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NIES Annual Report

2015

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National Institute for Environmental Studies
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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 (FY) 2014 (April 2014 to March 2015). FY 2014 marked the fourth year of the third NIES five-year plan (FY 2011–2015). It was also the fourth year in which our institute has been engaged in Research on Disaster Environment, which was initially undertaken in the aftermath of the Great East Japan Earthquake. In March of FY 2012, we revised our five-year plan to formally include this research. In this, NIES Annual Report 2014, we will take the opportunity to report on the research being undertaken at NIES as part of this revised five-year plan.

Under the strategy outlined in the third NIES five-year plan, research is first undertaken in the eight pillar fields of environmental research at our institute – global environment; material cycles and waste management; environmental risk; regional environment; environmental biology and ecosystems; environmental health; social and environmental systems; and environmental measurement and analysis. This research across a wide spectrum, from basic to issue-driven research, is carried out by NIES in its capacity as a leading institute in the region.

The second aspect of our research strategy is the implementation of 10 research programs for those topics which we consider to require an urgent or priority response, or research which is issue-driven or requires the efficient deployment of research resources in order to be addressed.

The third aspect involves the maintenance of medium- to long-term initiatives in step with the sustainment and furtherance of environmental research. This includes maintaining the equipment and facilities needed for initiatives such as global environmental monitoring - including that by satellites - and those initiatives that use ground-based systems, commercial airlines, and shipping to monitor and analyze the global carbon cycle. Other examples of such initiatives include the maintenance of a GHG emissions inventory; the storage and provision of environmental specimens; the maintenance of reference laboratory functions; and the creation and updating of many kinds of environmental databases. Other important topics at NIES include the advancement of research using the NIES Supercomputer and administration of the Japan Environment and Children’s Study (JECS) – which is continuing in a satisfactory manner.

Research on Disaster Environment, undertaken in the aftermath of the Great East Japan Earthquake, comprises the fourth aspect of our strategy. This research is being implemented around four themes (1) Establishment of treatment and disposal technologies and systems for radioactively contaminated off-site wastes (2) Clarification of the environmental dynamics of radioactive substances, analysis of human exposure, and impact assessment for organisms and ecosystems (3) Promotion of surveys and research for renewal and environmental creation of the post-disaster regional environment, and (4) Promotion of surveys and research on the environmental change and associated impacts which accompany earthquake and tsunami disasters. Moreover, the Fukushima Project Office has been established at NIES and we are currently cooperating in the setting up of the planned Fukushima Prefecture Center for Environmental Creation (provisional name) through which we intend to increase our presence and on-the-ground

activities in the area.

Many people have an image of environmental research as being about “recovery from adverse situations”. However, the actual nature of current environmental research is to seek to create the best possible future, taking into account current circumstances and constraints. In fact, environmental research can be considered an indispensible part of creating a society in which humankind—in both Japan and the wider world—in the 21st century can be genuinely happy and comfortable. NIES is committed to rallying its collective resources to work toward this future to the full extent of its abilities.

We hope that this report will go some way to facilitating a greater understanding of our institute’s activities, and we invite your full and frank feedback and opinions about those activities.

SUMI, Akimasa
President
October 2015

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.

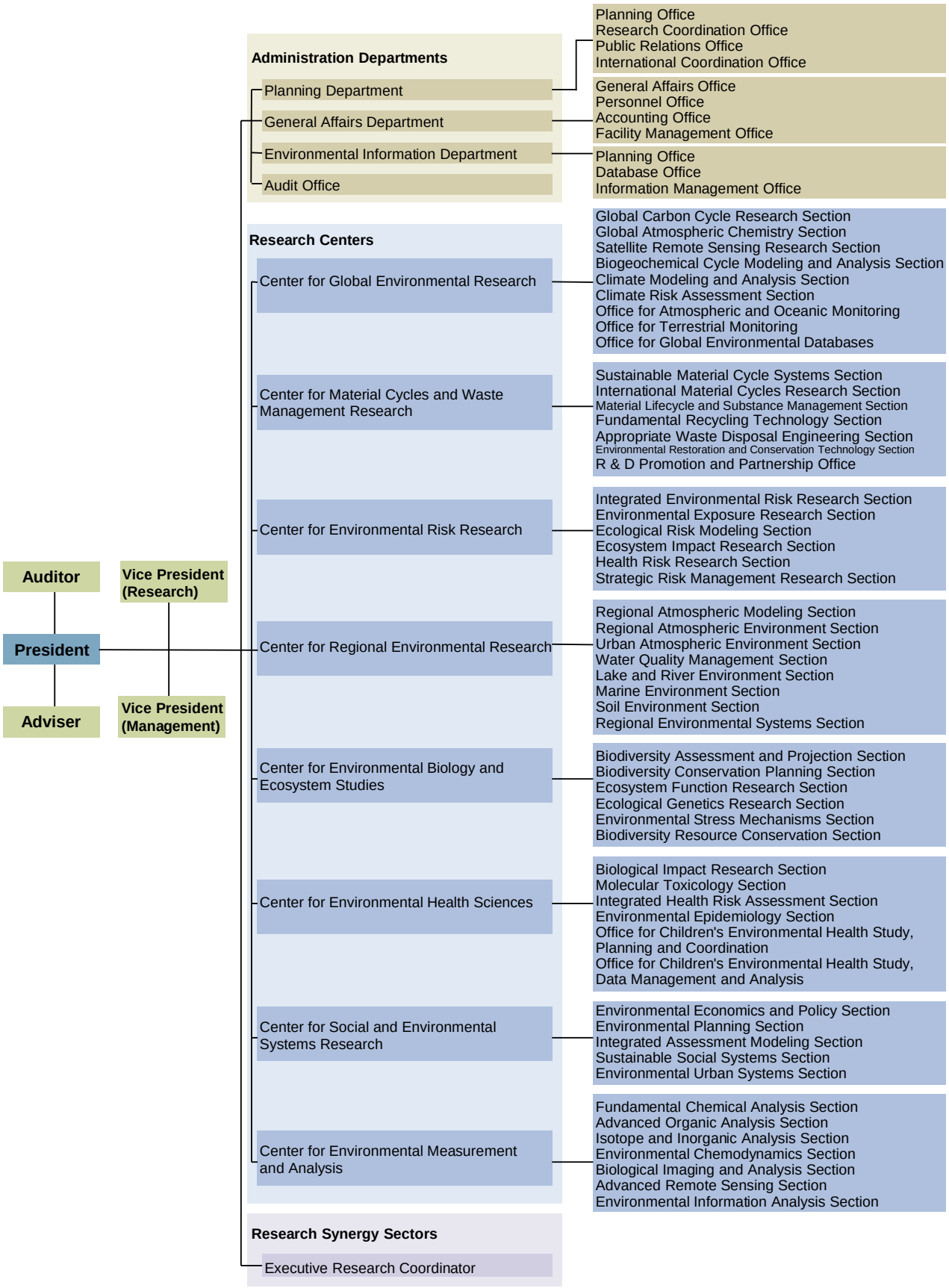
During the two decades following the establishment of NIES, rapid technological progress, structural changes in industry, and lifestyle changes, created additional issues for environmental science to confront. Moreover, global environmental problems such as climate change; depletion of the stratospheric ozone layer; acid deposition; destruction of tropical rain forests; and desertification, 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. Eight fundamental fields of environmental research are identified, and the research centers to be responsible for these areas are specified (Fig. 1). Research is carried out under our designated research programs and we also actively pursue ties with many institutions both in Japan and overseas.

Research activities to respond to and recover from the Great East Japan Earthquake have been ongoing since the direct aftermath of the disaster. Intermediate outcomes of this research have been summarized as "An Overview of Research on Disaster Environment" and are available from our homepage. In March 2013 the five-year plan was revised following a directive of the Minister of the Environment. Our mid-term objectives were modified to facilitate effective, integrated research on disasters and the environment.

Fig. 1 Organization



NIES is currently furthering preparations for the establishment of a branch in Fukushima Prefecture. As part of this initiative the following three research programs were also established: (1) Environmental Recovery Research Program (2) Environmental Renovation Research Program and (3) Environmental Emergency Management Research Program, in order to further contribute to recovery and environmental creation in Fukushima.

As of April 1, 2015, the NIES permanent staff number 274, and there are 554 non-permanent researchers (Table 1; Figs. 2 to 5). The total budget for FY2014 was 16,018 million yen (Table 2).

Table 1 Numbers of permanent staff

Administration Departments	58
Research≒Centers	211
Executive	5
Total	274

(As of April 1, 2015)

Table 2 Budget for the third five-year plan

(Unit: million yen)

	Category	2011–2015 Budget (5 years)	Fiscal Year 2014 Budget
Revenue	Grants for Operating Costs	68,519	12,051
	Subsidies for Facilities	1,540	330
	Commissioned Work	18,057	3,611
	Other	147	25
	Total	88,264	16,018
Expenditure	Project Costs	50,918	8,581
	Facility Improvements	1,540	330
	Expenses for Commissioned Work	18,057	3,611
	Personnel Expenses	15,516	3,050
	General Administrative Expenses	2,232	445
	Total	88,264	16,018

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

Administration Departments	:	58	
Research Centers	:	211	(6)
Executives	:	5	
Total		274	(6)

Notes:
1. Data is as of April 1, 2015.

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

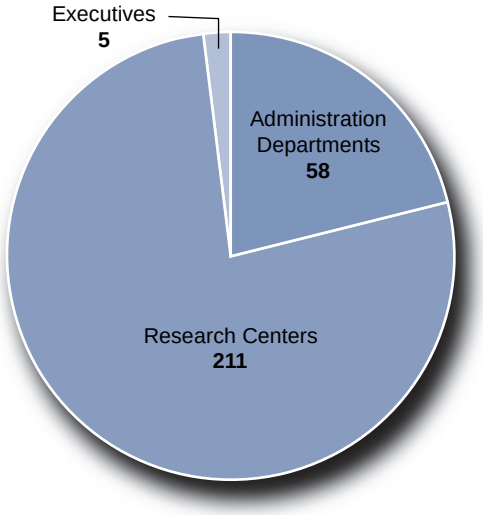


Fig. 2 Permanent staff breakdown

Basic Sciences (Physics, Chemistry, Biology)	:	79	38.54%
Engineering	:	68	33.17%
Agricultural Sciences	:	34	16.59%
Medical Sciences	:	11	5.37%
Pharmaceutical Sciences	:	5	2.44%
Fisheries Sciences	:	1	0.49%
Economics	:	2	0.98%
Sciences	:	3	1.46%
Law	:	1	0.49%
Veterinary Medicine	:	1	0.49%
Total		205	

Notes: Data is as of April 1,2015.

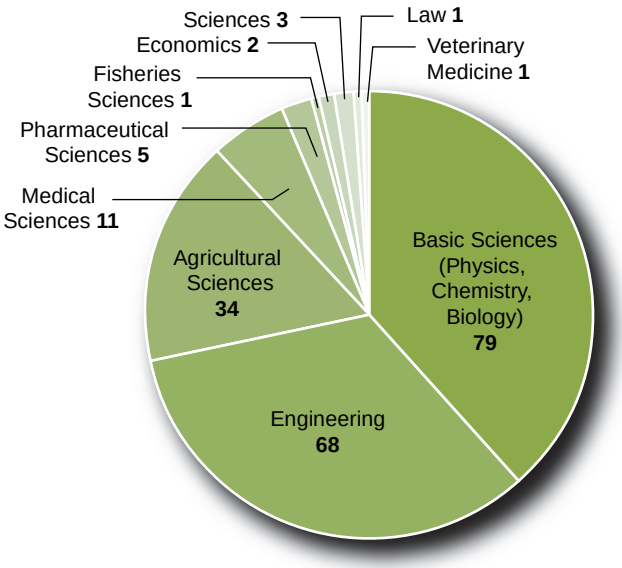


Fig. 3 Fields of expertise（Researchers holding doctorates（96.1%））

Fellow	:	18	
Research Associate	:	90	(21)
Junior Research Associate	:	14	(4)
Research Assistant	:	29	(5)
Specialist	:	198	(6)
Assistant Staff	:	261	(1)
Senior Staff	:	9	
Total		619	(37)

Notes:
1. Data is as of April 1,2015.

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

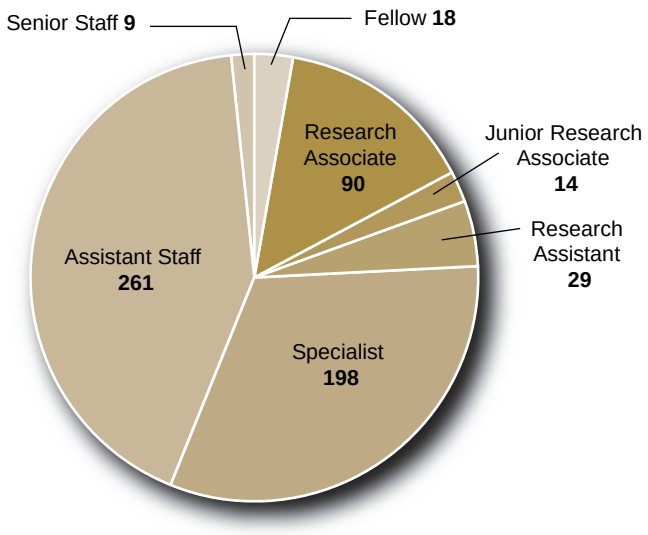


Fig. 4 Contract Staff Breakdown

Visiting Researchers	256	(9)
Research Students	58	(13)
Collaborative Researchers	89	(28)
Total	403	(50)

Notes:

1. Data is the total number accepted in FY2014.

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

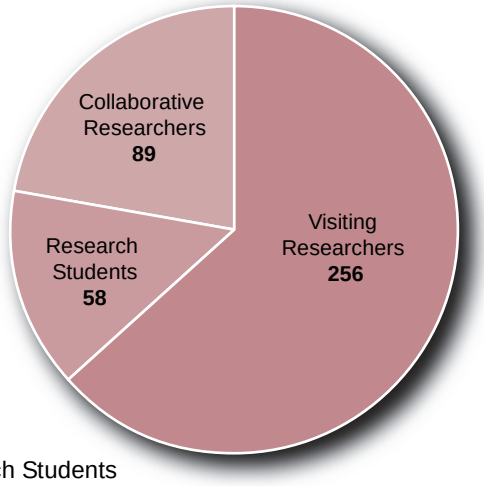


Fig.5 Visiting and Collaborative Researchers and Research Students

Center for Global Environmental Research

Ground-based GHG monitoring station established at Ochi-ishi in 1994.
There has been a 10% increase in ambient CO_2 concentrations observed at the station in the 20 years since it opened.

Outline of the Center for Global Environmental Research (CGER)

The global environment is the most basic and essential factor for the existence of human life. For instance, climate change, including global warming caused by increasing concentrations of anthropogenic greenhouse gases (GHGs) in the atmosphere, together with changes in the stratospheric ozone layer, has serious impacts on all ecosystems, and also on humans.

Considering the scale and seriousness of the predicted impacts, it is vital that we take measures to conserve the global environment towards the creation of sustainable societies. Because it takes a relatively long time for the environmental impacts of human activities to become manifest, it is essential that we adopt a long-term perspective and recognize the importance of mid- and long-term continuous research.

Therefore, on the basis of an accurate understanding of today's environmental conditions and their variations, CGER performs future projections and impact risk assessments of global environmental change. It also conducts research into measures to preserve the global environment. CGER implements climate change research with a special emphasis on observing and clarifying global variations in GHG concentrations in the atmosphere, in cooperation with other research centers at NIES. It also aims to elucidate historical climate change and predict future change, and performs global risk assessments and research on international adaptation and mitigation policies.

Furthermore, CGER conducts strategic environmental monitoring; develops and maintains environmental databases comprising data from the natural sciences as well as the social and economic sciences; and supports the promotion of global environmental research, both domestically and overseas. CGER also continues to monitor GHGs by satellite and to process, validate, and disseminate the data obtained. Along with the research activities mentioned above, CGER implements proactive and predictive research on the global environment, develops new technologies, and conducts pioneering and fundamental research.

Finally, CGER supports integrated and efficient collaborative research among domestic and international organizations; facilitates mutual understanding and the distribution of research results among researchers; and disseminates the various scientific findings to raise public awareness of global environmental problems.

Outline of the Climate Change Research Program

One of the key issues in climate change research is to clarify the mechanisms by which natural GHG sinks and emission sources vary and to improve the accuracy of predictions of changes in future sink strength. In the context of international climate policy, the development of global-scale strategies to manage the risks

posed by climate change and emissions has become a major issue. At the same time, it is acknowledged that, to achieve a low-carbon society, each country must reduce its GHG emissions. However, important issues such as policy options and international cooperation remain unresolved. An important objective of the Climate Change Research Program as part of the third NIES five-year plan is, therefore, to assemble and disseminate scientific knowledge with the aim of finding solutions to various climate change problems.

To this end, we are seeking to characterize the variations in GHG concentrations that are known to cause global warming. To do this, we are using comprehensive model analyses from integrated observations obtained from ground-based observation sites, ships, aircraft, and satellites. We are also seeking to provide the scientific knowledge needed to preserve natural GHG sinks.

Among the issues being debated towards social decision-making in risk management are climate change countermeasures and the pathways leading to the adoption of relevant management and countermeasures. To facilitate this decision-making process, we study not only the risks related to global warming (i.e. climate change) but also other global-scale risks such as water security and ecosystem conservation risks. We are also examining risk-management options and strategies in the context of public risk awareness.

Below, we present information on several of CGER's research activities in FY 2014.

Detection of CH_4 emitted by oil rigs in Southeast Asia

Measurements were taken during eight voyages between September 2009 and April 2012. Many CH_4 peaks were observed in the northern equatorial region along the Southeast Asian routes (Fig. 1). The locations at which these peaks occurred were concentrated in two areas: off the east coast of the Malay Peninsula (39 peaks) and off the northwest coast of Borneo (55 peaks). Although the durations of the observed CH_4 peaks were short (several minutes to 1 h), the increases in mole fraction of CH_4 were considerable (up to 1100 ppb above the baseline levels for the Southeast Asian region).

To identify sources of CH_4 emissions, we examined satellite-observed night-light data from the US Air Force Defense Meteorological Satellite Project Operational Linescan System (DMSP/OLS). Most of the oil platforms are located either off the east coast of the Malay Peninsula or off the northwest coast of Borneo and are near the locations of the CH_4 peaks along the Southeast Asian trade routes (Fig. 2). Generally, CH_4 is a dominant component of emissions from offshore oil platforms and is released as a result of gas flaring and venting, equipment leaks, and evaporation losses; concomitant emissions of carbon dioxide (CO_2) occur, mainly in gas flares. The DMSP/OLS results suggest that the observed methane (Fig.: CH_4) peaks represent

emissions from offshore production platforms.

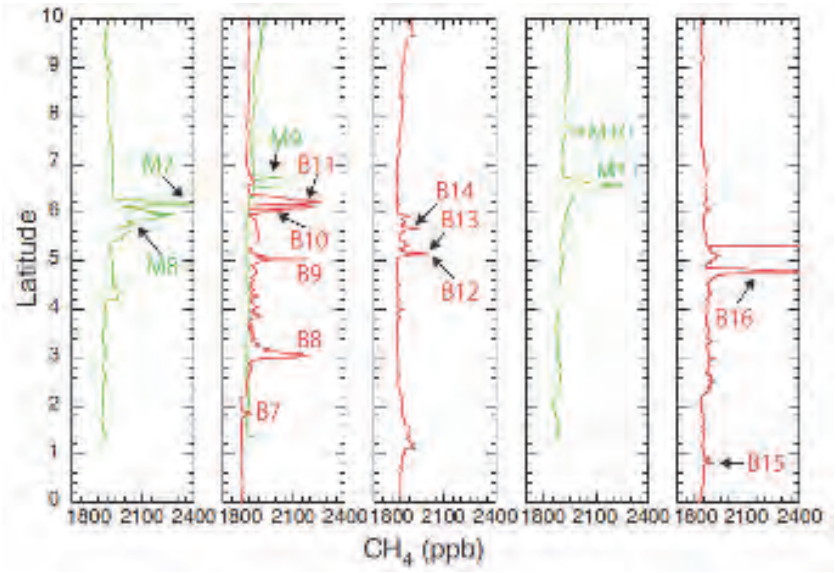


Fig. 1 Latitudinal distribution of 1-min temporally averaged CH_4 mole fractions between latitude 10°N and the equator, as observed during eight voyages along the Southeast Asian shipping routes between September 2009 and April 2012. Numbers are assigned only to the Malay (M) and Borneo (B) peaks that showed substantial CH_4 increases (>50 ppb) and a positive correlation between CH_4 and CO_2 levels.

