has been deposited in landfills or open dumpsites. There are several policy options to shift from MSW landfills to MSW incineration, recycling, or composting. As a case example, this study considered what would happen if Asian countries were to shift from MSW landfills to incineration, because it is necessary to take into account CO_2 emissions during incineration processes and whether the shift to incineration cancels out CH_4 emission reductions by increasing CO_2 emissions. Figure 1b shows net GHG emissions considering both CH_4 emission reductions and CO_2 emission increases resulting from the shift from landfills to incineration in the mid (EU-level) case and where the MSW landfill ratio is reduced by up to 90% by 2050 as compared with the 2010 level in Asian countries. In this scenario, net GHG emissions will increase in the first 10 years owing to the effects of CO_2 emissions from incineration. However, CH_4 will be emitted continuously in landfills on a time-delayed basis from the year of disposal to the emission year. By shifting from landfill to incineration, it would be possible to reduce these CH_4 emissions in the long term such that the net emission would decrease after about 2030.

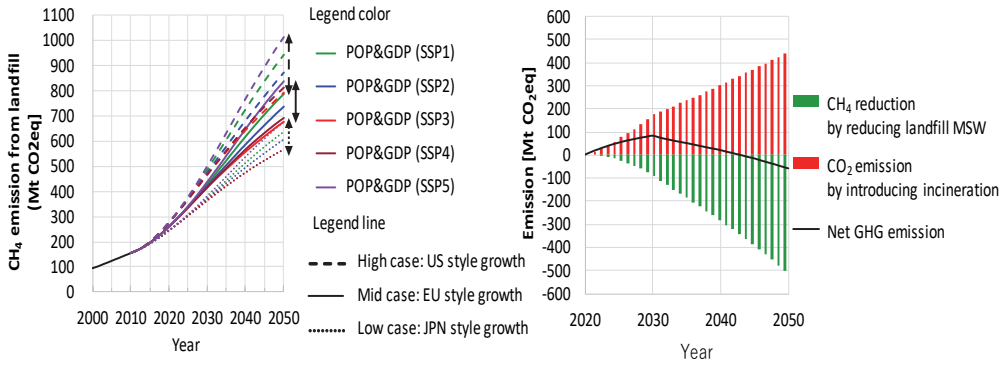


Fig. 1 (a) Uncertainty ranges of CH_4 emission projections from landfills in the reference scenarios in Asia. (b) CH_4 mitigation and CO_2 emission increase by reducing landfill and increasing incineration without energy recovery in the maximum policy shift from landfills to incineration in Asia

2. Collection and analysis of data for global-scale environmental modeling studies

To conduct global-scale environmental modeling studies we need to collect and preprocess the relevant data. This fiscal year, we collected the following two types of data. The first type was data on the spatial distribution of climate-change-related impacts. On the basis of results obtained through the S-14 project (Strategic Research on Global Mitigation and Local Adaptation to Climate Change), we created a dataset for nine kinds of climate-change-related impacts under diverse socioeconomic and GHG emission scenarios: changes in agricultural productivity, risk of hunger, heat-related deaths, cooling/heating demand, occupational-health costs, hydropower generation capacity, thermal power generation capacity, fluvial flooding, and sea level rise. The second type was land-use information related to biodiversity protection and land degradation. Biodiversity protection data were obtained from the World Database for Protected Areas and the World Database of Key Biodiversity Areas. Land degradation data were obtained from GLADIS (Global Land Degradation Information Systems). By using these datasets, we conducted a study to quantify the effect of land-protection policies on bioenergy potential.

In addition to the above-mentioned activities, we also participated in several global model comparison projects, and we gathered information on trends in related research fields. These projects include the Energy Modeling Forum, the Agricultural Model Inter-comparison and Improvement Project, Linking Climate and Development Policies–Leveraging International Networks and Knowledge Sharing, and Climate pOlicy assessment and Mitigation Modeling to Integrate national and global Transition pathways (COMMIT). In the COMMIT project, together with other teams, we helped to inform policymakers about climate-change mitigation pathways for the 24th session of the Conference of the Parties (COP 24) to the UNFCCC (Fig. 2).

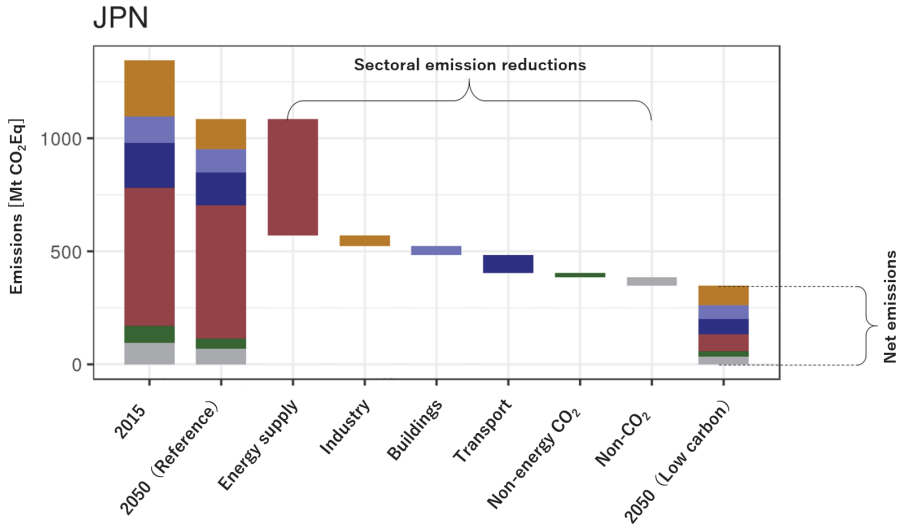


Fig. 2 Japanese emission and emission reductions in each sector corresponding to the 2 °C global target. This figure was used by the COMMIT project for a pre-COP 24 event. Colors represent sectors.