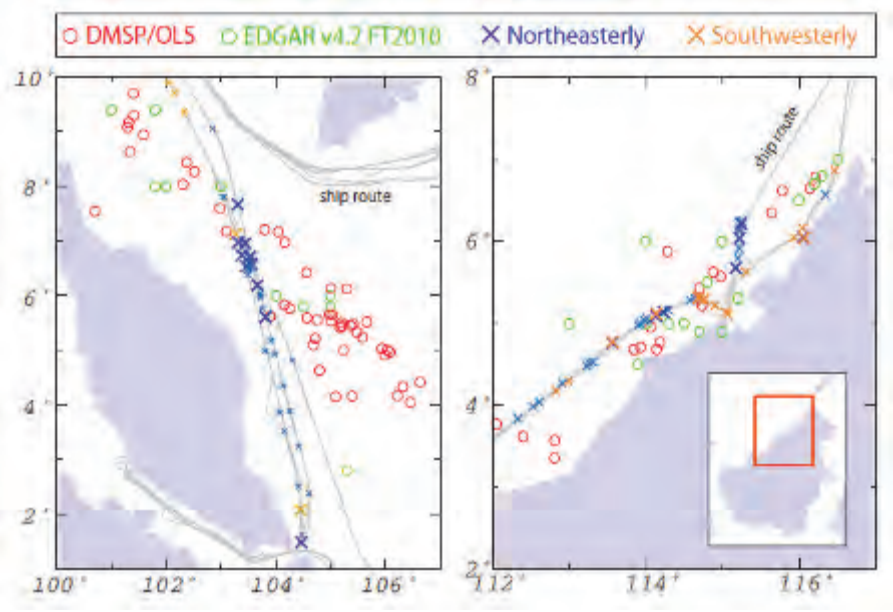


Fig. 2 Distributions of observed CH_4 peaks and oil platforms off the east coast of the Malay Peninsula (left) and the northwest coast of Borneo (right). Crosses indicate locations where CH_4 peaks were observed; different colors indicate different wind directions at the times when the CH_4 peaks were observed (blue: northeasterly wind; orange: southwesterly wind). Circles are locations of offshore oil platforms in 2010, identified from DMSP/OLS data (red circles) and as reported in the EDGAR ver. 4.2 FT2010 database (green circles). Gray solid lines mark shipping routes.

Top-down and bottom-up modeling of the terrestrial ecosystems of Asia

To estimate GHG sources and sinks with high accuracy, we developed and improved technologies for top-down approaches based on atmospheric observations and inverse models and for bottom-up approaches based on ground observations and process models for upscaling. For top-down approaches, inverse models were improved for better evaluation of the spatial and temporal distributions of surface fluxes, particularly in Siberia, Southeast Asia, China, and Japan. For bottom-up approaches, the accuracy and reliability of upscaled estimates were tested by using different types of process models. The top-down estimation from GOSAT (Greenhouse gases Observing SATellite) agreed with the results of a bottom-up model SVR (support vector regression) method over the

high-latitude areas tested, although there was a large difference between the two sets of results in tropical areas (Fig. 3).

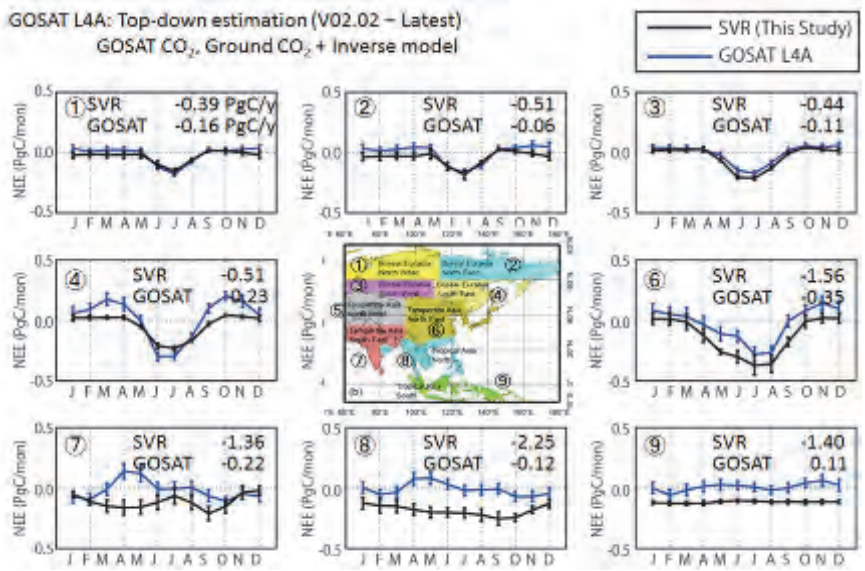


Fig. 3 Comparison of a top-down approach (GOSAT L4A, ver. 2.02, from June to September 2011) and a bottom-up approach (empirical upscaling based on support vector regression [SVR] using enhanced observed data for Asia) to spatial and temporal variations in the net exchange of CO_2 between land and the atmosphere. NEE, net ecosystem exchange.

Assessment of impact of climate change on past climate event

To determine whether human activity changed the probability of a past climate event—namely the 2010 drought in the South Amazon region—we conducted ensemble simulations by using the MIROC5 atmospheric general circulation model. The simulations were performed for realistic conditions (i.e., under both natural and anthropogenic forcing) and for counterfactual worlds without anthropogenic forcing (mainly GHGs and aerosols). The simulation results suggested that both human influences and the natural variability of sea surface temperatures increased the probability of the 2010 severe drought in the South Amazon region; they also suggested that changes in aerosol emissions had little effect on the drought (Fig. 4). It should be noted, however, that our assessments were sensitive to the bias corrections applied to the simulated precipitation; these corrections were based on the observed relationships between the natural variability of the sea surface temperature and precipitation.

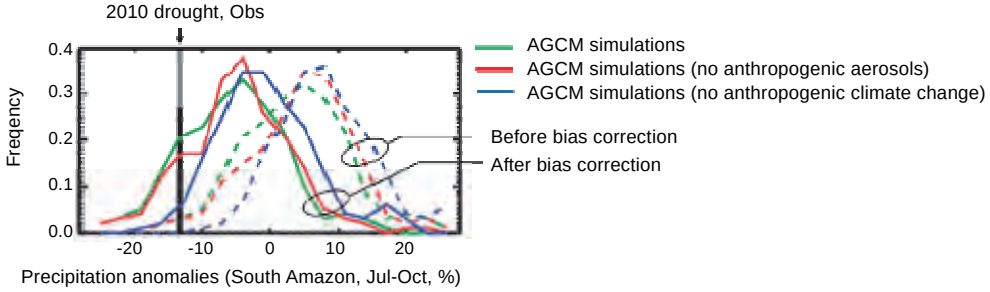


Fig. 4 Probability density functions of the precipitation anomalies simulated by the MIROC5 atmospheric general circulation model (AGCM) (South Amazon, July–October 2010). Adapted from Shiogama et al. (2013).

Comprehensive climate policy assessment and development of visions and scenarios toward a low-carbon society

Our aim in this project is to provide scientific knowledge from the perspectives of modeling and analysis, scenario development, and negotiation processes, in order to achieve a low-carbon society at the local, national, regional, and global levels. To achieve this aim, the project consists of three sub-themes: (1) scenarios and implementation strategies for a low-carbon society (LCS) in Asia; (2) quantitative assessment of climate change mitigation policies in Japan and the world; and (3) the study of international institutions and negotiation processes for developing LCS. The following are the main results obtained in 2014 in each sub-theme.

In sub-theme 1, we have continued to develop LCS scenarios and roadmaps at country-level and city-level scales in Asia. Iskandar Malaysia is one of the leading regions that have adopted our LCS study: a roadmap, including a timeline of various countermeasures and five local authorities' scenarios, was developed in 2014. Eighty primary schools joined the Iskandar Malaysia Ecolife Challenge program. We also started a new research collaboration with a local authority and research institute in Ho Chi Minh City (HCMC). An HCMC LCS scenario was developed by using AIM (Asia-Pacific Integrated Model) methodology; it identified the potential for introducing a JCM (Joint Crediting Mechanism) project (Fig. 5). Our AIM training sessions (teaching the AIM/Enduse and AIM/CGE [computer general equilibrium] models), especially to younger researchers, have continued. We introduced an energy/CO_2 emissions reporting system to the city of Putrajaya in Malaysia; this system is implemented by the Tokyo Metropolitan Government to encourage energy-efficiency improvement in the building sector. The results were introduced at a side event at the UNFCCC's COP (Conference of the Parties) 20 in Lima.

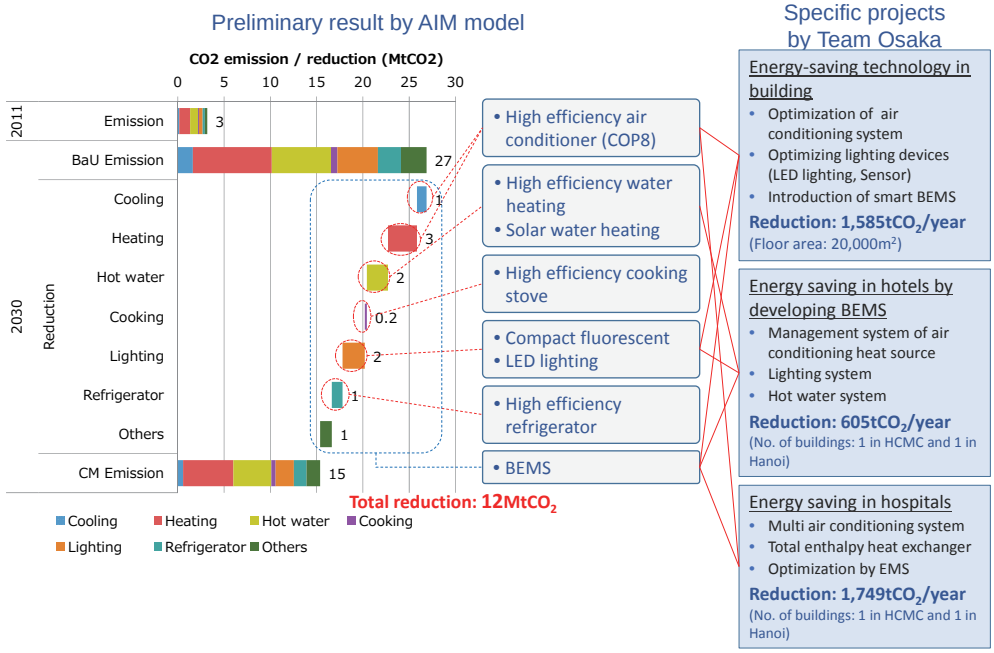


Fig. 5 Assessment of CO_2 emission reduction potential in the commercial sector of Ho Chi Minh City (HCMC) in 2020 by using an AIM model, and comparison with specific JCM projects run by Team Osaka

In sub-theme 2, we focused on short-lived climate pollutants (SLCPs) and air pollutants (APs) as well as long-lived GHGs; we used AIM/Enduse[Global] to analyze the co-benefits of reducing SLCPs and APs as part of GHG mitigation actions. Figure 6 shows the main results. SLCP and AP emissions in 2050 in the reference scenario will increase largely in non-Annex I countries, compared with 2005 levels, if additional air pollutant control policies are not adopted. Notably, the contributions of Asian non-Annex I countries to emissions of SO_2, NO_x, BC (black carbon), and particulate matter in 2050 would be relatively large at 76%, 55%, 69%, and 76% respectively. To achieve the 2 °C global temperature change limit target, a high carbon tax of around US$400/t CO_2 equivalent in 2050 will be required. However, emissions of SLCPs and APs will be markedly reduced as a co-benefit of mitigation measures such as energy-efficiency improvement and a drastic energy shift from high to low (or non-) carbon-intensive energies.

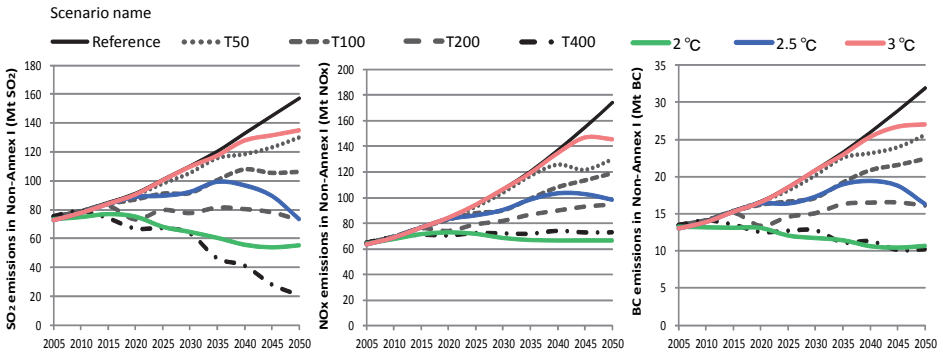


Fig. 6 Comparison of air-pollutant emission pathways in non-Annex I countries

Notes:

T400: Carbon tax will be imposed from 2013 to 2050, linearly increasing to reach US$400/t CO_2 in 2050.

2 °C: GHG emissions will follow the median global pathway in the range of emissions pathways, with a "likely" probability (≥ 66%) of staying below 2 °C.

In sub-theme 3, we conducted an expert dialogue workshop in January 2015 attended by Japanese negotiators, researchers, and environmental NGOs to collect their views. In addition, informal interview surveys were conducted online to gather the thoughts of experts outside Japan. The Japanese negotiators perceived the last COP20 meeting to be a success, because they were able to avoid categorizing the agreed-upon documents by using the terms “Annex I” and “non-Annex I.” The NGOs indicated that although the categorization was outdated, that did not mean that the principle of Common But Differentiated Responsibility and Respective Capabilities (CBDR/RC) could be done away with; other ways of respecting the principle are needed to reflect the concerns of developing countries. Many respondents expected that some kind of an agreement would be reached at COP21, but that the core agreement might not be called a protocol; rather, it might be considered a COP decision that is ensured by a political agreement to be “legally binding.”

Long-term monitoring of GHGs and other trace gases

Atmospheric GHGs (e.g. CO_2, CH_4, and N_2O) and other chemical species (CO, NO_x, and SO_x) are monitored from various platforms to determine the long-term variations in the concentrations of these gases and their spatial distributions. We have two ground-based stations, at Hateruma Island (over 1000 km southwest of the Japanese mainland) and at Cape Ochi-ishi (in northeastern Hokkaido). Commercial ships operating between Japan and Australia, New Zealand, North America, and Asian countries are used to observe the latitudinal or longitudinal distributions of GHGs (Fig. 7) and the partial pressures of CO_2 in the surface waters of the Pacific. Routine samplings are conducted from aircraft over three sites in Siberia to measure the vertical distributions of GHGs.

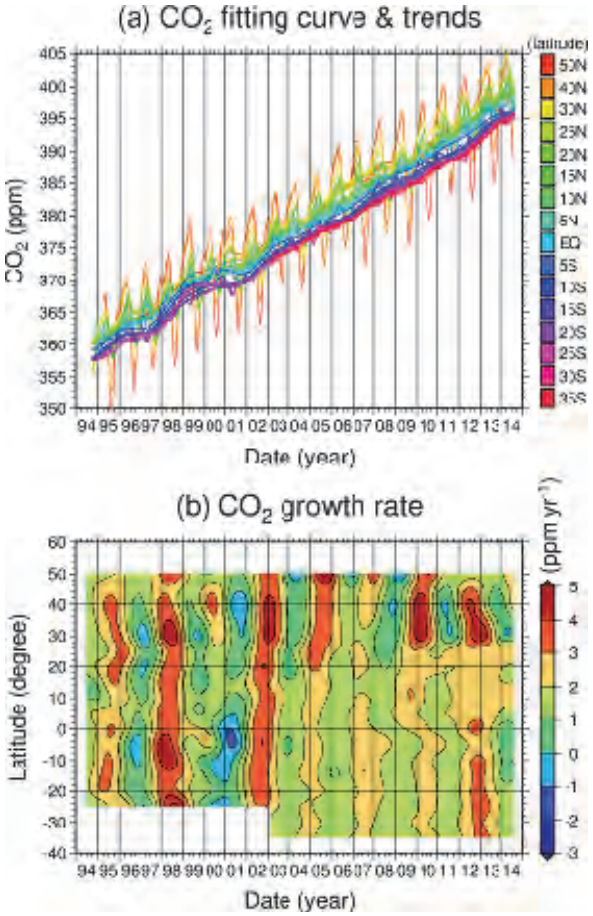


Fig. 7 (a) Time series of best-fit curves (thin lines) and long-term trends (thick lines) of observed CO_2 mixing ratios (50°N to 35°S); (b) time–latitude cross-sections of CO_2 growth rates

Ocean-surface CO_2 sinks and sources are important components of the ocean carbon cycle, including physical and biological processes. NIES also contributed to a data analysis using a NIES dataset to estimate the temporal and spatial variability of ocean surface monthly pCO_2 from 2002 to 2008 in the North Pacific by using a self-organizing map (SOM). We found that the SOM was useful for examining non-linear relationships between the observed pCO_2 and the ocean parameters of SST, sea surface salinity, mixed-layer depth, and chlorophyll-a concentration. The reconstructed pCO_2 values agreed well with the pCO_2 measurements, with the root-mean-square error ranging from 17.6 µatm for the NIES dataset used in the SOM to 20.2 µatm for an independent SOCAT dataset excluding the NIES dataset.

Carbon dioxide flux monitoring of terrestrial ecosystems

Long-term monitoring of carbon, water, and energy exchange between larch forests and the atmosphere, as well as of biological processes in these forests, has been conducted by our center to determine how the forests respond to climate change and how the responses depend on the process of recovery from natural and artificial disturbances. The Fuji Hokuroku Flux Observation Site is located in a mature larch forest at the foot of Mt. Fuji. Clear seasonal changes in carbon uptake were observed here and were related to the phenology of the larch trees.

The Teshio CC-LaG experimental site is an artificial larch forest planted after clear-cutting of a mixed forest in the Teshio Experimental Forest of Hokkaido University, northern Hokkaido, Japan. The aim of the research at this site is to determine the effects of forest management (clear-cutting, reforestation, and subsequent recovery) on the carbon balance of a larch forest in a cool, temperate region. We have been monitoring carbon flux at the site since 2001. Before clear-cutting, the forest was a naturally regenerated, mature, mixed forest in the late successional stage (~200 years old). In 2003, the trees at the site were clear-cut; 55% of the logs were removed, and the residual biomass was left in the forest. We observed an abrupt drop in the rate of carbon absorption soon after clear-cutting, followed by its recovery with the growth of trees (Fig. 8).