3. Research on outreach activities in environmental science

Environmental science outreach activities (Fig. 3) were reviewed to utilize their outcomes in policy making. Examples of these activities included the systematization of countermeasures against urban heat islands in support of workers in administrative sectors. Some of these activities were noted worldwide via publication in the Global Environmental Outlook reports of the UN Environment Programme. Research activities supported by considerable public funding are currently viewed not only as "one-way social contributions" but also as "two-way dialogues," whereby the interaction and review strengthen research activities. Feedback from other stakeholders is particularly important. Efforts to gain the understanding of other researchers and their support (e.g., funding) are necessary for the sustainability of outreach activities, even if the particular activity originated from personal interest.

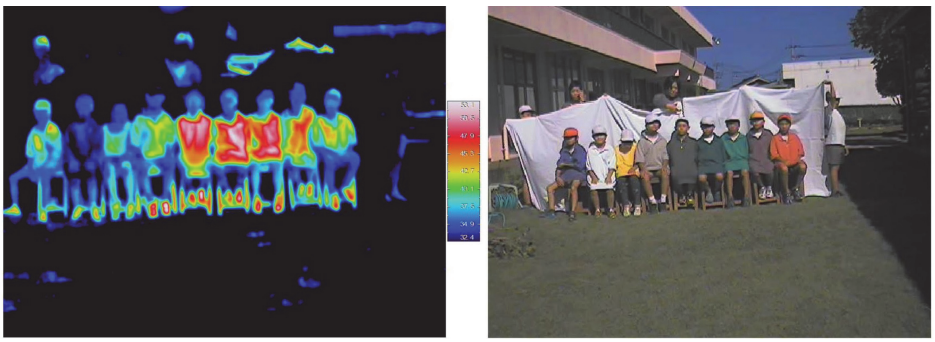


Fig. 3 Scientific demonstration at Kurihara Elementary School in Tsukuba (with third grade students, September 2013)

4. Contributions to national or local governmental committees

Many of the researchers at the Center for Social and Environmental Systems Research are involved in the environmental-policy-making processes of national

and local governments. As members of environmental committees and councils of national or local governments, they are often asked by government officials to add inputs to discussions from a scientific perspective. Our research outcomes—especially in regard to climate change mitigation and adaptation actions and urban planning system design—are often utilized by governments to facilitate discussions aimed at establishing sound environmental policies.

5. Continuation of inter-institutional research collaboration through the establishment of a cross-appointment system with IGES (Institute for Global Environmental Strategies)

In 2015, NIES and IGES established a cross-appointment system in which researchers at either institute could participate in exchanges with those from the other institute for several years. This has become an opportunity for researchers at the two institutes to collaborate intensively. The first person to use the exchange system was a member of the Center for Social and Environmental Systems Research, who has spent 3 years (from FY 2016 to FY 2018) at IGES. He was in charge of the IGES Sustainable Cities Task Force and was successful in building networks among local authorities in Japan, as well as in other countries in Asia.

Center for Environmental Measurement and Analysis

The goals of the Center for Environmental Measurement and Analysis (CEMA) are to help develop better scientific methodologies that will enable the early detection of environmental issues and changes, give us a deeper understanding of environmental issues, and improve the assessment of current and future environmental concerns. CEMA also helps manage the quality of chemical analyses of environmental samples. Furthermore, we have continued our environmental specimen banking as important work that complements the archiving of environmental changes.

To achieve these goals, the six research sections of CEMA have been conducting a variety of studies. The **Fundamental Analytical Chemistry Section** has been in charge of an environmental specimen banking program; it collects bivalve specimens annually to complete a round of sampling from many sites along the Japanese coast. The section has also been preparing and distributing environmental Certified Reference Materials to meet the demand for environmental chemical analysis. The **Advanced Analytical Chemistry Section** has been developing techniques for the comprehensive analysis of organic pollutants; for example, they have coupled a two-dimensional gas chromatograph (GC) to a high-resolution time-of-flight mass spectrometer. The **Environmental Chemodynamics Section** has been monitoring the temporal and spatial variation of chemical species in the atmosphere to gain an understanding of the sources and sinks of anthropogenic and natural substances. A microscale radiocarbon (^{14}C) analysis has also been conducted by this section to distinguish the fossil fuel and biogenic sources of carbon-containing materials such as airborne particulate matter. The **Advanced Remote Sensing Section** has been developing advanced techniques for remote sensing, such as lidar (laser radar), to monitor the temporal and spatial distribution of the main aerosol components (e.g., mineral dust, sea salt, and black carbon) in the atmosphere. The **Environmental Reaction Chemistry Section** has been tackling the development of methods to help us understand the mechanisms and efficiency of the production and chemical conversion of atmospheric fine particles—especially organic particles. The **Environmental Imaging and Spectrum Measurement Section** has been involved in the development of non-invasive and non-destructive techniques for monitoring the human brain by using a magnetic resonance (MR) imaging system. The possibility of utilizing measured MR images as *in vivo* biomarkers has been assessed by this section.