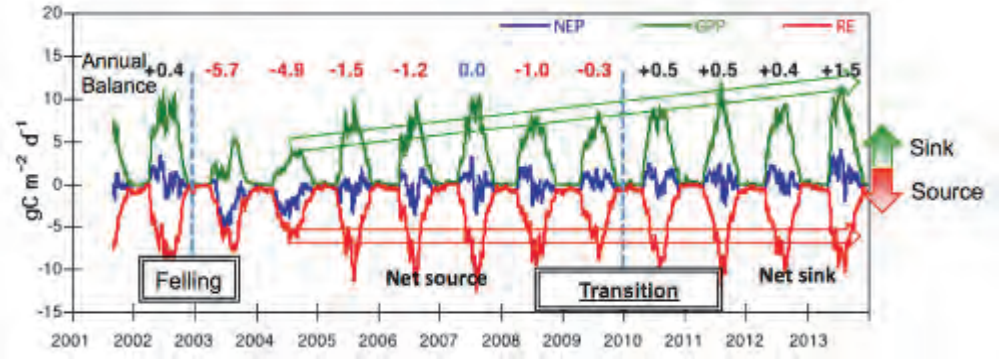


Fig. 8 Year-to-year variations in NEP, GPP, and RE observed at the Teshio CC-LaG experimental site. NEP, net ecosystem production; GPP, gross primary production; RE, ecosystem respiration

Monitoring the impact of global warming on corals around Japan

The presence of some tropical and subtropical organisms is limited to certain latitudes. In Japan, coral is found only as far north as Niigata Prefecture on the coast of the Sea of Japan and Chiba Prefecture on the coast of the Pacific Ocean. Over the past 100 years, the SST of coastal waters around Japan has risen by approximately 1 °C (Fig. 9). Historical records since the 1930s reveal that corals have undergone a rapid poleward range expansion in response to rising SSTs. Because corals serve as primary producers and have a three-dimensional structure that provides habitats for other organisms, coral communities need to be monitored long-term to assess the current and future impacts of climate change on coastal ecosystems. So far, we have done the following studies: (1) investigation of coral communities at different latitudes to determine which species exist in warmer climates (i.e. index species); (2) comparison of historical records of coral distribution with the current distribution to ascertain the northward movement of coral communities; and (3) genetic analysis to clarify the genotypes of zooxanthellae living in the index corals. On the basis of the results of these studies, we have been conducting long-term monitoring at eight sites around Japan since 2011, in cooperation with other research projects such as the Monitoring Sites 1000 project of the Ministry of the Environment of Japan. The monitoring results provide baselines for coastal ecosystems and can be used to project the future status of coral reefs.

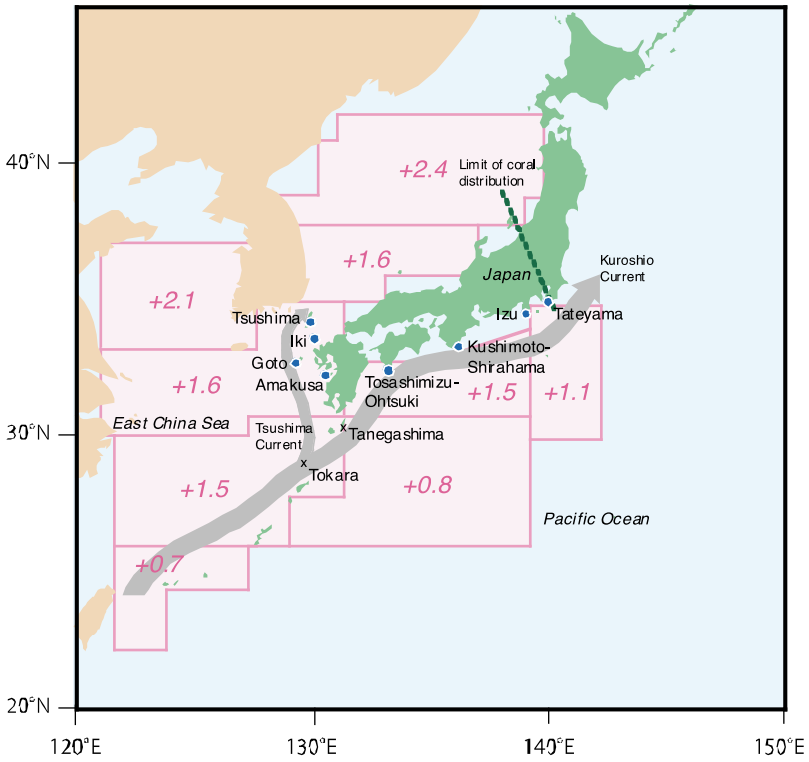


Fig. 9 Locations of monitoring sites (dots) and sea surface temperature rises over the past 100 years (http://www.data.jma.go.jp/kaiyou/shindan/)

NIES GOSAT project

The GOSAT, (nickname: "IBUKI") is the world's first satellite designed specifically to monitor GHGs from space. Since its launch on January 23, 2009, the satellite has continued to fulfill its main mission of monitoring atmospheric CO_2 and CH_4 concentrations from space to improve the accuracy of sink/source estimates. GOSAT carries two sensors: the Thermal And Near-infrared Sensor for carbon Observation – Fourier Transform Spectrometer (TANSO-FTS) and the TANSO-Cloud and Aerosol Imager (TANSO-CAI).

In 2014, CO_2 concentrations in megacities and their surroundings were analyzed for the 3.5 years from June 2009 to December 2012 by using observational data acquired by IBUKI. The results revealed a trend toward higher CO_2 concentrations in megacities than in their surroundings (Fig. 10). Furthermore, there were positive correlations between the differences in CO_2 concentrations and the concentrations estimated from data on fossil fuel consumption. IBUKI observations therefore have the potential to enable us to detect enhanced CO_2 concentrations that originate from fossil fuel consumption by megacities. These studies demonstrate the potential utility of satellite observation of CO_2 concentrations as an inventory tool for monitoring GHG emissions from fossil fuels. With progress in the monitoring of large CO_2 point sources by satellite observation and other methods, these results will be applied to current and forthcoming research projects involving IBUKI and its successor (GOSAT-2), which is to be launched in 2018.

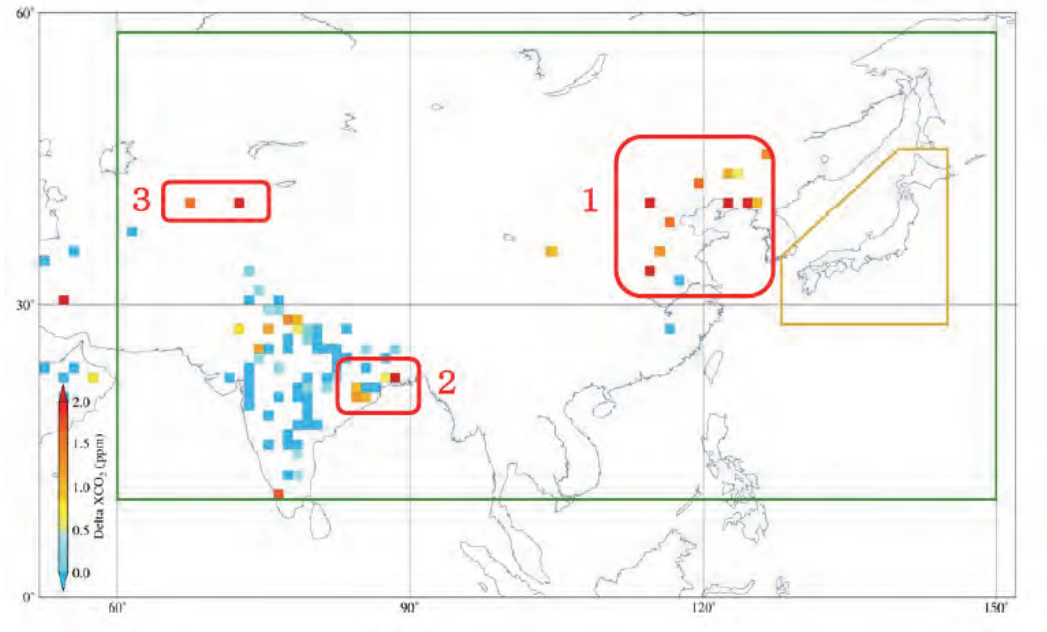


Fig. 10 Distribution of large value sites of anthropogenic CO_2 concentrations estimated from observational data acquired by IBUKI. Concentrations are shown by colors. Red rectangles show the areas of high concentrations of anthropogenic CO_2 emissions derived from "IBUKI", No.1: China (Zhangjiakou, Anshan, Harbin, and Tianjin), No.2: India (Kolkata), No.3: Eastern part of Uzbekistan, Southern edge of Kazakhstan, Eastern area of Kyrgyzstan, and Northern edge of Tajikistan.

NIES GOSAT-2 Project

Various algorithms for GOSAT-2 data processing are currently being developed in collaboration between Japan Aerospace Exploration Agency (JAXA) and GOSAT-2 Science Team members. Design of the GOSAT-2 Data Processing System (G2DPS) started in FY 2014 and will be finished in mid-FY 2016. Preparation of the computing facilities for G2DPS is ongoing. Most of G2DPS and its computing facilities will be ready for routine operation by the time of the GOSAT-2 launch.

The validation of GOSAT-2 data will be similar to that for GOSAT data. To mitigate the lack of ground observation data for validation, a new site with a high-resolution Fourier Transform Spectrometer will be established in the Asian region as a part of the project.

Applied research using GOSAT-2 data includes the following ongoing studies:
1) Improvement of terrestrial ecosystem models by using GOSAT-2 data
2) Development of a high-resolution fire emission inventory for tropical regions and comparison of global fire emission inventories
3) Development of a quasi-real-time data processing system using GOSAT CAI data for monitoring urban air pollution.

For more information, mail: gosat-2-info@nies.go.jp.

Ozone layer research project

This project focuses on research into changes in the ozone layer and their effect on climate. Our goal is to reduce the uncertainties in predicting depletion or recovery of the ozone layer and predicting the extent of associated global warming. To achieve our research objectives, we developed chemistry–climate models (CCMs) and chemical transport models (CTMs) by using satellite and ground-based data for ozone. We applied our models to the severe ozone depletion event in the Arctic of 2011. Our models suggest that the Arctic ozone layer is influenced not only by the chlorine budget in the stratosphere but also by ozone transport, both of which are associated with atmospheric dynamics, which show considerable yearly variations. We also simulated and analyzed ozone concentration changes globally, taking into account the influences of ozone-depleting substances and GHGs on ozone amounts.

Topics from this project include simulation and analysis of a low total ozone event at the southern tip of South America. Figure 11 shows the variations in total ozone contents at Rio Gallegos, Argentina (51.6°S, 61.2°W), in November 2009, as measured by an Ozone Monitoring Instrument and simulated by our CTM. At Rio Gallegos, where our counterpart in this international project observes the ozone profile by lidar, the amount of total ozone was unusually low for as long as three weeks. The model simulates this variation to a high degree of accuracy. The observational data and model output indicate that the low total ozone event was caused not by chemical ozone destruction at this site but rather by advection of a low-ozone air mass from the ozone-hole region owing to the presence of an unusual atmospheric dynamical field.

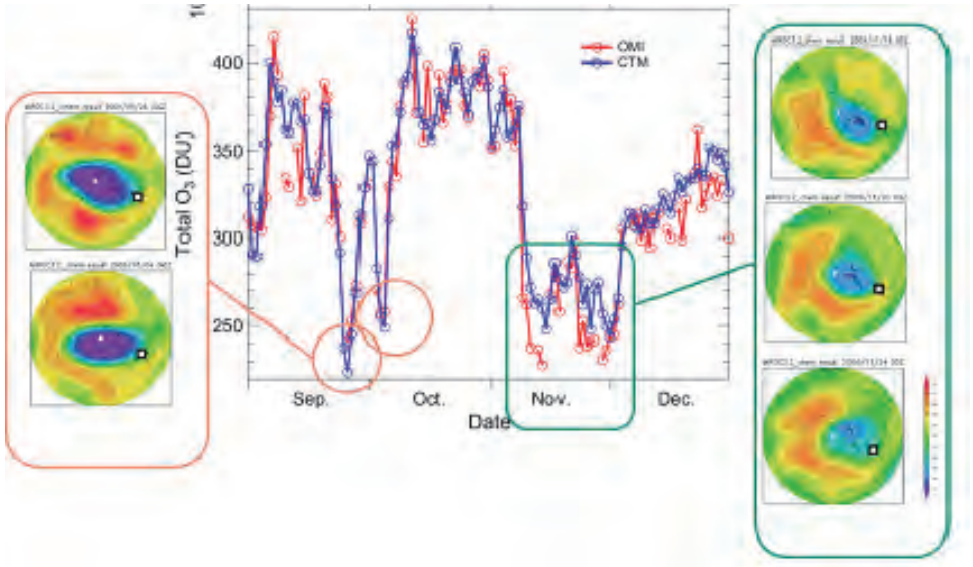


Fig. 11 Time series of observed (red line and circles) and simulated (blue line and circles) total ozone levels at Rio Gallegos, Argentina, in 2009. Total ozone maps for the low-ozone events are also shown, with small squares indicating the location of Rio Gallegos. The light blue, blue, and violet on the maps indicate low total ozone (<210 DU [Dobson units]).

Center for Material Cycles and Waste Management Research

Construction of landfill test cells at Laem Chabang, Thailand. The semi-aerobic landfill system is a promising technology for reducing the release of greenhouse gases and water pollutants from landfills. We have tested the performance of this system in a tropical climate at this site.

Since its foundation in 2001, the Center for Material Cycles and Waste Management Research has aimed to realize a society with optimal material cycles—that is, reduced use of natural resources; reduced generation of waste; increased recycling of materials; and appropriate waste management. In accordance with the third NIES five-year plan (covering the period 2011–2015), the center is playing a major role in promoting a research program on "Sustainable Material Cycles," which comprises three research projects. It is also conducting necessary research on material cycles and waste management in response to national policies and promoting fundamental research.

1. Sustainable Material Cycles Program

We engage with environmental issues on three fronts: international environmental issues that affect Japan and extend throughout the rest of Asia; issues affecting developing countries in Asia; and domestic issues. Our initiatives are related to the scientific and technical aspects of the efficient use and appropriate management of resources and waste. On this basis, we intend to actively support sustainable material societies—both in Japan and overseas—that reconcile climate change policy and implementation strategies.

1.1 Appropriate management of materials with hazard and resource potential in harmony with international material cycles (Research Project 1)

Global mining risk footprint of metals critical for low-carbon technologies in Japan

The life-cycle of a metal resource begins with mining and proceeds through the phases of processing, production, recycling, and then disposal. Today, however, there are virtually no instances in which this entire series of processes occurs within the borders of a single country. In the global supply chains that have been formed through international trade, metal resources move around the world as they go through the various phases of their life-cycles. Because many metals are mined in a limited number of countries and numerous other nations are manifesting a growing demand for products that use these metals, understanding the relationship between use of these resources and the global supply chains that begin with the mining process is becoming increasingly important.

One material index for quantitatively understanding the resources used in the economy of a single country via these kinds of global supply chains is the index known as the material footprint (MF) of a nation that shows direct and indirect consumption of resource. Exotic or rare metals are often recognized as "critical metals", namely those that are essential for future technologies but to which access is limited because they are mined in only a few countries. Discussions are ongoing in the industrial ecology field regarding the economic importance of these metals and the risks they pose from a resource-supply perspective. No consideration of the supply risks of critical metals from an MF perspective has

yet been reported in the literature. Our goal was therefore to measure the MFs of critical metals and to use the results to develop a methodology for evaluating the risks associated with their mining. In this case, we express the MF as a quantity of metal. In our empirical analysis, we identify the Japanese MF of each metal, which is well known globally for its dependence on resource imports. We then develop a footprint index that incorporates the political risks in the mining countries into the identified MF, with implications for the influence of government policies and actions on metals availability. We refer to this political risk associated with mining countries simply as the "mining risk," and we call our footprint index the "mining risk footprint" (MRF). We have so far performed a case study to quantify Japan's MRF with respect to three critical metals (Nd, Co, and Pt).

Field study of product and material cycles for managing resources and chemical risks

In January of 2011, 2012, and 2013, we collected surface soil and river sediment samples in and around a village that had held e-waste recycling workshops. Recycling methods, including open storage of e-waste; dismantling and crushing of electronic products; hand-sorting of recyclable materials; and manual removal of coatings from Cu wire, had been used during the workshop and in the surrounding area. Furthermore, e-waste had been openly burned on paths between the paddy fields around the village. We analyzed not only the chemicals potentially present in the e-waste, but also unintentionally present hazardous chemicals associated with the e-waste and its recycling, such as dioxin-related compounds (DRCs), in order to clarify the status of contamination by these chemicals and the sources from which their diffusion occurred. Open storage and burning of e-waste are especially important factors contributing to the emission of hazardous substances, including brominated flame retardants (FRs) such as PBDEs (polybrominated diphenylethers), phosphorus-containing FRs such as TPhP (triphenyl phosphate), heavy metals such as Pb and Cu, and DRCs derived from e-waste. Our results suggested that, although chemicals derived from e-waste may have had a low potential for pollution through diffusion at this site, e-waste recycling was one of their biggest sources. For commercial e-waste recycling operations, restrictions on the open storage and burning of e-waste might mitigate the associated environmental and human health risks.

Proposal of management measures toward an international sound material- cycle society

End-of-life (EoL) consumer durables such as e-waste and ELVs (end-of-life vehicles) have been an emerging issue in recent years. Accurate estimates of the future generation of EoL goods are needed as a basis for planning an appropriate scheme for managing these products in the Asian region. We therefore developed multiple linear regression models for a number of in-use products by applying various socioeconomic indicators as explanatory variables. Our multiple

regression models were good predictors of the number of in-use products for the target items (Fig. 1).

We also collected and reviewed information on e-waste recycling facilities in eight Asian countries. We found that Asian countries other than Japan and China had very few non-ferrous-metal smelting facilities that accepted scrap. A degree of transboundary transport of e-waste will thus continue to be necessitated in the Asian region, where more and more e-waste generation is expected in the near future.

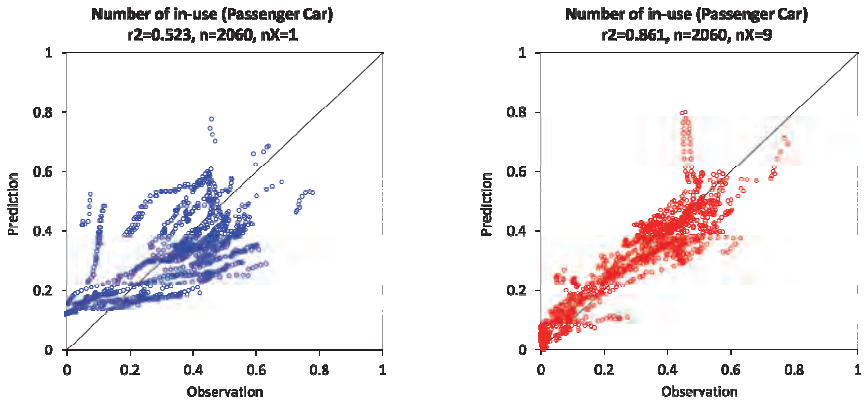


Fig. 1 Results of a regression analysis of the number of in-use passenger cars (left: simple regression using gross domestic product per capita; right: multiple regression)

1.2 Establishment of appropriate technological systems for municipal waste in Asia (Research Project 2)

Development of semi-aerobic landfill technologies appropriate for Asia

The model developed in this project for estimating greenhouse gas (GHG) emissions from solid waste disposal sites was revised to match emission behaviors from sanitary landfills and semi-aerobic landfills in Thailand. Application software that evaluates the environmental impacts of waste disposal, including leachate management, was developed and released. A pilot-scale experiment on a wetland constructed for leachate treatment at a landfill in Thailand revealed that subsurface flow with frequent input of leachate effectively reduced leachate volumes through evapotranspiration and stable removal of organic materials and nitrous compounds. We also evaluated the feasibility of mechanical-biological treatment (MBT) of solid waste in Tropical Asia by using a cost-benefit approach. Land availability, acceptance of refuse-derived fuel, and reduction of process residues were found to be essential for successful implementation of MBT.

Development of on-site wastewater treatment technologies for developing nations

Parallel experiments using three types of reactor—a newly developed anaerobic reactor with siphon-driven agitation, an unmixed conventional reactor, and a continuously mixed conventional reactor—revealed that the newly developed reactor achieved successful operation under a higher organic loading rate and also

improved solids dispersion. We tested the anaerobic digestibility of nine species of harvested aquatic plants used for water purification; of these, *Egeria densa* had the highest digestibility. A kinetic model of organic matter degradation versus retention time based on a continuous anaerobic digestion experiment using *E. densa* indicated that hydrolysis was the limiting step and a long retention time was required for sufficient degradation.

Development of tools for planning waste management systems

Historical data compilation of municipal solid waste (MSW) generation per capita, a core indicator of environmental pressure to evaluate the intensity of MSW generation, can contribute to better MSW management planning. In spite of the usefulness of this measure, international comparability is not fully assured because of unreliable data on MSW generation per capita, especially in developing countries. MSW generation per capita in countries with a per capita GDP of less than US$20,000 fluctuated more widely than those with a higher per capita GDP (Fig. 2). We note the current challenges in estimating MSW generation per capita in developing countries, including a lack of equipment (e.g., weighbridges), lower efficiencies of MSW collection, and rural–urban migration, all of which may have negative effects on data reliability. Incomplete data compilation systems at the national level also result in lower reliability and reduce the comparability of national data.