Below are brief accounts of some of the important results of our research in FY 2018.

1. Evaluation of a data-processing method for target and non-target screening using GC×GC-HRToFMS for environmental samples

Our group is focusing mainly on the development of target and non-target screening methods (Figs. 1 and 2) to elucidate the myriad pollutants, including unknown contaminants, in the environment. We have developed methods employing comprehensive two-dimensional gas chromatography coupled with high-resolution time-of-flight mass spectrometry (GC×GC-HRToFMS) and several software programs, such as a program called "T-SEN" for automatic integration of target peaks and a mass spectral deconvolution program called "NMFwithDBcreator," which is based on non-negative matrix factorization (NMF).

In this study, we evaluated the possibility of semi-automatic target and non-target screening by GC×GC-HRToFMS by using estuarine sediment samples. Two-way screening consisting of compound-based (target screening) and data-based (non-target screening) analyses was performed by using the two original software programs, the NIST Mass Spectral Library, and an in-house accurate mass spectral library with a retention index (RI) for the first column. Target screening detected 47 organohalogen compounds, including polychlorinated biphenyls, polybrominated diphenyl ethers, and organochlorine pesticides, in the sediment sample. Among about 54,000 peaks detected in the non-target screening, 53.6% showed match factors (MF) of ≥ 700 in an automatic mass spectral library search using the peak-top mass spectra. Both the mass error of molecular ions and RI error were calculated automatically for the first-hit compounds in the library search; 0.03% of peaks passed all criteria, namely MF ≥ 700, mass error ≤ ± 20 ppm, RI error ≤ ± 20, and intensity of molecular ions ≥ 10,000. Two compounds—a phosphorus flame retardant and a brominated phenol—were tentatively identified in the non-target screening process. The advantages of semi-automatic GC×GC-HRToFMS data processing with the two original software programs are its simplicity, high reproducibility, and shortened time for processing a large volume of data. These results suggest that a library matching technique using accurate mass spectra, such as the In-source HiRes search program published from NIST is useful and could be applied for non-target screening using high-resolution MS in the future.

Fig. 1 Flow diagram for target screening, and the pass rate at each step

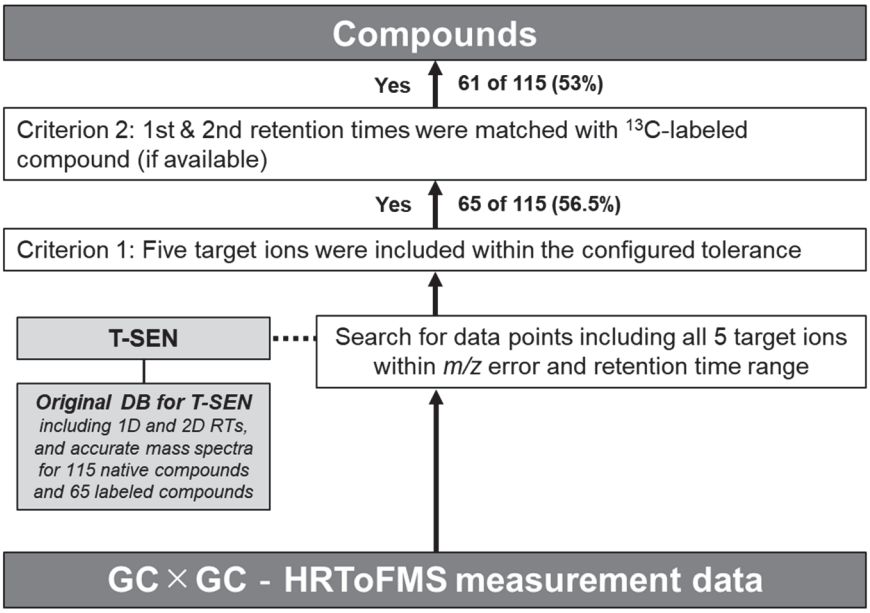
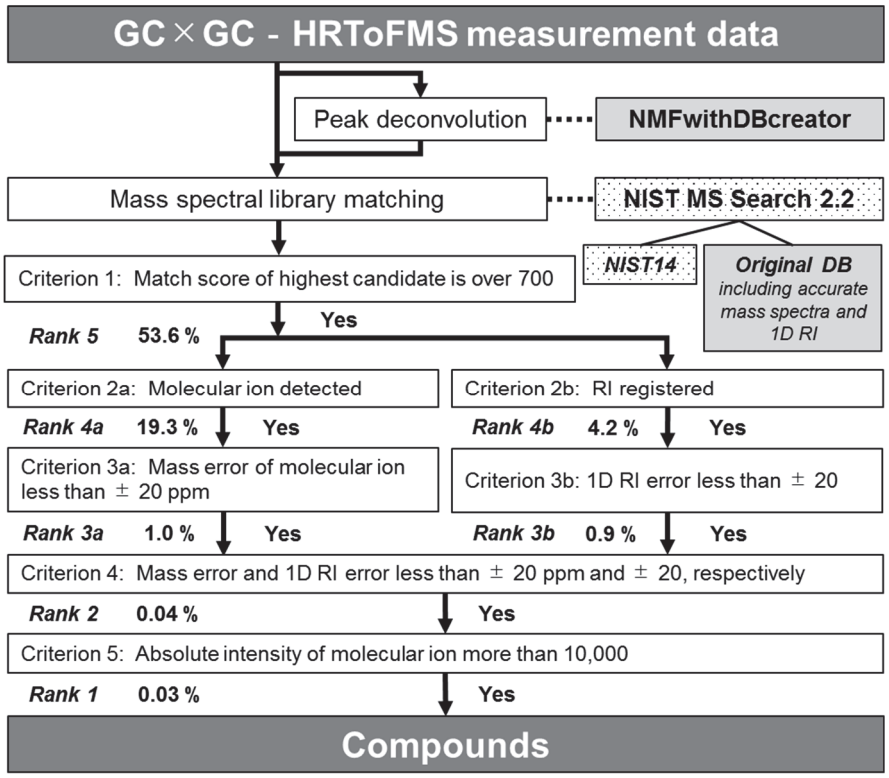