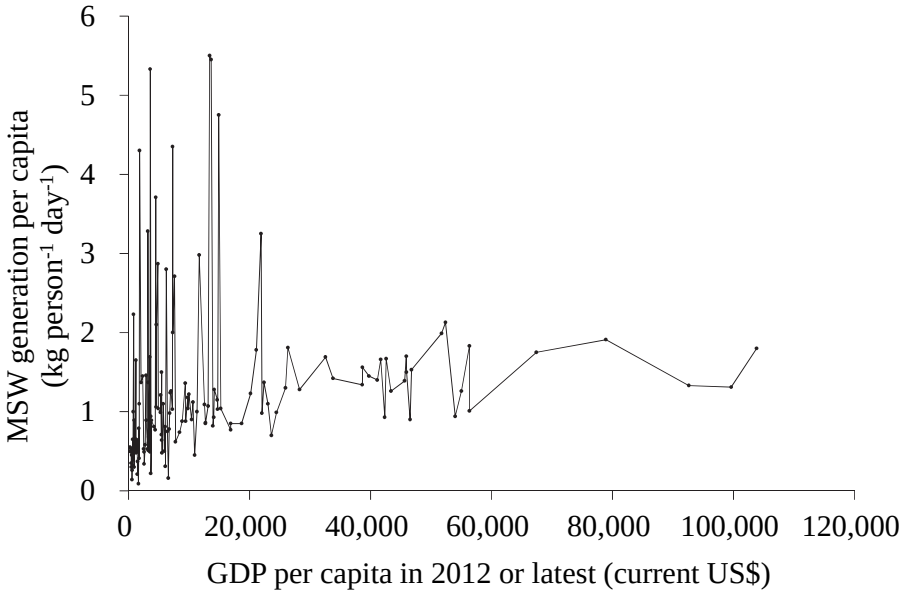


Fig. 2 Municipal solid waste (MSW) generation and gross domestic product (GDP) (both per capita) of 156 countries

1.3 Establishment of material cycle systems by utilizing regional characteristics (Research Project 3)

Proper material cycle systems on various geographical scales need to be established for a sound material cycle society. This project aims to contribute to regional communities by designing regional systems. It also aims to contribute to the science of material cycles by establishing methodologies for estimating

appropriate geological scales for such cycles and formulating concepts of regional and local material cycles. In the fourth year of the project, we continued to create solution libraries for regional recycling systems and systems analysis of local material cycle systems under the scenario of population decrease and an aging society. We also conducted a historical analysis of several cases of local material cycles to deepen our understanding on how actual systems were developed and to identify important elements.

Designing a framework for constructing regionally appropriate material cycle systems

To gain an understanding of the structure of regional issues and to compile a list of potential solutions to these issues in establishing a regional recycling system, we additionally surveyed five cases of regional recycling and compiled the information into a structured issue and solution library, as we had done the previous year. In total, about 640 data from seven cases, including last year's, were collected and compiled. This information library will be publicized as a part of our guidelines for establishing a regional material cycle system.

Design, assessment, and implementation of regionally appropriate material cycle systems

We analyzed the history of the seven cases associated with the establishment of a local material cycle society in Japan. The 10 strategy schools put forward by Mintzberg et al. (2009), "*Strategy Safari*", were used for the analysis, with a modification by which we summarized up to four strategic aspects: rational, practical, negotiatory, and institutional. A sample result is shown in Figure 3. In this case, the full-time appointment of a government officer assigned only to a specific task associated with local circular society was one of the dominant elements enabling successful management in the long term. An understanding of social power and the capacities of major, influential actors in the region were other important elements. Subsequently, we identified the key actions in local strategic management by evaluating the importance of individual strategic elements—for example, setting and sharing goals, single-loop and double-loop learning, and enhancing stakeholder awareness. Fifteen categories of key actions were identified and listed. Each category was summarized in terms of its features, applicability, and potential concrete actions.

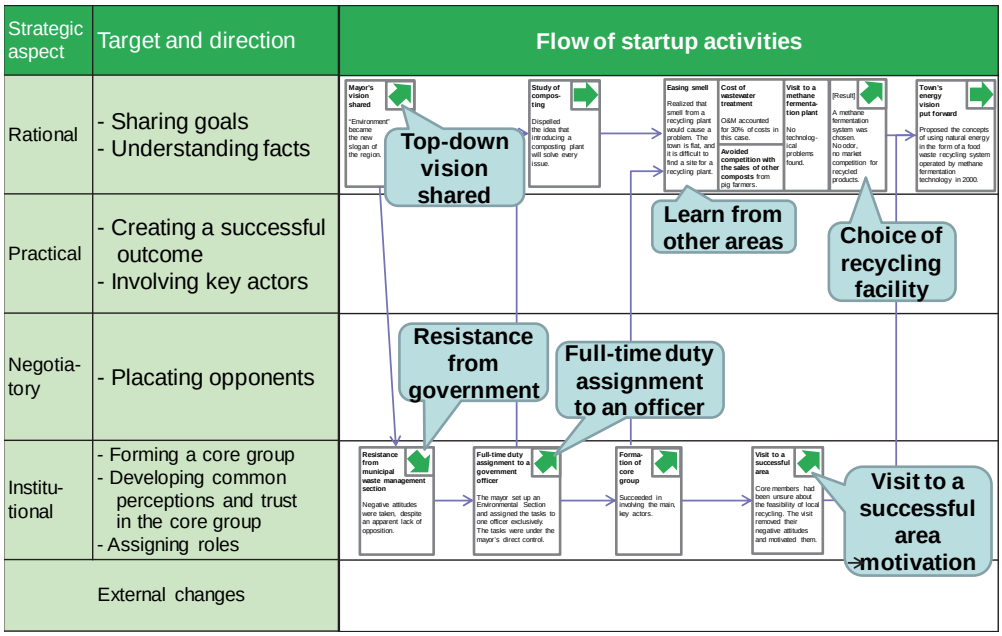


Fig. 3 Example of the results of a historical analysis of one of the seven cases of local material cycle society in Japan

2. Waste management research needed to cater to national policy

2.1 Evaluation of waste incineration systems and development of an energy recovery technology

We tried to develop indicators to evaluate the resilience, energy-saving capacity, and energy generation of municipal solid waste (MSW) incineration plants. In addition, we designed a questionnaire to evaluate the MSW plants.

We investigated the distribution of metals among the different incineration residues discharged from a sequential incineration process. To accomplish this, we sampled and analyzed the residue collected from two commercial MSW incineration plants with stoker-type furnaces. We developed a numerical model to represent the metal distributions on the basis of a multi-zonal thermodynamic equilibrium calculation. The model freshly considered the molten phase. As a preliminary step, we used a simple equilibrium calculation to determine the relationships between temperature and the chemical forms produced in the case of four heavy metals (Zn, Pb, Cu, and Hg).

2.2 Development of a quality-control engineering system for wastes towards an advanced sound material cycle society

We used a column leaching test to evaluate the leaching behavior of inorganic ions from shredded residues of construction and demolition waste. Potassium was uniformly leached along the column depth, whereas calcium was leached only from the top of the column.

We also evaluated the leaching behavior of heavy metals from a fly ash treated

with chelating agent. Larger amounts of lead were leached in a saturated up-flow column test (i.e. under anaerobic conditions) than in an unsaturated down-flow column (i.e. under aerobic conditions).

Drainage behavior of leachate inside a seashore landfill was investigated by using an intermediate-scale tank. By installing a horizontal drainage layer for the leachate between waste layers, we restrained the movement of high-salinity leachate more successfully than with traditional drainage pipes.

2.3 Establishment of appropriate measures for regional environmental restoration and domestic liquid-waste treatment

We investigated the effects of water-saving devices and anaerobic-aerobic circulation on GHG emissions from a household wastewater treatment facility known as a *johkasou*. GHG emissions were reduced by 67%. The total GHG emissions in the test house, which included energy-derived CO_2, decreased by 5.4% after the introduction of water-saving devices and anaerobic-aerobic circulation. We also investigated the composting and agricultural application of the excess biomass produced during wastewater treatment by hyperthermophilic fermentation and hydrothermal reaction. The results of long-term experiments suggested that agricultural application was promising for good crop production. In addition, we studied the enhancement of energy conversion of the excess biomass by using a combination of biological and electrochemical methods. We found that a voltage impression of 1.0 V improved anaerobic methane production in the treatment of harvested submerged aquatic weeds.

2.4 Development and evaluation of treatment technologies and analytical methods for the countermeasures toward legacy wastes and materials with recycling difficulties

In the study on appropriate ways to manage asbestos-containing wastes (ACWs), we experimentally examined the scattering of asbestos fibers from soils containing ACWs. We confirmed that scattering of asbestos fibers was efficiently reduced by moistening.

To find appropriate treatment technologies for wastes containing persistent organic pollutants (POPs), we conducted improvement and performance testing of a small-scale incinerator used for experimental thermal treatment of POPs.

To establish fire-prevention specifications for combustible decontamination waste depots, we provided information obtained from an investigation of the depot sites conducted in cooperation with the Fukushima Office for Environmental Restoration and the Fukushima Prefectural Government.

2.5 Development, standardization, and application of methods for testing the environmental soundness of chemicals in recycled products

To enable steel slag to be used for marine applications, we investigated the leaching of alkaline substances from marine products made from the slag and the subsequent rise in pH of seawater. From the results of a large-scale tank experiment (length 6.5 m × width 0.5 m × height 1.2 m), we proposed a combination of a flow-through-type test and a single batch test for assessing the environmental impact of the slag in marine environments.

Towards ensuring the safe use of recycled materials on land, we evaluated the adaptability of an up-flow percolation test based on ISO/TS 21268-3 by performing a ring test at three institutes. The results showed good agreement in terms of maximum concentration and the cumulative amount leached, with less than 20% deviation from the average.

3. Promotion of seed and fundamental research

3.1 Systems approach to, and policy study of, life-cycle resource management

In this study we developed a methodology for time-series material flow analysis (MFA) with a global system boundary. The global system boundary was ensured by encompassing 231 countries and regions and by considering all possible trade commodities that might contain critical metals. The critical metals of interest in our study are neodymium (Nd), which is used for motors associated with wind power and electric vehicles, cobalt (Co) for electrodes in electric vehicle batteries, and platinum (Pt) for catalysts in fuel cells. The target years of the analysis are from 1995 to 2010 because international trade data are available for these years. The MFA procedures begin with the selection of possible commodities from among all trade commodities defined by BACI, an international trade database in which the data inconsistency between import and export countries in the United Nations COMTRADE database has been solved. The trade volumes (on a physical or monetary basis) of the commodities selected among the countries are then prepared by using BACI. The amount of the critical metal in question that is contained in each commodity is calculated by multiplying the trade volume by the content of the metal per unit volume. Finally, this initial amount of metal is calibrated to satisfy the material balance of the metal within each country by using an optimization problem.

We also analyzed the responses to an international survey on extended producer responsibility (EPR) that had been run the previous year. Cluster analysis showed that perceptions regarding EPR were significantly divided into those emphasizing theoretical concepts and those emphasizing practical aspects. Dialogue to fill the gaps around these perceptions of EPR is needed. We are preparing to publish the results of the survey.

3.2 Study of fundamental technologies required for material cycles and waste treatment

We used our battery of bioassays to evaluate the hazards of flame retardants used as alternatives to POP-PBDEs; we detected hazards associated with impurities in the alternatives. We measured the vapor pressures of some of the alternative chemicals with POP-like characteristics.

In a study of a dual-fuel production system for converting grease trap waste (GTW) to biofuel-oil (BFO) and biogas, we developed a blending technology for creating a homogeneous mixture of BFO and fossil fuel oil. We also used some different approaches to improve the biogas production technology to avoid inhibition due to saturated fatty acid. Furthermore, we investigated seasonal variations in GTW in terms of chemical composition and degree of decomposition.

We successfully improved the lifetime of a nickel metal hydride (Ni-MH) battery by using a high-pressure crystallization method. This technology can be used to completely regenerate Ni-MH batteries.

3.3 Strategic establishment of information research fundamentals for resource circulation and waste management

We continued to compile data for databases on municipal solid waste management in Japan and on international supply chains. For the former database, we created a computer tool to visualize changes in waste generation and disposal at the prefectural level. For the latter, we collected material flow data and improved the estimation method. We collected and compiled data on the amounts of 55 metals in e-waste.

4. Promotion of collaborative R&D projects

4.1 R&D promotion and partnership activities in the Asian region

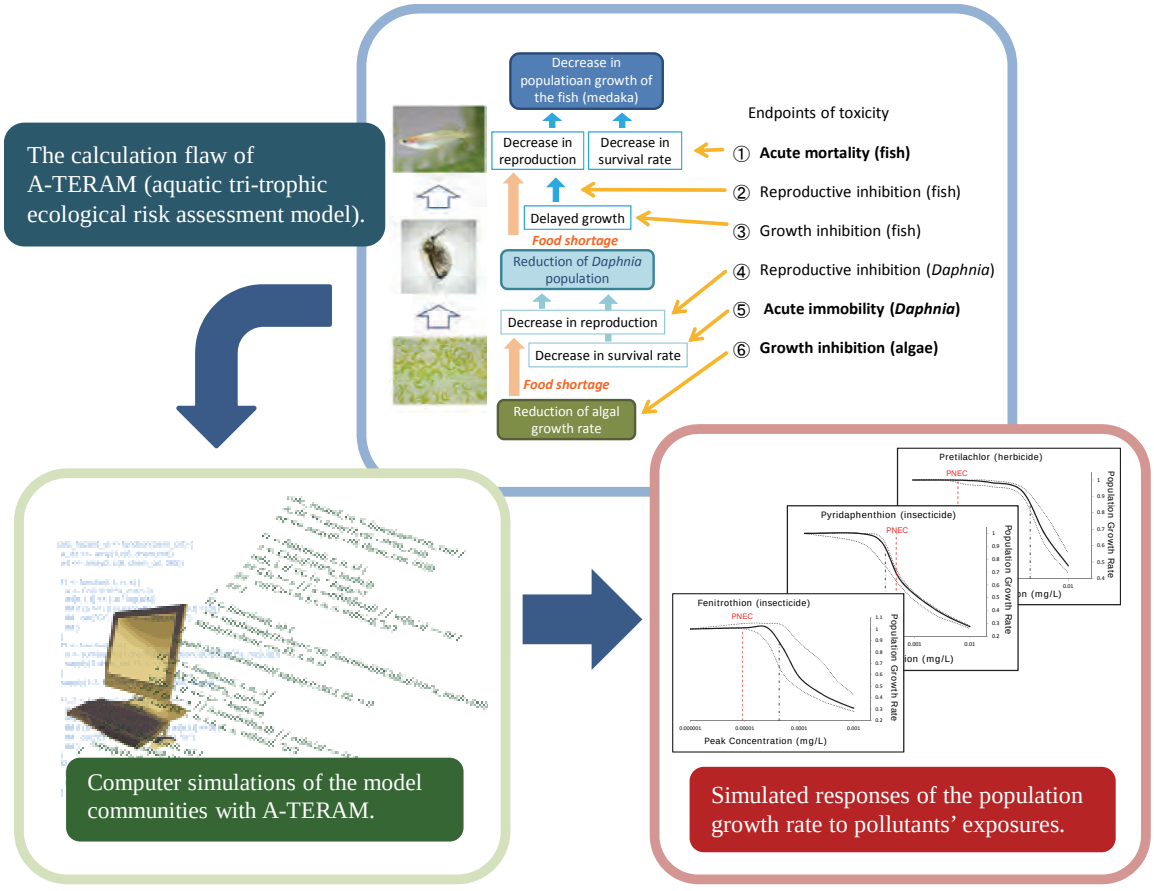
FY 2014 was a year involving expansion on various fronts. As part of our memorandam of understanding (MoU)-based research partnerships we have exchanged new MoUs with five different academic institutions and organizations in five countries in the Asian region. This has been accompanied by the launch of new collaborative research and activities.

We have been reinforcing the capacity to institutionalize existing research outputs in the form of policies, guidelines, and laws. One initiative highlighted this year was the establishment of performance-testing methods for a decentralized wastewater treatment plant in Indonesia. In developing countries, wastewater is discharged untreated into natural water resources such as rivers and lakes. This

leads to degradation of natural water sources and thus affects human lives. Our institute, together with the Institute of Technology Bandung, has been introducing the concept of treatment performance-testing methods in Indonesia to different key players, including the central government and manufacturers, in an effort to establish testing methods in that country. We have also been working on a research project on flood-waste management in mid-scale Asian cities; the two-year project is supported by the Asia-Pacific Network for Global Change Research. We spent most of this year collecting microdata from residents, communities, and districts so that we can gain an understanding of the situation and the countermeasures needed in times of severe flooding in Thailand and Vietnam. A summary of our overseas research, including our collaborative research, is presented in Figure 4.

Fig. 4 Overview of our international R&D collaboration and the major outputs of FY 2014. On the basis of research outputs, we collaborate with various stakeholders, conducting socially influential activities such as institutional design and development of policy-making assistance tools, capacity building, and researcher exchange.

Center for Environmental Risk Research



Our research in the field of environmental risk is focused on chemical substances in the environment. To “use and produce chemicals in ways that minimize significant adverse effects on human health and the environment” (World Summit on Sustainable Development 2002), we are focusing on various ways of advancing the evaluation and management of environmental risks. We are elucidating the routes and dynamics of chemical exposure and developing exposure evaluation methods; developing techniques for ascertaining the status and effects of exposure to chemicals in the environment; studying mechanisms for assessing, and developing methods for evaluating, ecological risks; studying mechanisms and methods for evaluating adverse effects on human health and assessing health risks; examining policies and management on environmental risks; and gathering information on environmental risks.

In FY 2011, the Center for Environmental Risk Research started the “Research Program on Risk Assessment and Control of Environmental Chemicals.” We have since continued this key and innovative research into the evaluation and management of chemical substances. In addition, we have continued to develop environmental research infrastructure for ecotoxicological tests through our reference laboratory, and in our chemical substances databases we are gathering information related to the risks posed by environmental chemicals.

1. Research Program on Risk Assessment and Control of Environmental Chemicals

In recent years, programs for managing chemical substances have incorporated assessments of their impacts on living organisms in the environment. However, the concept of ecosystem protection is not fully entrenched in risk assessment. Accordingly, we need to focus on developing techniques for evaluating ecological risk. Conventional techniques for hazard assessment might not allow a full evaluation of the effects of nanomaterials on human health and ecosystems. Strategic approaches to managing a variety of chemicals need to be established to enable more effective control of the risks they pose. To address these issues, we have been conducting a research program on innovation in the evaluation and management of chemical substances. This program consists of three research projects (described below as Projects 1 to 3), namely on chemical risks to ecosystems; nanomaterials toxicology; and management strategies for the risks posed by numerous chemical substances. The project teams work with each other and also conduct fundamental research to support environmental action plans.

1.1 Research into methodologies for ecological risk assessment and management of chemical substances (Project 1)

We have been investigating ways of estimating the adverse effects of chemical substances on ecosystems in terms of their potential to cause extinctions in populations of living organisms or to degrade ecosystem functions. For this

purpose, we proposed a tri-trophic (three-species) biotic community model that postulated an algae–zooplankton–fish system, namely the Aquatic Tri-trophic Ecological Risk Assessment Model (A-TERAM). This model highlights the ecological aspects of chemical risk assessment by including interspecific interactions between trophic levels (prey–predator interactions); the age structure of fish stocks; and the temporal changes in environmental concentrations of chemicals. The comprehensive properties of the model permitted the integration of various ecotoxicity data (mortality rates and reproductive and growth inhibition of fish; immobility and reproductive inhibition of water fleas [*Daphnia magna*]; and growth inhibition of algae) estimated for species at the three trophic levels. Ecological risks are consistently evaluated by reductions in the population growth rate of the top species. The ecotoxicity data relevant to A-TERAM cover most of the internationally-approved ecotoxicity testing methods for aquatic ecosystems (e.g. the Organization for Economic Cooperation and Development [OECD] test guidelines).