Fig. 2 Flow diagram for non-target screening, and the pass rate at each criterion



2. Long-term monitoring of Lake Mashu and quality control of monitoring data

NIES has been carrying out long-term monitoring on Lake Mashu, located in a remote area of Hokkaido, since 1981. Lake Mashu has unique geographical and environmental characteristics. It is a caldera lake formed several thousand years ago, and the lake surface is surrounded by steep caldera walls. It has no inflowing or outflowing rivers. There is no human activity such as agriculture and forestry in the catchment area, and the anthropogenic pollution load is extremely small. A Secchi disk transparency of 41.6 m—the largest ever recorded—was documented in 1931. Lake Mashu has been registered as the only baseline monitoring station lake in Japan in the UNEP GEMS (Global Environmental Monitoring)/Water Programme since 1994, because it is suitable for detecting long-range transported airborne pollutants.

Our long-term monitoring of Lake Mashu closed, with the final observations taken in 2017, and the observation system was then transferred to an organization consisting of local governments. During the 37 years of observations, we collaborated with universities and research institutions and have conducted trace analyses of persistent organic pollutants, nutrients, and trace metals. We have also obtained continuous data for water temperature and optics by mooring various kinds of data loggers.

Temporal variations of logger chlorophyll and estimated transparency in 2015 are shown in the upper and middle panels of Figure 3. The estimated transparency was calculated by using the downward attenuation coefficient obtained from the readings of two photon flux loggers moored at different depths. The estimated transparency agreed well with the observed transparency, indicated by the open circles in Figure 3 (middle panel). From July to September, the concentration of chlorophyll, indicating phytoplankton biomass, was maximized at shallower depths and minimized in circulation periods (triangles in Fig. 3). Concentrations of biological particles are low in the bottom-layer water. When the water upwells, light permeability and transparency increase. A two-dimensional distribution of the absorption coefficient in August 2015 is shown in the bottom panel of Figure 3. A relatively high absorption band was found near the transparency depth of 17.2 m, corresponding to the chlorophyll maximum. Prominent absorption at a wavelength of about 400 nm also corresponded to the absorption band for chlorophylls.

During the monitoring of Lake Mashu over 30 years, both the researchers and their analytical methods varied. An example of the results for potassium (K) is shown in Table 1. Although it is difficult to ensure absolute accuracy, the relative precision is good. To detect natural minute changes of less than 1% requires accurate and precise analytical techniques over a period of years. It was an extremely difficult task to realize this goal, because analytical conditions change.

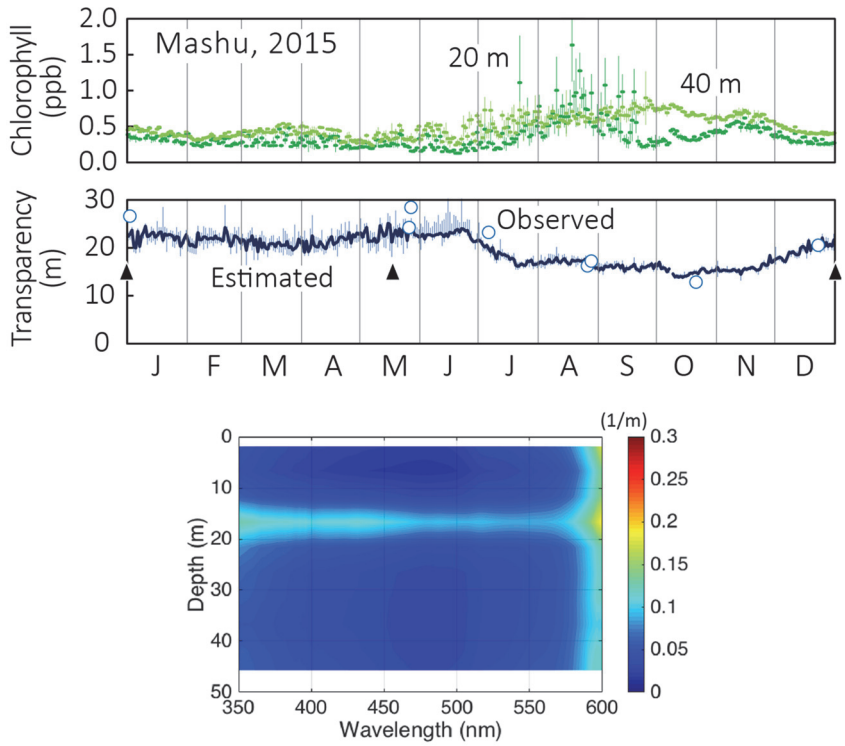


Fig. 3 Seasonal variation in chlorophyll concentration (top) and estimated transparency (middle) in 2015 (upper) and absorption coefficient in August 2015 (bottom). The circulation periods were shown as closed triangles in the upper figure.

Table 1. Long-term analytical data for K in Lake Mashu water

Year	K (mg/kg)	analytical method
1983	0.91	atomic absorption spectrometry
1987	0.92	flame emission spectrometry
2006	0.92	ICP atomic emmision spectrometry
2015	0.90	ion chromatography

3. Ozonolysis of monoterpenes on the surface of an aqueous organic aerosol

Emission of biogenic monoterpenes from vegetation and microorganisms is a major source of volatile organic compounds (VOCs) in the troposphere. Ozonolysis is a major sink for monoterpenes; the reaction yields reactive carbonyl oxide diradicals known as Criegee intermediates (CIs). About 80% of the CI source strength in the Sierra Nevada region of the United States has been reported to be derived from monoterpenes and related compounds. Recent studies suggest that ozonolysis of monoterpenes occurs not only in the gas phase but also at the

air–aerosol interface, and this reaction plays central roles in the formation of atmospheric aerosol particles. However, the experimental investigation of ozonolysis of monoterpenes, which immediately produces CIs, on liquid surfaces has been challenging because of a lack of suitable experimental probes.

We studied the mass spectrometric detection of intermediates and products, including labile hydroperoxides, from reactions of the CIs of representative monoterpenes (α-terpinene, γ-terpinene, terpinolene, D-limonene, and α-pinene) with water, cis-pinonic acid (CPA), and octanoic acid (OA) on the surface of water microjets in the presence of acetonitrile (Fig. 4). The relative yields of α-hydroxy-hydroperoxides (α-HHs) from the reactions of CIs with water at the gas–aqueous interface were: α-terpinene (1.00) >> D-limonene (0.18) > γ-terpinene (0.11) ≈ terpinolene (0.10) >> α-pinene (0.01).
This order does not track the reported rate constants of the gas-phase ozonolysis, implying that these reactions proceed by interface-specific mechanisms. Furthermore, in contrast with the inert nature of the other CIs, the CIs derived from α-terpinene ozonolysis react efficiently with CPA and OA to produce C_{20} and C_{18} ester hydroperoxides, respectively. This process may be a hitherto missing pathway leading to the growth of atmospheric particles. Our results unveiled, for the first time, structural effects on the reactivities of CIs at aqueous interfaces, thus improving our understanding of multiphase aerosol chemistry in the atmosphere.

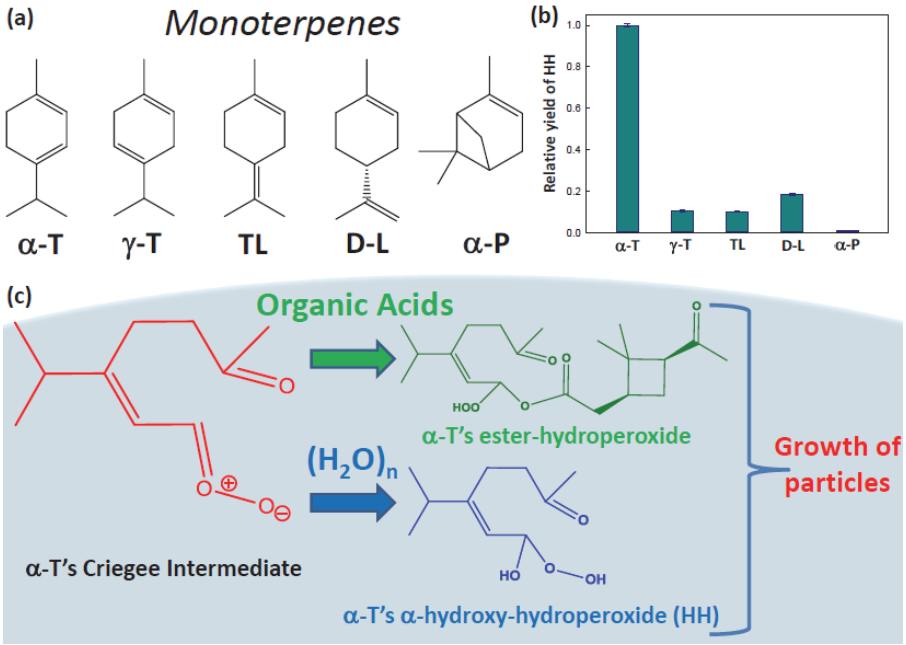


Fig. 4 (a) Chemical structures of monoterpenes used in the present study; (b) relative yields of α-hydroxy-hydroperoxides (HH) from 1 mM α-terpinene, γ-terpinene, terpinolene, D-limonene, or α-pinene + 0.2 mM NaCl in water:acetonitrile (1:4 vol:vol) solution microjets exposed to O_3(g) at 1 atm and 298 K; and (c) reaction schemes of ozonolysis of α-terpinene at the air–liquid interface

4. Identifying jet lubrication oil as a major component of aircraft exhaust nanoparticles

Global use of jet engine aircraft has been rapidly increasing. Effects of aircraft emissions on atmospheric compositions, including those of particulate matter (PM), are ubiquitously found from the ground level to the upper troposphere. A new PM emission standard for jet engines will come into effect globally in 2020. However, the chemical characteristics of aircraft exhaust particles—especially the chemical compositions of nanoparticles—are poorly understood.