To characterize the risks indicated by A-TERAM in comparison with those by conventional methods, we evaluated the community-level effect (com-EC10: the concentration at which the population growth rate of the top fish species is degraded by 10%) based on A-TERAM as compared with a conventional benchmark, the PNEC (predicted no-effect concentration), as determined from base data (Fig. 1) across the chemicals already subjected by the MOE to an initial Environmental Risk Assessment of Chemicals: (http://www.env.go.jp/en/chemi/chemicals/profile_erac/ index.html).

There were maximum differences of two orders of magnitude in the estimated community-level effect across substances with the same PNEC level, implying that incorporating ecological principles into ecological risk assessment greatly influences the outcome of risk estimation.

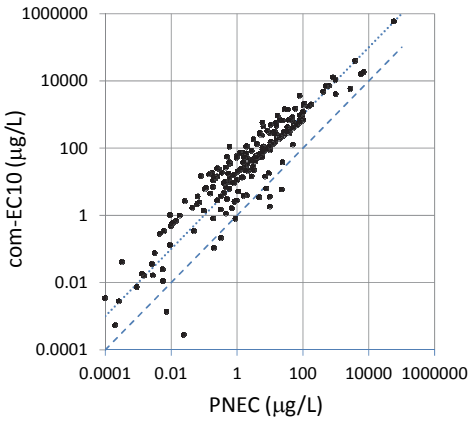


Fig. 1
Comparison between the conventional benchmark, PNEC (predicted no-effect concentration), for ecotoxicity and the community-level benchmark, com-EC10, based on A-TERAM

For ecological risk assessment of chemicals on a large spatial scale, we conducted an integrated analysis of the observed biodiversity in rivers and predicted the environmental concentrations of pollutant chemicals to reveal the ecological impact of the chemicals and derive the best management strategy. The biodiversity information was based on river benthos bio-monitoring data

administered by the Ministry of Land, Infrastructure, Transport and Tourism, Japan (River Environmental Database and Water Information System). For the environmental concentrations of herbicides and insecticides, our analyses relied on the PeCHREM/G-CIEMS model, which was developed by NIES. In total, 44 chemicals, including herbicides, insecticides, and bactericides, were available for concentration prediction at the benthos sampling sites. The predicted concentrations were scaled by the acute toxicity of each chemical to give a cumulative hazard index (HI). The HI, an indicator of gross chemical contamination, was negatively associated with species richness and the numerical abundances of entire species. We used total numerical abundance as a measure of ecological risk because it was more clearly associated with HI than was species richness.

As a management measure, we chose a decrease in the use of all agrochemicals by 5% in each of the eight prefectures (Yamanashi, Gunma, Nagano, Shizuoka, Tochigi, Saitama, Ibaraki, and Chiba) in the Kanto district of Japan. By using the PeCHREM/G-CIEMS model, we were able to account for the hydrological properties of river systems, in which the chemical loading in upstream areas spreads to downstream areas, in our estimation of the environmental concentrations of the chemicals. Thus, a 5% reduction in agrochemical use in a prefecture located in an upstream region was generally expected to have a greater impact than the same measure taken in a downstream region. In addition, the effect of the measure depended on the baseline biodiversity in each prefecture as well as on the geographical location.

1.2 Development of a methodology for nanomaterials toxicity evaluation and research into nanomaterials safety (Project 2)

In our first nanotechnology project, conducted from FY 2006 to 2010, we used laboratory animals and mammalian cells to investigate the health effects of nanoparticles, such as the ultrafine particles in diesel exhaust, carbon nanotubes, and heat-treated asbestos. The current project, which started in FY 2011, focuses on the mechanisms of toxicity of carbon nanotubes, the *in vitro* and *in vivo* toxicity of silver nanoparticles and dendrimers, and the ecotoxicological evaluation of titanium dioxide nanoparticles by using the embryos and sac fry of zebra fish (*Danio rerio*). We have also improved an *in vitro* system of nanoparticle exposure at the air–water interface for toxicity screening of various types of nanoparticles and nanomaterials. Our goal is to develop a health-risk-assessment method for the safety evaluation of nanomaterials. To this end, we intend to develop toxicity testing guidelines that are suitable for nanosized particulates, focusing on the shape, dispersibility, and surface charge of nanomaterials.

Fibrous particles trigger inflammasome-initiated caspase 1 cleavage in phagocytic cells, and interleukin-1 beta is released from the cells after cleavage of caspase 1.

We investigated whether multi-walled carbon nanotubes (MWCNTs) activate NLRP3 (NOD-like receptor family, pyrin domain containing 3) inflammasome in the same way as asbestos does. Human monocytic THP-1 cells were differentiated into macrophages by treatment with phorbol myristate acetate and were then exposed to MWCNTs, crocidolite asbestos, or lipopolysaccharide. Exposure of the cells to MWCNTs or asbestos provoked IL-1 beta secretion, and the secretion was suppressed by Z-YVAD, an inhibitor of caspase 1. Y27632, a selective inhibitor of rho-associated protein kinase (ROCK), also inhibited IL-1beta secretion, indicating that the GTPase effector ROCK is involved in MWCNT-induced IL-1beta production in THP-1 cells. We also exposed J774.1 murine macrophages to either lipopolysaccharide, titanium dioxide nanofibers (F-TiO_2), or both, and investigated the expression levels of 40 cytokines in the culture supernatant. Production of granulocyte colony stimulating factor (CSF), granulocyte-macrophage CSF, interleukin (IL)-1alpha, IL-1ra, IL-1beta, IL-6, and IP-10 was increased by lipopolysaccharide. IL-1alpha and IL-1beta production was synergistically increased by co-exposure to lipopolysaccharide and F-TiO_2. These results suggest that IL-1alpha and IL-1beta are benchmark inflammatory cytokines, the production of which is increased by fibrous particles in the presence of lipopolysaccharide.

The health effects of silver nanoparticles (AgNPs) have not been well investigated, despite AgNPs now being widely used in consumer products. We previously compared the metabolic behavior and toxicity of AgNPs with those of silver nitrate ($AgNO_3$) in mice and found that $AgNO_3$ recruited more neutrophils in the alveolar space than did AgNPs. In our current *in vitro* study we used macrophages and neural cells. AgNPs were colocalized with lysosomes in the murine macrophages (Fig. 2). The AgNPs were gradually dissolved in the lysosomes of the macrophages.

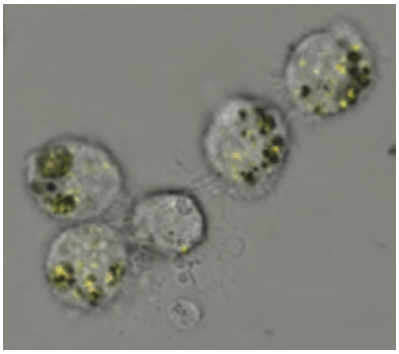


Fig. 2 Silver nanoparticles (AgNPs; 20 nm, black granules) colocalized with lysosomes (yellow fluorescence) in J774.1 murine macrophages. The cells were incubated with 10 μg Ag/mL AgNPs for 3 h. (Adapted from. *Toxicology* 328: 84–92, 2015).

We also examined the toxicity of silver nanoparticles *in vivo* by using rat neonates. Per oral administration of silver nanoparticles (10 to 30 nm diameter) at a dose of 30 μg/pup significantly increased locomotor activity, suggesting that ingestion of silver nanoparticles had the potential to affect neurobehavioral activity in these animals.

We previously observed that exposure of mice to polyamidoamine (PAMAM) dendrimers had neuronal effects by modulating the expression of genes involved

in brain-derived neurotrophic factor signaling pathways. We intended further to confirm the neuronal effects of PAPAM by using two- and three-dimensional neurosphere culture systems. Both the neuronal extension length in two-dimensional culture and the neuronal extension area in three-dimensional culture were decreased by amine-modified PAPAM, but not by other PAPAMs. Among PAPAMs of generations 0 to 7, the toxicity of generation 4 PAPAM was highest, suggesting that the toxicity of PAPAM is size-dependent.

TiO_2 nanoparticles have been widely used in construction materials and cosmetics and are presumably released into the environment, where they could affect aquatic ecosystems. In the last NIES annual report, we reported our finding that anatase-type TiO_2 nanoparticles were toxic to fish embryos in the presence of ultraviolet irradiation; the total surface area of TiO_2 was correlated with toxicity. We analyzed the viability data and found that the lowest observed effective concentration of the TiO_2 nanoparticles was 100 mg/mL.

1.3 Research into strategic approaches to managing the risks posed by chemical substances (Project 3)

Chemical substances differ widely in their effects and characteristics. In this project, we are investigating strategic approaches to managing the risks posed by various chemical substances. The project is based on two major study themes, namely (1) methods of assessing the environmental fates and spatiotemporal distributions of chemicals, and (2) control strategies for chemicals in society. Theme (1) is further divided into three sub-themes.

Sub-theme 1-1 focuses on developing a model for predicting spatiotemporal changes in the emissions and levels of agricultural chemicals. Assessment methods that consider temporal variations in emissions and risks to the aquatic environment are studied as major examples of this theme; PeCHREM/G-CIEMS (see section 1.1) models are used. Sub-theme 1-2 focuses on developing and studying emissions and exposure scenarios over the entire life cycles of substances, from manufacture to disposal. Flame retardants and PFOS (perfluorooctanesulfonate) have been selected as the current targets of the study. Sub-theme 1-3 focuses on developing a global multimedia model (the Finely Advanced Transboundary Environmental model; FATE) for predicting the fate of persistent organic pollutants (POPs). We are exploring the development of an assessment methodology based on the global distributions of these substances. Theme 2 focuses on strategies for managing the different dimensions of risk posed by various chemical substances in society. We are exploring the topic in relation to chemical spatiotemporal variation, characteristics of chemical life cycles, the uncertainties of scientific knowledge, and the variable nature of chemical impacts and social receptivity. We intend to collate the results of these research activities so as to propose a basis for a methodology and ideas for efficiently evaluating and managing the risks posed by chemical substances.

In FY 2014, as part of sub-theme 1-1, we used the PeCHREM/G-CIEMS model to calculate the time trends of shipment volumes and predicted concentrations in river water for five pesticides (cafenstrol, fenobucarb, butachlor, pentoxazone, and pretilachlor) commonly used in Japan. In sub-theme 1-2 we made improvements to our mathematical model for the emissions of semi-volatile compounds from products and continued experiments to measure these emissions. As part of sub-theme 1-3, we began to develop FATE for mercury (FATE-Hg). We implemented a new module that computes Hg transformations in the atmosphere and the oceans. In theme 2 we surveyed the possible differences between scientific and societal understanding of the basic concept of risk.

This year we specifically report our achievements under theme 2, in which we considered the relationship among certainty and the accumulation of scientific knowledge, risk criteria in society, and the perceptions of various stakeholders. A web-based survey was used to reveal the different reasons why the public is concerned about environmental issues: we studied the degree to which increases in public levels of concern about various factors were related to such things as the acceptability of applying the results of animal experiments to humans or the uncertainty of accounting for physical differences among individuals or differences in exposure periods (Fig. 3). The number of people concerned about radiation and electromagnetic waves has increased in the last 15 years. We found that levels of concern over an issue were increased by such factors as increases in their levels of uncertainty about research results; physical differences among individuals; the level of control over environmental effects; and the possibility of contamination or a higher contamination level than the environmental standard. We are continuing to conduct research to promote strategic risk management.

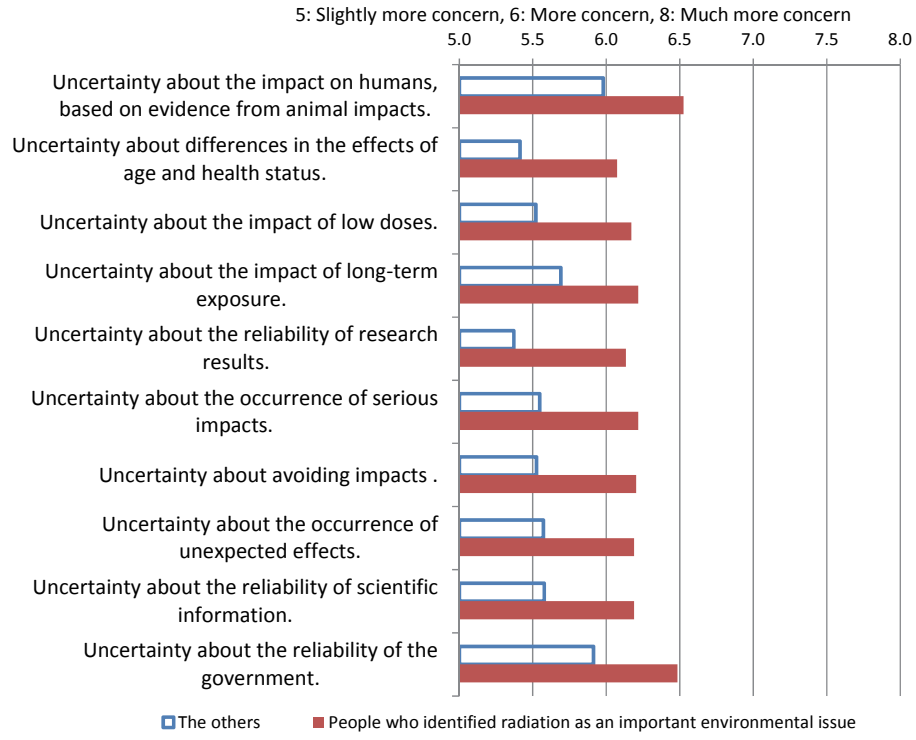


Fig. 3
Reasons why people who identified radiation as an important environmental issue felt greater concern about this issue.
Uncertainty about the reliability of research results; avoiding impacts; the effects of physical differences among individuals; and the application of animal experimental results to humans were the main reasons for these concerns.

2. Fundamental research to support environmental action plans

To minimize the risks posed by chemical substances we have been running fundamental research projects to develop a comprehensive view of risks to human health and ecosystems. We have also been developing techniques for assessing and managing these risks on the basis of transparent and scientific evidence in line with environmental action plans.

2.1 Development of a new method for estimating emissions of chemical substances to the environment

We aim to develop a new technique for estimating the emissions of chemical substances into the environment by taking into consideration various factors that have not been considered sufficiently. Such factors include emissions from various processes, as well as the changes in these emissions over time. In FY 2014, we developed a tool that estimates emissions in processes such as product use. The tool uses basic concepts and dimensions of emissions with regard to time, as well as general mathematical representations of chemical emissions from products established in the previous year. This tool (Fig. 4) runs on Microsoft Excel software. Users specify the time course of production volume, the distribution of product lifetime, and changes in emission factors, and the tool calculates the resulting emission rates over time.

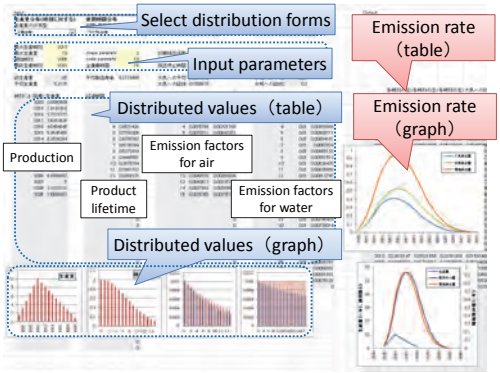


Fig. 4
Screenshot of the tool that estimates emissions in processes in a product life cycle, considering temporal changes in relevant factors

2.2 Research into development and use of a method for predicting the toxicity of chemicals

Under the requirements of regulations for the screening of existing chemicals, (quantitative) structure–activity relationships [(Q)SARs] have become a useful tool for estimating ecotoxicity. We introduced interspecies quantitative structure–activity–activity relationships (QSAARs), which are QSARs used to estimate species-specific acute aquatic toxicity, by using datasets consisting of aromatic amines and phenols. We found that molecular weight data and selected indicator variables improved the goodness-of-fit of the fish and algae toxicity prediction models relative to the interspecies relationships with daphnia toxicity.

External validation revealed the structural profiles of outlier chemicals for fish toxicity and proved the predictive ability of the QSAAR within 1.0 log unit for algae toxicity. In addition, the use of a criterion based on the calculated log *D* at pH 7.4 (i.e. log *P*(1) – log *D* > 1) enabled us to identify amines and phenols for which good relationships could be predicted between fish and daphnia toxicities and between algae and daphnia toxicities. Chemicals that met this criterion could be expected to have similar mechanisms of toxicity.

We also developed an approach to extrapolating chronic ecotoxicity from acute ecotoxicity data. We applied a simple Bayesian framework to predict the posterior probability that the chronic toxicity exceeded a threshold value for screening chemicals. From acute ecotoxicity data on chemicals, the false-negative rate for chemicals during the screening process can be estimated with this approach. The approach also yields candidate values for assessment factors that maximize the rate of correct screening under given financial limitations.

2.3 Development of biological testing techniques based on mechanisms of action of chemicals

Human health and ecosystems may be affected by combined exposure to various chemicals in the environment, including chemicals that have been unintentionally produced. To plan measures for reducing the risks of combined exposures, we are assessing the total impact of multiple chemicals in the environment. The following research projects are focused on evaluating the hazards of multiple chemical substances in the ambient air and aquatic environment on the basis of the data gathered from bioassays.

i. Anatomization of the mutagenic or carcinogenic potency of environmental chemicals: We used chemical analysis in an attempt to identify major components inducing carcinogenicity and to assess the total carcinogenic risk posed by polycyclic aromatic hydrocarbons (PAHs) in particulate matter and semi-volatile PAHs in ambient air. Because the relative potency factors (RPFs) of several semi-volatile PAHs (benzo[*c*]fluorene [BcFE], cyclopenta[*c*,*d*]pyrene, and benzo[*j*]fluoranthene) were estimated to be higher than that of benzo[*a*]pyrene (BaP), which is used as an index chemical, we analyzed the concentrations of these PAHs in both the gas and particulate phases in Japan. Taking the RPF and the atmospheric concentrations of BcFE into account, the contribution of BcFE to carcinogenic risk for mice from PAHs in the atmosphere was shown to be five to seven times higher than that of BaP.

ii. Analysis of the endocrine-disrupting activities of chemical substances: By using a yeast two-hybrid bioassay system, we subjected various chemicals detected mainly in aquatic environments to screening for ligand-dependent transcriptional activity. About 600 chemicals have been screened for binding

activities to hER (human estrogen receptor), medER (medaka (*Oryzias latipes*) estrogen receptor), and AhR (aryl hydrocarbon receptor). Data from the screening will be published on the NIES homepage.

3. Development of infrastructure for environmental research

To establish infrastructure for assessing and managing the risks posed by chemical substances, we performed the major task of establishing a reference laboratory and developing databases to gather environmental-risk-related information, as follows.

3.1 Establishment of a reference laboratory for ecological hazard assessment

We have established a reference laboratory for ecological hazard assessment with the aims of creating references for ecotoxicity testing to develop standardized eco-toxicity tests in Japan and abroad; promoting techniques for eco-toxicity testing; improving the reliability and accuracy of toxicity data for environmental risk assessment; and supporting the development of infrastructure, such as testing laboratories in Japan.

i. **Collaboration and cooperation with institutions inside and outside Japan.** We are collaborating with the relevant institutions from Japan and abroad to develop new test methods by using the latest research trends and social scenarios associated with environmental risk. In FY 2014, we investigated eight samples at five industrials by using whole-effluent toxicity testing. We also worked on developing new testing methods for endocrine disruptors; some of these test protocols have already been approved as OECD test guidelines.

ii. **Promotion and improvement of ecotoxicity tests.** We are working on promoting elementary knowledge and techniques for ecotoxicity tests and improving the reliability and accuracy of test data. As part of these activities, we held our sixth and seventh practical training seminars (in May and December, respectively) to teach elementary knowledge and techniques for eco-toxicity testing on zebrafish (*D. rerio*), daphnids, and algae through lectures, practical training, and tours of our laboratory. Both training seminars were attended by more than 30 participants from various organizations (companies, research institutes, and universities); they were keen to learn about eco-toxicity testing and enjoyed the seminars. They also took advantage of the opportunity to form new relationships.