We collected size-resolved particulate samples from an area near a runway at Narita International Airport by using low-pressure cascade impactors. We used highly sensitive analytical methods, such as thermal desorption – gas chromatography mass spectrometry, to identify the organic composition of nanoparticles with diameters smaller than approximately 30 nm originating from real-world aircraft emissions.

The mass chromatograms (*m/z* 85) of the nanoparticle sample, jet lubrication oil (Jet Oil II, Mobil), and a filter (Au-foil) blank are shown in Figure 5. The nanoparticle samples clearly show the presence of oil-marker peaks at a retention time of approximately 21 to 27 min (likely fatty acid esters of pentaerythritol). The intensity ratios of these peaks at 22.3 min or later were very similar to those of the jet lubrication oil, and the mass spectra of the peaks at 21 to 27 min in the nanoparticles were also very similar to those of jet lubrication oil. Thus, we identified for the first time that unburned, nearly intact forms of lubrication oil are a major component of nanoparticles emitted from in-use commercial aircraft.
This finding provides direct evidence for the importance of unburned lubrication oil as a source of aircraft exhaust nanoparticles. It also has implications for the environmental impacts of these nanoparticles near airports and in the upper troposphere.

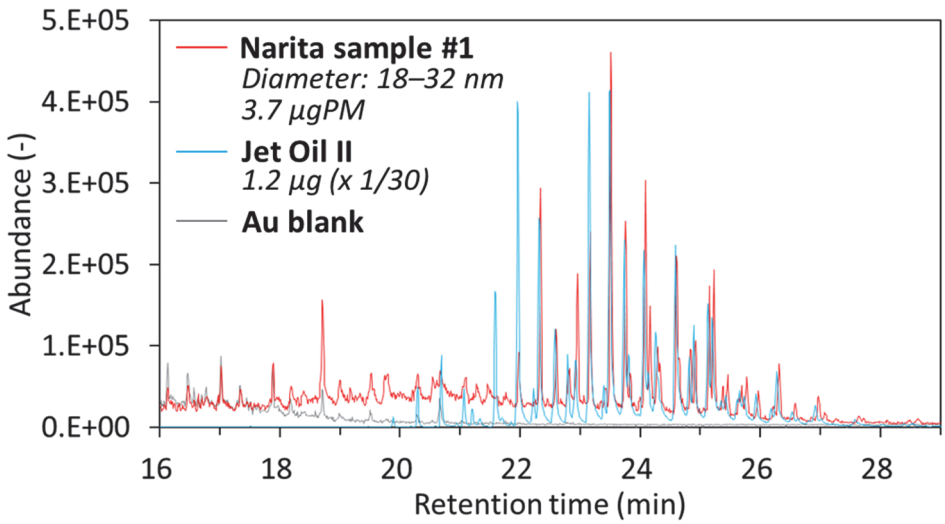


Fig. 5 Mass chromatograms (*m/z* 85) of the nanoparticle sample (sample #1, daytime, 9–13 February 2018; diameter: 18–32 nm) at Narita International Airport, and of samples of Jet Oil II and an Au-foil blank.

Fukushima Branch

In April 2016, NIES opened its Fukushima Branch in the research building of the Fukushima Prefectural Centre for Environmental Creation (Fukushima CEC), located in the town of Miharu in Fukushima Prefecture. The Institute's objective is to promote and maintain rigorous scientific research focused on disaster-affected areas. NIES uses its Fukushima Branch as a collaboration hub to conduct environmental emergency research aimed at environmental recovery and renovation in disaster-affected areas. The collaborating partners include various relevant organizations, including the government of Fukushima Prefecture and JAEA (the Japan Atomic Energy Agency). NIES, by providing its environmental emergency research expertise, also extends support to Fukushima CEC's efforts to collect and disseminate environmental information and to prepare educational, training, and exchange programs (Fig. 1).

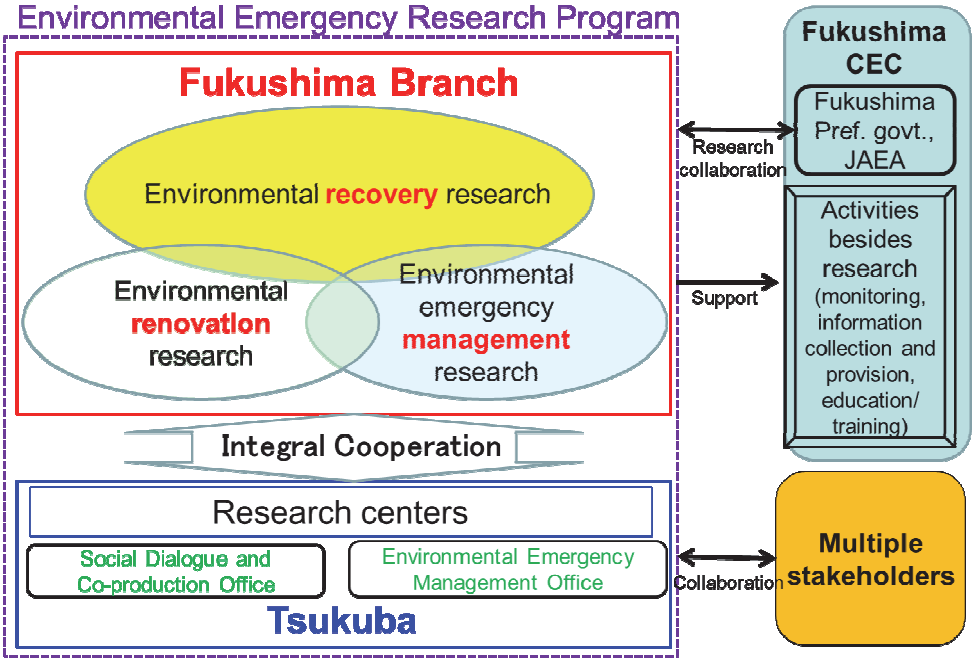


Fig. 1 Outline of environmental emergency research conducted at the NIES Fukushima Branch

In FY 2018, Fukushima Branch continued to conduct many kinds of research (laboratory work, field measurement, model simulation, and field studies) in the field of environmental emergency research, in collaboration with researchers in the research centers at Tsukuba. Research staff at Fukushima Branch also took part in the Environmental Emergency Research Program (see "Environmental Emergency Research Programs" in this report). Fukushima Branch led efforts to build a structure for collaboration among government, industry, and academia in the field of environmental emergency research. It held discussions and cooperated with local governments, non-profit organizations, and local people in Fukushima Prefecture. In particular, a collaboration with many local governments has

advanced in FY 2018. In addition, Fukushima Branch circulated research outcomes and related information to the public through public lectures, publications, and our website.

Environmental Information Department

Environmental Information Department

The Environmental Information Department provides information technology (IT) support for research and related functions at NIES; supports public relations initiatives (including publishing NIES research reports); and performs miscellaneous other activities, including collecting and processing environmental information and disseminating it to the general public and performing tasks commissioned by the Ministry of the Environment (MOE). These tasks are described in detail below.

1. IT support for research and related activities at NIES

The Department manages and operates the computers and related systems at NIES, uses IT to improve the work efficiency of NIES, and runs a library service.

1.1 Management and operation of computers and related systems

A new computer system began operation in June 2013. The UNIX-based computing environment consists of a supercomputer system and various subsystems, including a scalar-computing server, a front-end server, and storage devices. Our vector supercomputer (NEC SX-ACE; Fig. 1), which is equipped with a FORTRAN compiler with high-level debugging capability and high-efficiency optimization, executes the large-scale programs needed to model global environmental problems.

A local-area network called NIESNET was established at NIES in 1992. NIESNET was upgraded in March 2013. Registered users outside NIES can use the supercomputer system through the Tsukuba wide-area network via the SINET (Science Information Network) connection to the Internet.

Fig. 1 The NEC SX-ACE supercomputer

1.2 Use of IT to improve work efficiency at NIES

The Department provides IT support to the administration and planning divisions of NIES with the aim of increasing work efficiency. It also provides NIES researchers with processed research data and helps them to disseminate their data through the NIES website. In FY 2018, the Department supported:

- development of an electronic application and registration system at NIES
- operation of a thin-client PC management system for the administrative section
- development of the NIES research information database
- modification and operation of a database of basic information on each staff member at the Institute.

1.3 Library services

As of March 2019, the NIES library (Fig. 2) held 68,359 books, 897 journals (including electronic resources), and various other technical reports and reference materials. These materials can be searched by using OPAC (Online Public Access Catalog) and a link resolver via the Intranet.

In addition to these resources, researchers at NIES can use abstracts and full-text articles through scientific and technical information databases such as Web of Science (including Essential Science Indicators and Journal Citation Reports) and CiNii.

Library facilities include separate rooms for reading books, journals, and reports.