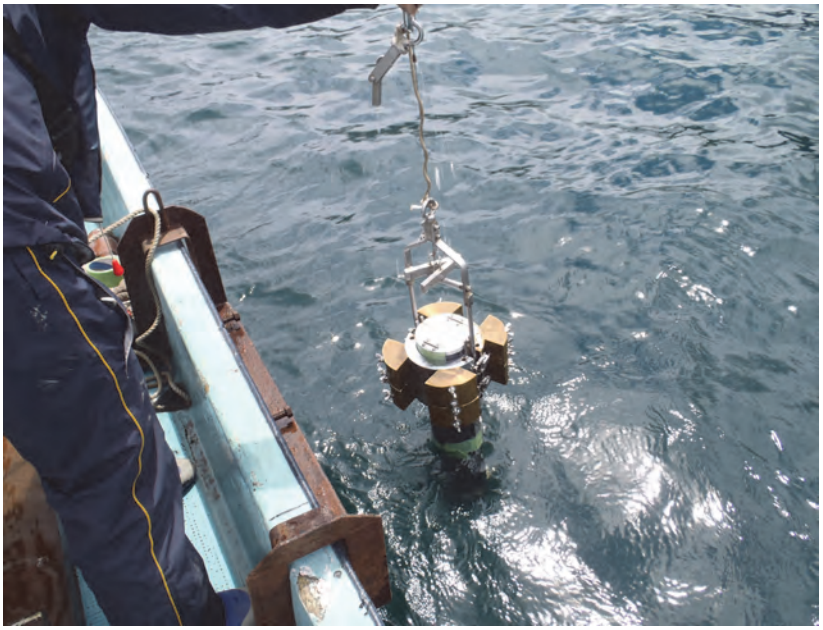
iii. **Development of, and support for, infrastructure for ecotoxicity tests.** We have developed an efficient system for maintaining and supplying the organisms (e.g. medaka and water fleas) used in tests performed by other laboratories in Japan and abroad. We also renewed the homepage of our Aquatron (hydrobiological facility).

3.2 Development of chemical substance databases and dissemination of data

We have been continually updating and improving our chemical substance database and a related website (Webkis-Plus: http://w-chemdb.nies.go.jp/). These are publicly accessible, as are a related database and website (EnvMethod: http://db-out.nies.go.jp/emdb/). The Webkis-Plus database contains information on about 10,000 substances, including their physicochemical properties; regulations, related mainly to environmental pollution; environmental concentrations, from surveys performed by the Ministry of the Environment (MOE) (e.g. “The State of Chemical Substances in the Environment”); amounts of chemical substances manufactured and imported; volumes of agricultural chemicals shipped into each prefecture; PRTR (Pollutant Release and Transfer Register) emissions and transportation amounts; the results of risk assessments performed by several organizations; and other related information. The EnvMethod database contains details about analytical methods used in the environmental surveys. Anyone can access these websites and easily obtain chemical information via input of a search word (e.g. a Japanese chemical name, an English chemical name, or a CAS [Chemical Abstracts Service] Registration Number) or by selecting an item from a categorized list. The two databases are effectively linked by chemical substance code and medium. For example, users can easily obtain information about analytical methods for a target substance in a certain medium on the EnvMethod site by directly accessing it from the substance’s survey result on the Webkis-Plus site. We have also promoted cooperation with the operators of other related websites, namely ChemiCOCO (managed by the MOE) and BIGDr (managed by the Japan Chemical Industry Association [JCIA]). As a result of this cooperation, these websites now offer users direct links to each substance’s page on Webkis-Plus. We have also been developing a new database and website featuring the results of our bioassay research on pure substances and river water.

Center for Regional Environmental Research

Setting up a high-volume sampler to collect particulate matter (PM) in Saitama Prefecture. Collected samples are used for toxicity studies.



Sediment core sampling in Lake Chuzenji, in Tochigi Prefecture

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 their means of application to real world issues and situations.

The center consists of eight sections (Regional Atmospheric Modeling Section, Regional Atmospheric Environment Section, Urban Atmospheric Environment Section, Water Quality Management Section, Lake and River Environment Section, Marine Environment Section, Soil Environment Section, and Regional Environmental Systems Section) and has two Principal Researchers.

In FY 2014, we implemented many research projects covering a wide range of regional environmental issues. Our main research projects were conducted under the following structure:
(1) A Priority Research Program (the East Asian Environment Research Program);
(2) Two Advanced Research Programs (the Basin Ecosystem Functions Research Program and the Eco-city Systems Research Program); and
(3) NIES Internal Research Funding Projects. These include ‘Flux Estimation from Sediment in Nutrients and Global Warming Gas by MRI and Stable Isotope Analysis’; ‘A Study of PM in Urban Atmosphere for Reduction of PM and Evaluation of Toxicity and Health Impact of PM Based on Chemical Compositions’; and ‘A Comparative Study on Development and Evaluation of Amendment Technologies for Sediment in Coastal Sea’.

Of particular interest were research projects concerning multimedia modeling and long-term monitoring of radioactive substances emitted from the Fukushima Daiichi Nuclear Power Plant. Most of the projects are collaborations with other centers at NIES. 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.

We will now give brief accounts of some of the important results of the Center’s research in FY 2014.

1. Research Programs

East Asian Environment Program

Japan is closely connected to the rest of Asia both geographically and economically, and rapid development is expected in Asia into the future. In this

context, Japan as part of this region needs to facilitate conservation of the East Asian environment towards the promotion of environmental security and creation of sustainable society throughout Asia. The East Asian Environment Program conducts research on multi-scale air pollution in East Asia (Project 1) and on wide-scale anthropogenic impacts on marine ecosystems in the East China Sea and the seas around Japan (Project 2). Project 1 aims to clarify the current status and formation mechanisms of transboundary air and water pollution in East Asia by means of field observations and model simulations. Project 2 aims to reveal the relationships between environmental burdens and their impacts, and to suggest solutions that will benefit marine ecosystems. We expect that the program as a whole will contribute to solving wide-scale environmental issues in East Asia.

Project 1: Analysis and Evaluation of Multi-Scale Air Pollution by Integration of Observations and Modeling

In Project 1, Analysis and Evaluation of Multi-scale Air Pollution by Integration of Observations and Modeling, we are examining air quality issues ranging from local to hemispheric scales, with particular emphasis on trans-boundary transport of air pollutants and its impacts on human health and ecosystems in East Asia.

The *Ozone Monitoring Team* has analyzed the emission of ozone precursors from open crop-residue burning in China. Measurements of trace gases, including non-methane volatile organic compounds (NMVOCs), in a rural area in Central East China were examined in June 2010. During the campaign, six biomass burning events were identified through the simultaneous enhancement of atmospheric carbon monoxide and acetonitrile levels. The observed normalized excess mixing ratios (NEMRs) of oxygenated volatile organic compounds and alkenes showed dependence on air mass age—even in fresh smoke plumes—supporting the hypothesis that these species are rapidly produced and destroyed, respectively, during plume evolution. We used data on NEMRs in the fresh plumes to calculate the emission factors (EFs) of individual NMVOCs. Comparison with data from previous reports suggests that the EFs of formaldehyde and acetic acid have been overestimated, whereas those of alkenes have been underestimated. We suggest that open burning of wheat residue in China releases about 0.34 Tg NMVOCs annually. If the same EFs were applied to all crops, the annual Chinese NMVOC emission would be 2.33 Tg. The EFs of speciated NMVOCs can be used to improve existing inventories.

The *Aerosol Measurement Team* has set up an aerodyne quadrupole-type aerosol mass spectrometer (Q-AMS) in the city of Fukuoka, one of the biggest cities in western Japan. We are trying to distinguish PM produced within the city (local PM) from that transported from the Asian continent. Figure 1 shows chemical compositions measured by using the Q-AMS according to $PM_{2.5}$ mass concentration. When the $PM_{2.5}$ mass concentration was high (>35 g m^{-3}), the

fraction of sulfate was high, whereas when the $PM_{2.5}$ mass concentration was low (<10 g m^{-3}), the nitrate fraction was larger. When the sulfate concentration was high, the air mass was transported from the Asian continent. We calculated the air mass trajectory by using the NOAA ARL HYSPLIT (National Oceanic and Atmospheric Administration Air Resources Laboratory Hybrid Single Particle Lagrangian Integrated Trajectory) model. When the $PM_{2.5}$ mass concentration was low and the nitrate fraction was high, the air mass was often transported within the Kyushu/Fukuoka area. This indicates that trans-boundary air pollution influences the PM mass concentration; moreover, analysis of chemical composition can be used to infer the origin of the air mass. The organic signal is considered to be a marker of aging (oxidation), which in turn is an indicator of the duration of air mass transport. The organic signal was analyzed by using the Positive Matrix Factorization (PMF) method (Fig. 2). The PMF method separates oxygenated organic aerosol (OOA: aged organic species) from hydrocarbon-like organic aerosol (HOA: fresh, non-aged organic species). The fraction of OOA was high when the $PM_{2.5}$ mass and sulfate concentrations were high. In contrast, the fraction of OOA decreased when the $PM_{2.5}$ mass was low and the nitrate fraction was high. This also indicates that long range transport (i.e. trans-boundary air pollution) influences the PM mass concentration and chemical composition. We analyzed the health impacts of PM by using dust data, the mass concentration and chemical composition of PM, and data on health outcomes in Fukuoka. Our preliminary results indicated that the risk of myocardial infarction increased with increasing dust concentration and was positively correlated with nitrate concentration. The incidence of respiratory system disease was also positively correlated with $PM_{2.5}$ mass concentration.

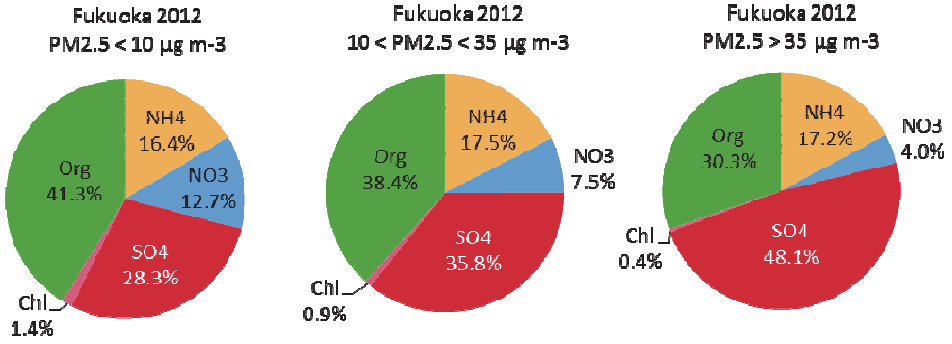


Fig. 1 Chemical composition of PM, as measured by using the Q-AMS. NH4: ammonium ion, NO3: nitrate ion, SO4: sulfate ion, Chl: Chloride ion, Org: organic species

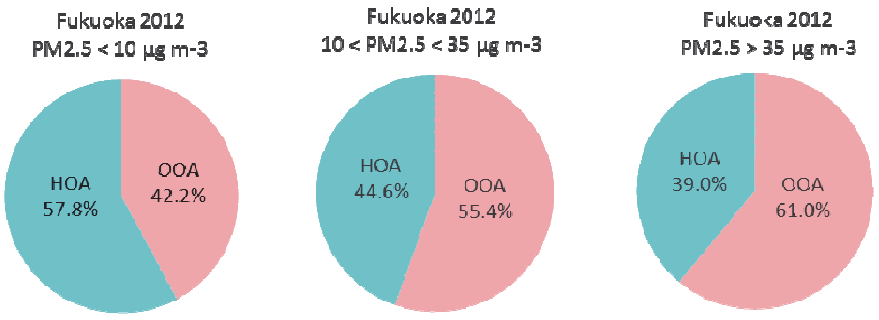


Fig. 2 Results of PMF analyses for organic matter. OOA, aged organic species; HOA, fresh, non-aged organic species.

The *Modeling Team* has performed a simulation of the air quality in East Asia from 2000 to 2012. The output of the simulation has been compared with observation data from the other theme of this research program and with data obtained by other NIES-related research projects. These comparisons have focused on O_3 and $PM_{2.5}$ and show that the Chemical Transport Model (CTM) system has reasonable ability to simulate the inter-annual variation or longitudinal gradient of the concentrations of both substances in Japan. Some problems in the seasonal transition of O_3 concentration along coastal regions of the Japan Sea and some biases in $PM_{2.5}$ concentration (either negative or positive, depending on the $PM_{2.5}$ component) have been identified, and some of these have been improved by tuning several of the parameters of the CTM. The effects of O_3 on Japanese vegetation—in particular on *Fagus crenata* Blume (Japanese beech)—were estimated by using the CTM output and the dose–response relationship between O_3 exposure and growth of beech seedlings; the latter was derived from data obtained by low-concentration long-term experiments in regulated-environment chambers. The ratios of growth inhibition of Japanese beech trees under O_3 and water stress were mapped, revealing the areas highly affected by O_3 exposure and drought. In addition, changes in gene expression, hormone generation, and the contents of redox substances in the leaves of Japanese beech were clarified through the regulated-environment experiments. These results can be applied to O_3-stress diagnosis in Japanese beech.

Project 2: Study of wide-scale anthropogenic impacts on marine ecosystems in the East China Sea and the seas around Japan

There is concern that increasing anthropogenic pollutant loads from terrestrial East Asia may cause wide-scale degradation of marine environments, as exemplified by the occurrences of red tides on the continental shelf of the East China Sea (ECS). This project aims to develop integrated numerical models that can simulate the impact of human activity in China's Yangtze River basin (YRB) on the environment in the ECS and the seas around Japan. For this purpose, we intend to (1) estimate natural and anthropogenic emissions of nitrogen (N) and phosphorus (P) in the basin and their discharges to the marine environment; and

(2) clarify the mechanisms of transport of these emissions to the continental shelf in the ECS and their impact on marine ecosystems.

In FY 2014, we improved our land and ocean models to obtain greater reproducibility. For the land model, we have revised the parameters concerning N inputs to the YRB, including atmospheric deposition, synthetic N fertilizer, and N from human waste and animal excreta, on the basis of statistical data from China. For the ocean model, we have used an analysis of our cruise data to newly establish an empirical prediction equation for the diffuse attenuation coefficient of photosynthetically active radiation in the ECS. We have replaced a conventional generic equation used in our previous ocean model with a new one for better estimation of the light environment for primary producers (phytoplankton). In conjunction with the above improvements in the land and ocean models, the latest models achieved improved performance in terms of the reproducibility of spatiotemporal variations in temperature, salinity, nutrient content, and phytoplankton biomass in the ECS during 2000–2010. This included improved reproducibility of data on the occurrences of subsurface chlorophyll-*a* maxima on the continental shelf.

We performed sensitivity simulations using our models, to elucidate the responses of water quality and primary producers in the ECS to changes in pollutant loadings from the YRB. These simulations showed that changes in the total anthropogenic N and P loadings and the N:P ratio of the river could have a considerable influence on the total phytoplankton biomass, its spatial distribution, and the dominant algal class (diatoms or flagellates). This was found to be true not only in the estuary and in the adjacent western shelf area, but also in the central and eastern shelf areas, although it has generally been considered that phytoplankton biomass and primary production on the central and eastern shelves are controlled mostly by the intrusion of ocean water with rich nutrients from beyond the shelf edge. We have also found that the recent tendency for dinoflagellates to predominate over diatoms on the central continental shelf of the ECS is likely caused by the high N:P ratio (~100) in nutrients in the discharged river water.

To address the near-future runoff of water and pollutants from the YRB and to assess their effects on the marine environment of the ECS, we have evaluated near-future pollutant emission from the YRB. This year, we evaluated spatiotemporal variations in water withdrawal, water discharge, and the accompanying emission of pollutants from various economic sectors in China from 2002–2030. Our aim was to identify those industrial sectors that have had the greatest influence on China’s aquatic environment and to predict how that situation might change in the near future according to the various possible future patterns of socioeconomic development, availability of water resources, and government measures for environmental protection. First, we analyzed provincial-scale statistics on the economy, water use, and pollution discharge to

evaluate their spatiotemporal variations from 2002–2010 and obtained their quantitative relationships (i.e. the regional amounts of water and pollutant loads per unit industrial gross output). Second, we predicted the spatiotemporal variations in water and pollutants for the period 2010–2030 by using both the relationships we obtained and the Chinese provincial-scale economic growth forecast. This forecast predicts the gross output of each industrial sector on the basis of the Asia–Pacific Integrated Model/Computable General Equilibrium (AIM/CGE), which was developed independently by the Center for Social and Environmental Systems Research within our institute on the basis of the future "conventional society" (CNV) scenario of global climate change. Under the CNV scenario, the annual water withdrawal of all China would increase by 2.3 times from 2002 to 2030, whereas the industrial gross output would increase by 5.3 times. The withdrawal increase would be caused by marked growth of the electricity and heat supply sectors. The estimations also revealed that the pollution load will increase dramatically and will be accompanied by an increase in water discharge by manufacturing industries; for example, by 2030 the discharge of COD (chemical oxygen demand) by industry will rise to more than 6.0 times that in 2002 (Fig. 3). These results suggest that point-source management will become increasingly important in the future for China. Furthermore, considering that the discharges of water and pollutants per unit gross output of China's industrial sectors are larger than those of Japan, it could be argued that there is potential to reduce China's pollution loads.

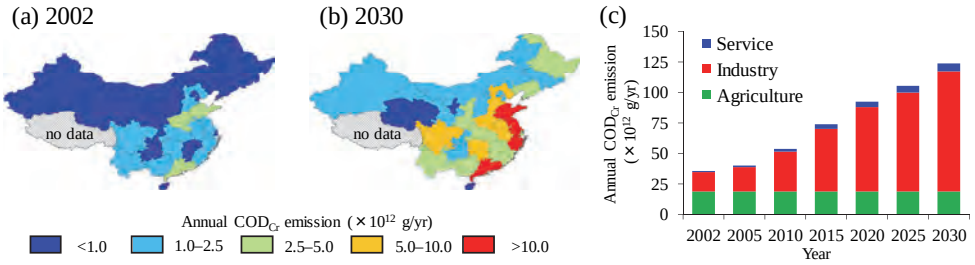


Fig. 3 Comparison of predicted annual chemical oxygen demand (COD) emission by province in 2002 and 2030 (a and b), and annual trends in COD emission by the whole of China from 2002–2030 (c)

Basin Ecosystem Functions Research Program

Our objective is to develop methodologies for the quantitative assessment of ecosystem function. We are focusing on the material and water cycles of basin ecosystems (e.g. forests, lakes and wetlands, rivers, and coastal regions). We are also performing long-term strategic monitoring of typical basin ecosystems and assessing quantitatively the relationships between ecosystem function and various environmental factors. On the basis of these scientific findings and associated information, we intend to extend our project to a large basin (the Mekong River Basin) and assess the relationship between losses of fishery production due to damming and production gains through aquaculture in reservoirs.

Project 1: Quantitative evaluation of links between ecosystem functions and environmental factors in natural ecosystems

At quarterly intervals from August 2007 to May 2008, we measured nitrate concentrations in the base flows of headwater streams in 40 forested catchments (drainage area: 1.9 to 52.4 ha) on Mt. Tsukuba in central Japan. Stream nitrate concentrations in 31 catchments constantly exceeded 1 mg N L–1, suggesting mountainous forests were nitrogen saturated. To investigate the cause of spatial variations in stream nitrate concentrations in nitrogen saturated forests, we used a digital elevation model and GIS to calculate catchment topographies (including drainage area, mean elevation, mean slope gradient, and percentage of south-facing slopes). We also computed the percentage of land covered by coniferous forests in each watershed by analyzing QuickBird satellite imagery. Stream nitrate concentrations were correlated with mean slope ($r = 0.404$, $p < 0.01$), but they were not correlated with other topographic characteristics or with coniferous forest coverage. However, a regression tree analysis with multiple environmental factors showed that coniferous forest coverage was the second most important variable explaining the variance in stream nitrate concentrations among the catchments. Moreover, when stream nitrate concentrations were compared among five adjacent catchments with similar topographies, the two catchments with higher coniferous forest coverage had higher stream nitrate concentrations. We therefore concluded that catchment topography primarily controlled the spatial variations in stream nitrate concentrations, and that the extent of coniferous forest cover had an additional effect on nitrate concentrations in these nitrogen-saturated forests.