Fig. 2 The NIES library

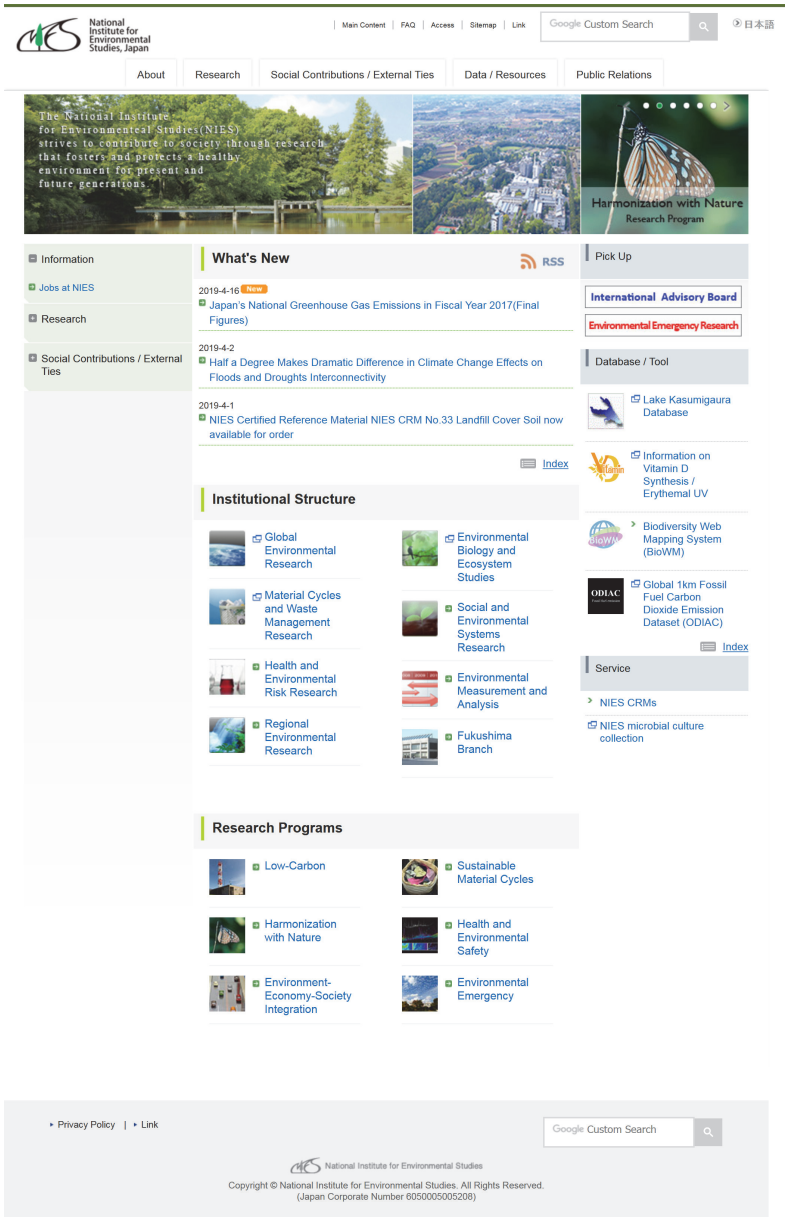
2. NIES public relations activities

The Department manages the NIES website. It also edits and publishes NIES reports such as research reports and this *Annual Report*.

2.1 Management of the NIES website

NIES began to provide publicly accessible information on its research activities and results via the Internet (http://www.nies.go.jp/; Fig. 3) in March 1996. In April 2001, the website was completely revamped and improved in step with the restructuring of NIES as an Independent Administrative Institution. The website was again revamped in July 2013. It also provides information on NIES initiatives related to the Great East Japan Earthquake.

Fig. 3 The NIES website



2.2 Editing and publication of NIES reports

Reports on NIES research activities and outcomes, such as the NIES *Annual Report* and research reports, official newsletters (*NIES News*, in Japanese), and NIES research booklets (*Kankyo-gi*, in Japanese), are edited, published, and distributed by the Department.

2.3 Promoting Open Science

To facilitate the use and application of research resources, prevent the loss of research results, and assure permanent accessibility, we have started attaching digital object identifiers (DOI) to research data. Accordingly, we have set up a system for publishing URLs (metadata) associated with DOIs on the NIES website.

In response to calls for the establishment of a system for promoting open science, we have also started exploring an archive system (an institutional repository) to be created and operated by NIES. In addition, to estimate the costs of APCs (article processing charges) each year, we conducted a survey of open access activities at NIES.

3. Other activities

3.1 Collection, processing, and dissemination of environmental information

One of the major tasks at NIES is the "collection, processing, and dissemination of environmental information." The Department provides various kinds of environmental information to the public through websites. It also processes and manages environmental information databases and provides environmental information via GIS (Geographic Information Systems).

3.1.1 Environmental Observatory (Information Platform for Environmental Outlook)

The Environmental Observatory (Information Platform for Environmental Outlook) is a multimedia site providing integrated environmental information to promote wider involvement of the public and relevant institutions in environmental conservation. It gives users broad access to a range of systematically organized environmental information aimed at creating a sustainable society. The site offers a quick search facility to access news updates on such things as environmental issues in Japan and throughout the globe; descriptions of key environmental technologies; information on policies and laws in environmental fields; environmental information via GIS; and other content to aid environmental learning.

3.1.2 Processing and management of environmental information databases

Various environmental data are needed for research, policy decisions, and policy enforcement. We compile and process air-quality and water-quality data collected by local governments and reported to MOE. These processed data can be accessed through the database on the NIES website. Duplication and lending services are also available.

3.1.3 Provision of environmental information via GIS

The Department, with the cooperation of MOE, has been using GIS to develop an environmental data provision system. By displaying data on environmental quality and other information on maps, this system helps users to understand the status of the environment easily. The system has been publicly available through the Internet since September 2002 and was revised in March 2011.

3.2 Tasks commissioned by the Ministry of the Environment

In FY 2018, the Department performed the following task, as commissioned by MOE:

- conversion of hourly values of regular air-monitoring data to standard format.

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