We developed new, rapid, and non-radioactive methods such as fast repetition rate fluorometry (FRRF) for measuring primary production in the water column. FRRF proved viable as a new methodology through comparison with the primary production rates measured by a traditional method (^{13}C method) under laboratory conditions (Fig. 4). We also developed a quantitative procedure for desalting samples with high salt concentrations, such as seawater, and successfully measured the molecular weight distribution of marine dissolved organic matter as the concentration of carbon. These new methods developed in this subtheme will be applied to other projects (other subtheme in Project 1, and Project 2) within the Basin Ecosystem Functions Research Program.

To evaluate the effect of nitrogen saturation at Mt. Tsukuba on the water quality in Lake Kasumigaura, in collaboration with work on the subtheme (Mt. Tsukuba) of Project 1, we are constructing a flow model (Princeton Ocean Model) and a process-based water-quality model (CE-QUAL-ICM). By using these models, we will be able to calculate the dynamics of nitrate in Takahamairi Bay according to source (forest, paddy field, farm, etc.).

We also investigated the effects of a green tide on the ecological functions of

Yatsu-higata tidelands, in the innermost part of Tokyo Bay. Green tide occurred because of extreme dominance of the invasive algae species Ulva ohnoi. Toward this goal, we analyzed the sediment interstitial water quality at 5 cm depth at three microtopographic sites located at different ground levels on the tidal flat. Eighty to ninety percent of total dissolved nitrogen in the sediment interstitial water was occupied by the chemical form of NH4-N at all microtopographic sites. At the middle ground-level site, which was the center of distribution of the Ulva, the dissolved inorganic nitrogen concentration was 2 to 4 times those at the higher and lower sites, and the PO4-P concentration was 1.5 to 3 times higher.

Dissolved nitrogen collected at low tide from standing water in the space between the folds of Ulva changed its chemical form from organic to inorganic as the temperature increased. The amount of inorganic nitrogen dissolved in this water declined rapidly as the Ulva biomass increased in autumn. In contrast, the organic nitrogen concentration in the interstitial water of the sediment at the lower ground-level site, was stable at 80% of the total nitrogen throughout the year and was 2.5 times that in the sediment water at the middle ground-level site. These results indicate that repeated emergence and submergence promotes mineralization of nitrogen. Ulva uses this mineralization process to gain nutrients effectively, thus maintaining its current expansive distribution in this tidal flat.

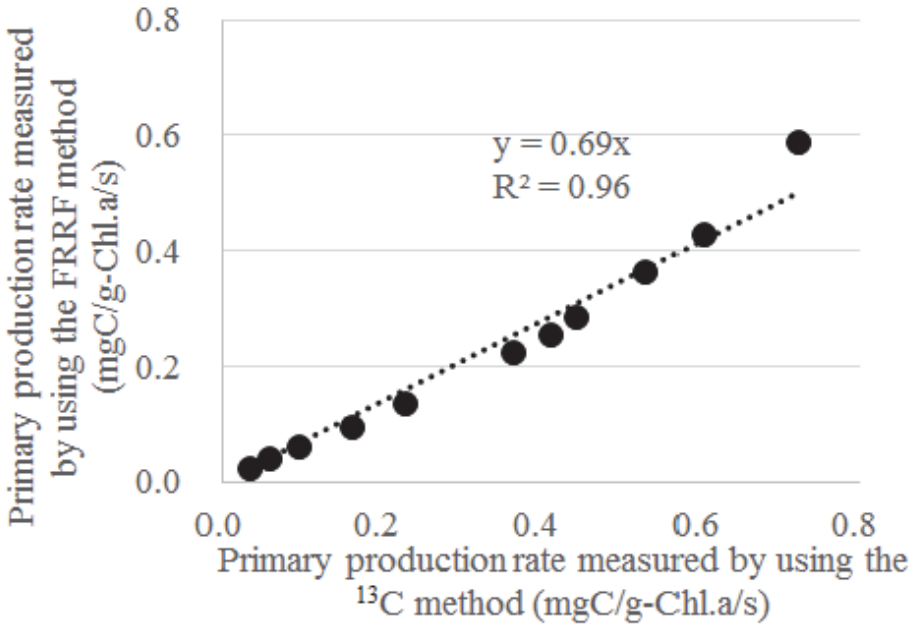


Fig. 4 Data comparison of primary production rates between the ^{13}C method and FRRF method

Project 2: Development of a strategic environmental assessment technology and its application to watershed restoration

The most obvious consequence of damming is the blockage of fish migration.

This is especially true on the Mekong River, because more than half the fish species in this river have migratory life cycles. We investigated the migration of Siamese mud carp (*Henicorhynchus siamensis* and *H. lobatus*), two of the most economically important fish species in the Mekong River, by using an otolith microchemistry technique. Otolith strontium and barium profiling revealed extensive synchronized migrations, with similar natal origins among individuals captured within the same sampling location. The profiles also revealed that movement of *H. siamensis* had been severely suppressed in one of the Mekong River tributaries where a series of irrigation dams had blocked their migration path.

Henicorhynchus lobatus collected both up- and downstream from a proposed major hydroelectric dam (the Don Sahong Dam) exhibited significantly different otolith “surface” elemental signatures but not different “core” signatures; these represent the water elemental signatures of fishing grounds and spawning grounds, respectively (Fig. 5). This suggests that a population of the species, dispersing from a single natal origin, migrated either up- or downstream through the proposed dam site before being captured by the fishermen. Together with other evidence, this finding raises concerns over this and other hydropower projects along the river.

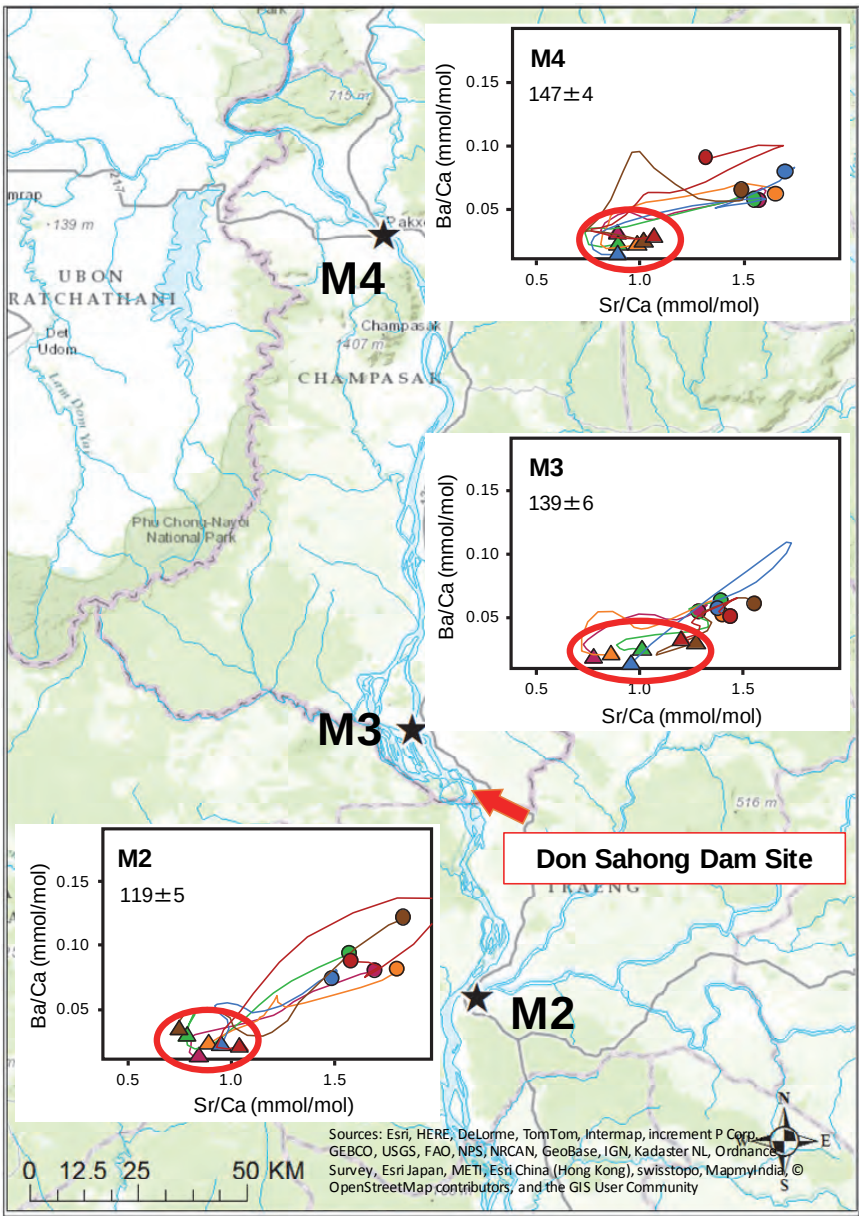


Fig. 5 Lifelong Sr-Ba profiles of Siamese mud carp otoliths from birth (△) to death (○) in individuals collected at three sites located down- (M2) and upstream (M3, M4) of the proposed Don Sahong Dam site

To predict the impact of dam construction on fish species diversity and biomass in the Mekong River, we developed a meta-ecosystem model, which assumed multiple (>10) riverine ecosystems characterized by unique food web structures and connected longitudinally along a river channel. We then ran a computer simulation using this model under two scenarios: dammed and undammed. The simulations showed that fish diversity would decrease significantly not only near the dam but also in areas further upstream to the dam. Contrary to our expectations, the effect of damming on species diversity was much more severe for non-migratory fish than for migratory fish. After damming, fish biomass near the dam would increase; however, this effect varied depending on the feeding types of the fish (Fig. 6).

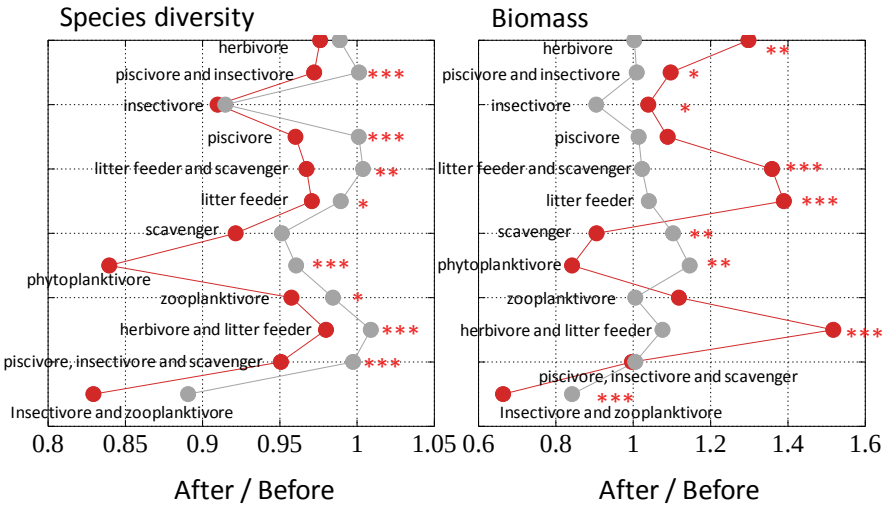


Fig. 6 Results of a simulation using the meta-ecosystem model, showing changes in species diversity (left) and biomass (right) after damming (red circles) compared with the control scenario of no damming (gray circles). Significant differences are indicated by * $P < 0.05$, ** $P < 0.01$, and *** $P < 0.001$.

We also began assessing the damming impact at a catchment scale by using the National Integrated Catchment-based Eco-hydrology (NICE) model. NICE is a process-based model that incorporates surface–groundwater interactions, has up- and down-scaling capabilities across multiple spatial scales, and simulates feedback from hydrologic, geomorphic, and ecological processes. The model was successful in reproducing hydrological events unique to the Mekong River. The model predicted changes in hydrologic characteristics, sedimentation processes, and nutrient cycling associated with the construction of a dam and its reservoir on the main stream of the Mekong River.

Modeling is valuable for providing alternative plans for hydroelectric dam development in the Mekong River Basin; it provides information on possible environmental changes and their implications for fish diversity and biomass and the ecological services they provide. For example, it may allow the proposal of alternative locations for dam construction within the same river basin that might result in lesser impacts.

2. Special Research Projects

Special issue 1: A study of PM in urban atmosphere for reduction of PM and evaluation of toxicity and health impact of PM based on chemical compositions

An environmental standard for fine particulate matter ($PM_{2.5}$) in Japan was set in September 2009. In order to conform to this environmental standard, it is necessary to consider the countermeasures to air pollutant emissions on the basis of information on the various emission sources. The performance of the chemical transport model (CTM) needs to be improved, because organic matter content is largely underestimated by this model when CTM is compared with the observed results. The environmental standard of for $PM_{2.5}$ was determined on the basis of its health effects. However, little is known about the toxicity of secondary organic aerosols (SOAs) produced from various volatile organic compounds (VOCs). SOA toxicity therefore needs to be assessed. The following studies are planned:

1) Spatial and temporal elucidation of PM concentration distributions on the basis of an improved emissions inventory, physico-chemical properties of PM, field observations, and improved CTM.
2) Toxicity studies of the chemical constituents of PM are performed with PM chemical composition.

SOA production and toxicity studies

To study the toxicity of SOAs, we developed a small reaction chamber system for α-pinene/ozone reaction and photo-oxidation of m-xylene, 1,3,5-trimethylbenzene, 1,3-butadiene, and isoprene in the presence of nitric oxide. After reaction, each SOA was collected on a Teflon filter for use in experiments to determine the chemical properties and toxicities associated with oxidative stress. Amounts of oxidants were determined by using the KI (potassium iodide) method; we also measured the consumption of dithiothreitol (DTT) as an indicator of the oxidative potential of SOA. Each SOA solution was added to alveolar epithelial cells and its cytotoxicity was assessed. Furthermore, we assessed the expression of the heme-oxygenase-1 (HO-1) gene, which is a sensitive marker of oxidative stress. The amount of oxidant was highest in the case of α-pinene-SOA, but consumption of DTT was higher in other SOAs: it was highest for isoprene-SOA and second highest for m-xylene-SOA. Cytotoxicity and HO-1 induction by m-xylene-SOA were higher than those of any other SOAs; they were second highest in 1,3-butadiene-SOA. Toxicities were higher for SOAs generated from precursors emitted from anthropogenic sources (m-xylene, 1,3,5-trimethylbenzene, and 1,3-butadiene) than for those generated from natural sources such as α-pinene and isoprene. To study the effect of aging on the toxicity of m-xylene-SOA, we conducted aging experiments for 3, 5, and 15 h. We found that cytotoxicity increased with increasing reaction duration, and HO-1 induction peaked at 5 h;

toxicity thus changed with aging, and aging may play an important role in the health effects of SOAs. These results also indicated that the time scale of the response differed between the KI and DTT assays and suggested that toxic reactants in SOAs were degraded with aging.

Field observations and toxicity studies of PM in the atmosphere

We performed field measurements in the Kanto area of Japan in summer 2012 and analyzed the chemical composition of PM. The results were then compared with those of the CTM to evaluate the CTM's performance. The CTM overestimated the results for nitrate and underestimated them for organic matter. Oxidative stress associated with airborne PM, as measured by quantifying HO-1, was lower by one order of magnitude than that associated with anthropogenic-origin SOAs (e.g. SOAs produced from m-xylene) in the atmospheric chamber. The major species of PM were organic matter and sulfate; the percentage of organic matter was about 50%. We used the positive matrix factorization method to evaluate the oxidation of organic matter. Eighty percent of organic matter was oxygenated—a higher value than in previous studies in urban areas. The correlation between the oxidation of organic matter and oxidative stress as assessed by using HO-1 was low.

Improvement of chemical transport model and simulation of $PM_{2.5}$ distribution

Improvement of SOA models is critical for an accurate understanding of the behavior and sources of atmospheric aerosols. In this study, we compared the results of box-model simulations using five SOA models [two yield models, a volatility basis set (VBS) model, a mechanistic model, and a near-explicit model]. The performances of the models were evaluated by comparing the simulation data with the observed ratios of SOA concentration to odd oxygen concentration in Tokyo. All five models gave similar results for the concentrations of gaseous species, including ozone, reactive nitrogen, hydroxyl radicals, and VOCs. In contrast, SOA concentrations varied substantially among the five models. The VBS model reproduced the observed [SOA] to [O_x] ratio well, whereas the other four models substantially underestimated the ratio.

Evaluation of models simulating temporal and spatial variations in $PM_{2.5}$ chemical compositions in Japan has been limited by the lack of observational data. In this study, we used $PM_{2.5}$ chemical composition data collected simultaneously over the Kanto area in summer 2013 to evaluate the results of three-dimensional simulation models. Three sensitivity simulations—one based on a SOA yield model and two based on a VBS model—were compared. The SO_4^{2-} concentration was reproduced well by all the simulations. The NO_3^- concentration was overestimated by the standard simulation and was better reproduced by a model in which the dry-deposition velocities of nitric acid and ammonia were enhanced by a factor of 5, as was done in a previous study. The OA concentration was greatly underestimated by the simulation based on the SOA yield model but was better reproduced by the simulations based on the VBS model, because aging reactions

were considered in the latter. Among the simulated organic aerosols, biogenic SOA had the highest contributions to the organic aerosol mass concentration, followed by anthropogenic SOA. These contributions need to be validated against the observation-based source contributions of organic aerosols in future studies.

Special issue 2: Flux estimation from sediment in nutrients and global warming gas by MRI and stable isotope analysis

Many shallow inland waters globally are subjected to high nutrient concentrations and high levels of primary production. Excessive amounts of particulate organic matter (POM) in the water column accumulate in surface sediments and accelerate the sediment oxygen demand (SOD). Even in shallow lakes and ponds, increased SOD decreases the utilization of dissolved oxygen (DO) in surface sediments, causing the disappearance of large benthic organisms such as bivalves and chironomids. Chironomids are primary benthic organisms that help produce oxidative conditions in surface sediments via their tube structures. The disappearance of chironomid larvae would therefore accelerate the development of anoxic conditions at the sediment surface and the efflux of nutrients to the water column. In addition, changes in oxic and anoxic conditions would affect the flux potentials of global warming gases such as methane and CO_2. Despite these issues, there is little knowledge about the relationships among oxic or anoxic conditions, tube structures, and nutrient efflux from the sediment surface. A lack of techniques to visualize and quantify tube structures in the sediment has hampered progress on this research subject. Therefore, in this study, in a world first, we used MRI analysis to visualize chironomid tube structures in sediments (Fig. 7). After optimizing the MRI analysis, we were able to estimate the maximum depth of the tube structures in sediment cores and examine its relationship with the vertical profile of pore-water chloride concentrations.

Fig. 7 MRI analysis of sediments (left), and self-advanced apparatus to quantify global warming gases in either the gaseous or dissolved phase in sediments (right)

As a second research issue, to analyze the flux potentials of global warming gases, we developed an apparatus to extract methane or CO_2 gas that was partly dissolved in pore water. We then measured the stable carbon isotope ratios and the concentration of the extracted gas. We used the sediment MRI results from Lake

Kasumigaura to determine whether the presence of tube structures affected nutrient flux from the sediment. From the carbon isotope ratios of the methane and CO_2 in the sediment, we were able to understand the primary methane production process and its levels of activity.

Tube structures revealed by MRI analysis: In Lake Kasumigaura there are two chironomid species. In our MRI study we used *Chironomus plumosus*, which constructs relatively stable tubes, the insides of which are reinforced by the organism's secretion product. The analysis enabled us to observe the 3D distribution of the tube structures of *C. plumosus* (Fig. 8). In the sediment cores to which we had added chironomid larvae (9 individuals, 2 weeks' incubation), we found at least five thick, long tubes. In contrast, fewer than two tubes that were constructed by the individuals in the field were observed in the control cores. The significant difference in the number of thick tubes suggested that MRI analysis would be valuable for evaluating the existence and characteristics of chironomid tube structures in sediments.

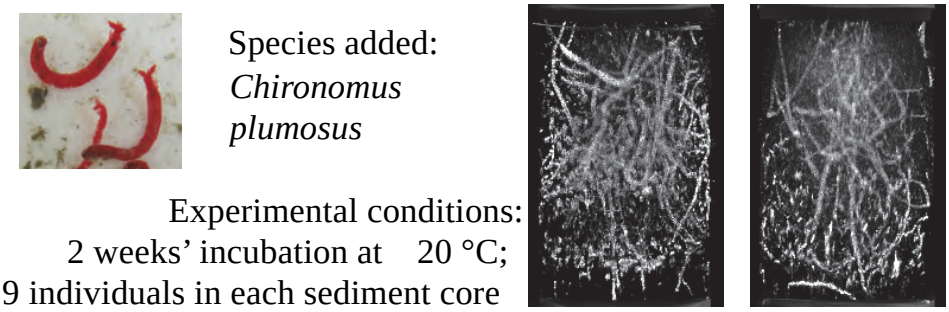


Fig. 8 Tube structure of chironomid larvae in lake sediment, as revealed by MRI analysis.

Stable carbon isotope ratios ($\delta^{13}C$) of methane and dissolved inorganic carbon (DIC) in sediments: In Lake Kasumigaura, the $\delta^{13}C$ of methane extracted from sediments was –69.7‰ ± 4.5 ‰ (n = 50); this value was typical of methane production via the reduction of DIC. In sediments where methane production via the reduction of DIC proceeds, the DIC that is the source of the methane becomes enriched in ^{13}C, whereas the methane that is produced is depleted in ^{13}C. Thus, we can expect a 1:1 relationship between the $\delta^{13}C$ values of methane and DIC in the sediment, especially when methane oxidation, which results in the reverse sense of ^{13}C enrichment, has little effect. Our results showed that there were significant 1:1 relationships between the $\delta^{13}C$ values of methane and DIC in the sediment, suggesting that methane production in the sediment was occurring via the reduction of DIC, with little methane oxidation (Fig. 9). In addition, we found a significant positive relationship between the methane concentration and the $\delta^{13}C$ of DIC. This finding showed that methane production activity could be estimated from the $\delta^{13}C$ values of methane and DIC.

The methane concentration was highest at a depth of about 10 cm from the surface. In an assessment of the effects of sediment temperature, methane production was high upon incubation above 20 °C and low at 4 °C.

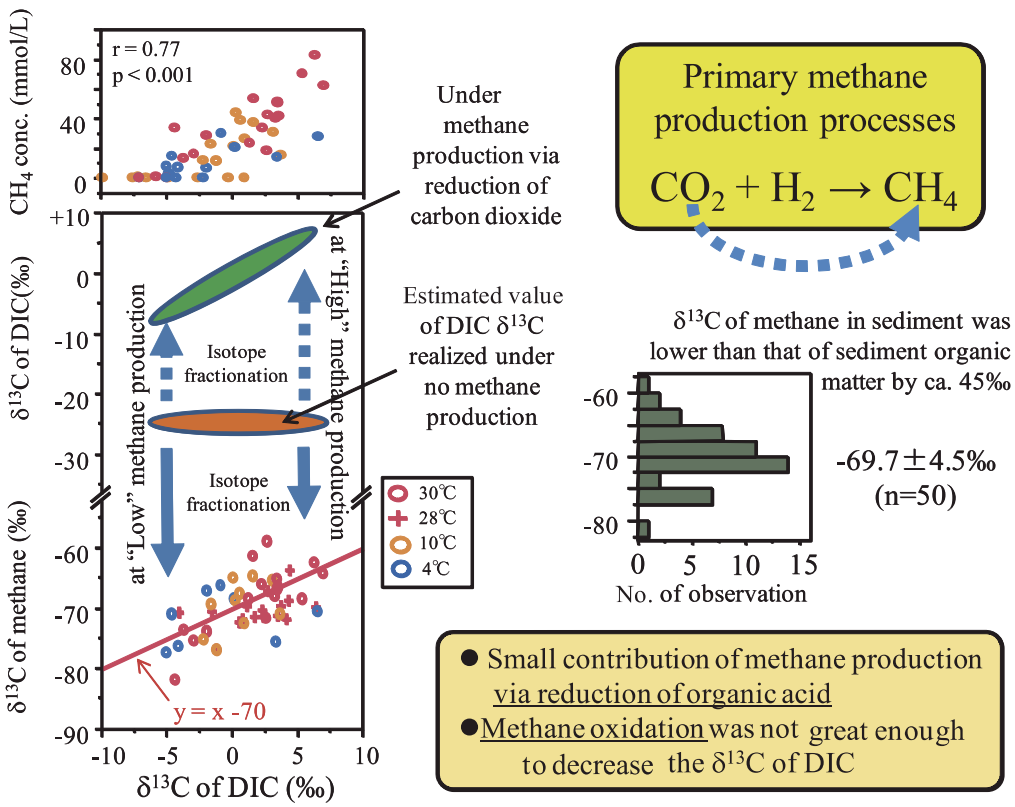


Fig. 9 Processes of methane production, as determined by the analysis of stable carbon isotope ratios ($\delta^{13}C$) in methane and dissolved inorganic carbon (DIC) in sediments

Center for Environmental Biology and Ecosystem Studies







A wetland with a large number of unique, endangered, and rare species, including (clockwise from left in the top panels) *Galium tokyoense*, *Monochoria korsakowii*, *Impatiens ohwadae*, *Swertia tosaensis*, *Ophioglossum namegatae*, *Amsonia elliptica*, and *Euphorbia adenochlora*. Such sites are of high priority for efficient conservation. (Photo taken in Watarase wetland, central Japan)

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 Priority Research Programs in the third 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. CEBES is also studying ecosystem management in the Mekong River watershed in partnership with the NIES Center for Regional Environmental Research. 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.

CEBES considers commitment to national and international frameworks and policies to be an important task in the conservation of biodiversity and ecosystem services. In 2014, three CEBES researchers were selected as experts and participated in the scoping and assessment tasks 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. Such contributions resulted in the citation of scientific papers by CEBES researchers in the technical report of the 4th edition of *Global Biodiversity Outlook*. 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. Biodiversity Research Program

The Biodiversity Research Program aims to elucidate the current status of biodiversity, predict its future, and propose reliable and effective methods for its conservation on scientific bases. Our tasks are to develop methods and protocols for monitoring the status of biodiversity at the genetic and landscape levels; assess the state of biodiversity on a broad scale and analyze scenarios for future prediction; and elucidate the effects of anthropogenic disturbances on biodiversity and find ways of managing these effects. The following are examples of our achievements in 2014.

1. 1 Estimation of extinction risks of Japanese plants and conservation area prioritization

To quantify the risks of extinction of entire taxa of living organisms we need to monitor changes in the population size of as many component species as possible over time. We performed the world's first quantitative projection of plant species loss at a national level, with stochastic simulations based on the results of population censuses of 1618 threatened plant species recorded in 3574 map cells, each about 100 km^2 in area. More than 500 lay botanists helped to monitor these taxa in 1994–1995 and 2003–2004. We used the resulting extensive dataset to perform a population viability analysis of each of the target species. We projected that between 370 and 561 vascular plant species will become extinct in Japan during the next 100 years if past trends of population decline continue (Fig. 1).

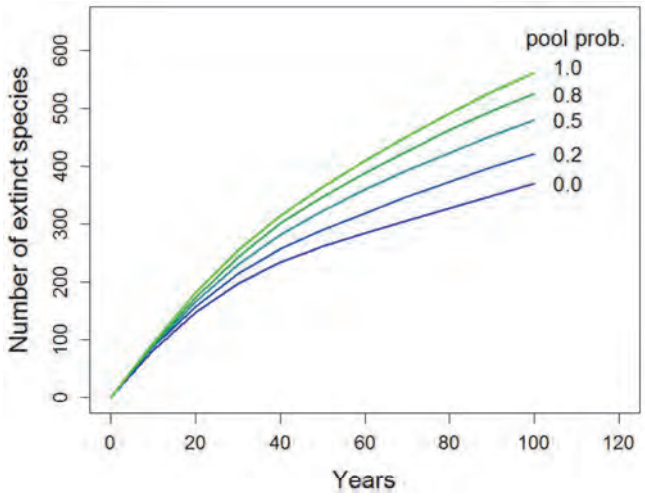


Fig. 1 Numbers of extinct species, as predicted by population viability analyses (PVAs) of 1618 vascular plant taxa in Japan. Results are given for different scenarios in the choice of the class of rate of change in population size for the PVAs: classes were drawn (i) from a pool of observed classes for each taxon over all of Japan (pool *P* = 1.0); (ii) from both the whole-of-Japan pool and the class observed in the same cell at a certain ratio (*P* = 0.2 to 0.8); and (iii) only from the class observed in the same cell (*P* = 0.0). Results from assumption (i) always gave the greatest rate of extinction.

By using time-series data, we showed that the existing national protected areas (PAs) covering about 7% of Japan will not adequately prevent population declines: even core PAs can protect, at best, 60% of local populations from decline. The Aichi Biodiversity Target to expand PAs to 17% of land areas (including inland waters) is not enough: only 29.2% of currently threatened species will become non-threatened under the assumption that the probability of the success of protection by PAs is 0.5, which our assessment shows is realistic.

Spatial allocation of management effort is essential for developing cost-effective strategies for biodiversity conservation. Computational optimization is a powerful tool for selecting a set of conservation sites that covers the maximum number of species under a given constraint, such as total budget. We developed a calculation tool for PA prioritization on the basis of reduction in extinction risks. The output of the calculation is a set of PAs that complementally reduces the extinction risks of multiple species. This set of PAs is more efficient than that provided by other methods, especially when the total area of a PA is limited.

1. 2 Study of the recent pandemic of amphibian diseases

Emerging infectious diseases play an important role in today's ongoing mass extinctions. Fungi constitute a greater threat than other taxonomic classes of pathogens and have recently caused some of the most severe die-offs and extinctions among a wide range of organisms. *Batrachochytrium dendrobatidis*, the classical cause of amphibian chytridiomycosis, has resulted in extensive disease and declines in a wide variety of amphibian species across the three orders [i.e., frogs and toads (Anura), salamanders and newts (Urodela), and caecilians (Gymnophiona)]. By using molecular DNA data, we discovered the genetic diversity and endemism of *B. dendrobatidis* in Japan. Our phylogenetic analysis of DNA variation in *B. dendrobatidis* strains worldwide suggested that the fungus originated on Okinawa Island.

Recently, a second highly pathogenic chytrid fungus, *Batrachochytrium salamandrivorans*, has emerged as the cause of a novel amphibian chytridiomycosis and of extirpation of populations of the fire salamander *Salamandra salamandra* in northern Europe in a region where *B. dendrobatidis* is in a state of stable coexistence with the amphibian communities. We screened more than 5000 amphibians from across four continents (Europe, Africa, Asia, and North and South America). Detection of *B. salamandrivorans* DNA was limited to East Asia (Thailand, Vietnam, and Japan) in the absence of obvious disease and to Europe (the Netherlands and Belgium) in association with severe disease outbreaks. These findings suggest long-term endemism of this species in Asia and a recent incursion into Europe.

Experimental assessment of pathogenicity to amphibian species showed that *B. salamandrivorans* is restricted to, but highly pathogenic for, salamanders and newts. Phylogenetic analysis and analysis of data on the disease susceptibility of each amphibian species tested revealed that the pathogen likely originated, and remained in coexistence, with a clade of salamander hosts for millions of years in Asia (Fig. 2).

From our studies of *B. dendrobatidis* and *B. salamandrivorans*, we concluded that globalization and lack of biosecurity in the wildlife trade have triggered a pandemic of wildlife infectious diseases and have thus increased extinction risks.

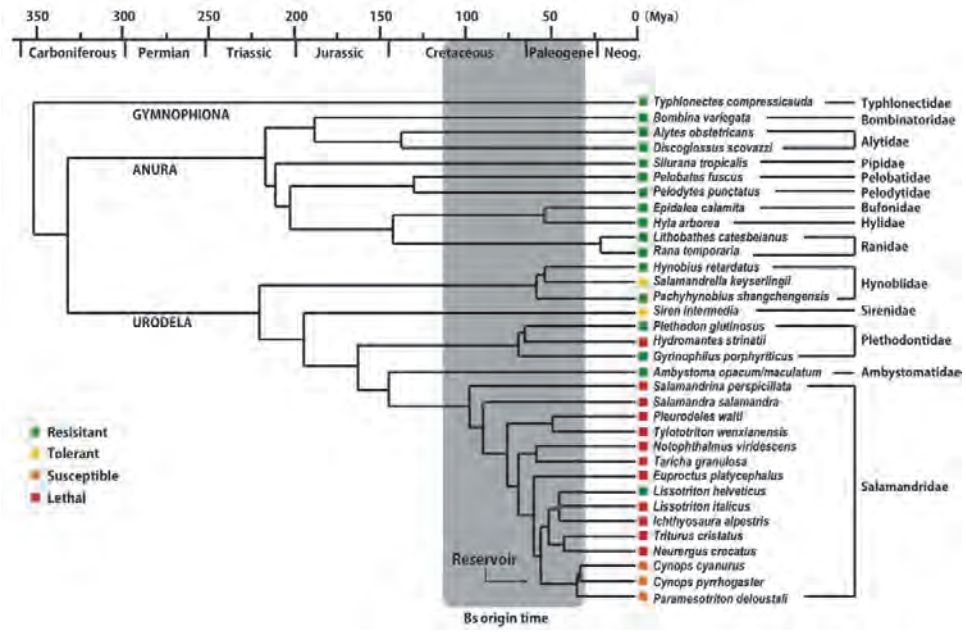


Fig. 2 Amphibian susceptibility to *Batrachochytrium salamandrivorans* (Bs) through time. Molecular time scale (millions of years ago) is shown for 34 species; colored squares indicate species categories based on experimental infection tests. Resistant: no infection, no disease; tolerant: infection in the absence of disease; susceptible: infection resulting in clinical disease with possibility of subsequent recovery; and lethal: infection resulting in lethal disease in all infected animals. Colored squares on nodes indicate the results of the maximum likelihood ancestral reconstructions ($P > 0.95$). The clade of susceptible Asian salamanders that originated in the early Paleogene is indicated by orange squares. The 95% highest posterior density for time of divergence between *B. salamandrivorans* and *B. dendrobatidis* is indicated in gray.

1. 3 High-resolution digital surface models using the Structure-from-Motion technique

Surface morphology is an important aspect of landscapes. In the 2010s, advances in computer vision and image analysis enabled the development of a novel photogrammetric approach called Structure from Motion (SfM). SfM is used to generate high-resolution digital surface models (DSMs) by using a fully automated procedure with stereo pairs of images. Reconstructing historical DEMs from historical aerial photographs is thus possible.

We used SfM to assess the accuracy of DSMs generated by using archived aerial photographs of Kume Island, Okinawa, Japan. Elevations from DSMs that had been generated from aerial photographs with ground-control points obtained by two-frequency GPS were compared with the results of a ground-leveling survey. It was possible to generate a DSM with accuracy comparable to that generated by conventional photogrammetry. We could thus obtain high-quality DSMs at a reduced cost. These models could be used not only to reconstruct landscapes (Fig. 3) but also to track the growth and decline of vegetation, both of which factors could be used to assess biodiversity.

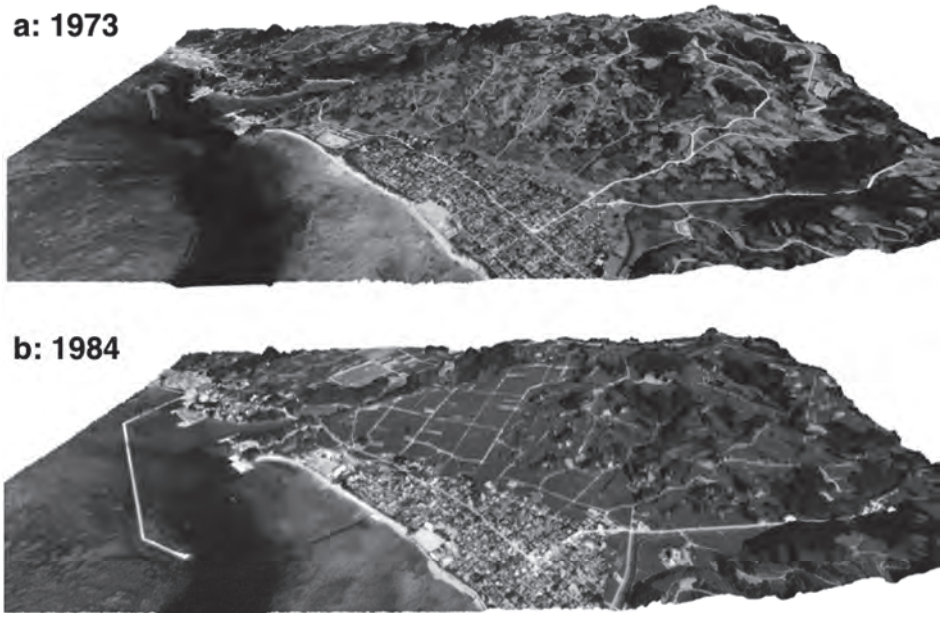


Fig. 3. Landscapes on the south side of Kume Island reconstructed from aerial photographs in (a) 1973 and (b) 1984 by using the Structure from Motion technique. Significant land modification occurred between these years.

2. Fundamental Research

2.1 Natural adaptation to water loss in terrestrial plants

Plants cope with severe climatic conditions through physiological acclimatization and evolutionary adaptation. Water availability and temperature strongly limit the natural distribution of terrestrial plant species. Because water deficiency can inhibit plant growth and limit wild plant propagation and crop yields, understanding plant responses to water deficiency is very important to our understanding of plant adaptation to environments. To determine how plants respond to water-deficiency stress, detailed genetic analyses of plant physiological responses to such stresses have been performed in a few crops and model plant species. For example, identifying genes by using mutants and transgenic plants helps to explain the mechanisms underlying water-loss resistance in plants. However, little is known about the genes and molecular mechanisms that could explain naturally occurring variations in this resistance in the environment. To further our understanding of plant adaptation to local water conditions it would be useful to compare drought-adapted and non-adapted wild species or cultivars.

We therefore analyzed intraspecific water-loss tolerance in two accessions of *Arabidopsis thaliana*, Columbia (Col)-0 and Wassilewskija (Ws)-2. Measurement of weight loss in detached seedlings and survival rates under water-deficient conditions showed a clear difference between the water-loss-tolerant Col-0 and the water-loss-sensitive Ws-2 (Fig. 4A and 4C). Thermal imaging of detached seedlings showed that the stomatal response occurred more rapidly in Col-0 than in Ws-2. To identify the gene loci responsible for the difference in water loss resistance between Col-0 and Ws-2, we performed a QTL (quantitative trait loci)

analysis in 59 recombinant inbred lines. Only one peak with a significant LOD (logarithm of the odd) score (>3), located on chromosome 1 (jv26/27 marker located at 12.6 cM), was detected; this QTL was a possible candidate. To narrow down the location of this QTL, we searched the vicinity of the detected peak for genes known to be involved in stomatal movement. We found that the jv26/27 marker lies close to the *SLOW ANION CHANNEL–ASSOCIATED 1* (*SLAC1*) gene, which encodes a central guard cell S-type anion channel protein that is essential for stomatal closure in response to water loss. Comparison of the nucleotide and amino acid sequences in the two accessions revealed no distinct difference in the regions encoding SLAC1 protein. However, we found a 2.9-kbp deletion in the promoter region of *SLAC1* in Ws-2, suggesting that expression of *SLAC1* may have been altered between Col-0 and Ws-2. Consequently, we examined the *SLAC1* expression patterns in Col-0 and Ws-2. Histochemical GUS (β-glucuronidase) staining showed that *SLAC1* was expressed predominantly in the guard cells of Col-0 leaves (Fig. 4B). In Ws-2, *SLAC1* expression predominated in the vascular strands, with only trace levels detected in the guard cells (Fig. 4D). Furthermore, quantitative PCR analysis showed that *SLAC1* transcript levels in the guard cells were higher in Col-0 than in Ws-2. These *SLAC1* transcription analyses thus revealed low levels of accumulation of SLAC1 in the guard cells of Ws-2. The difference in water loss tolerance between Col-0 and Ws-2 was therefore due to the difference in the *SLAC1* promoter region: *SLAC1* promoter–driven *SLAC1* expression was greater in Col-0 than in Ws-2, as was the consequent SLAC1 protein production. As a result, the stomata in Col-0 were able to close more robustly than those in Ws-2 under water-loss conditions.

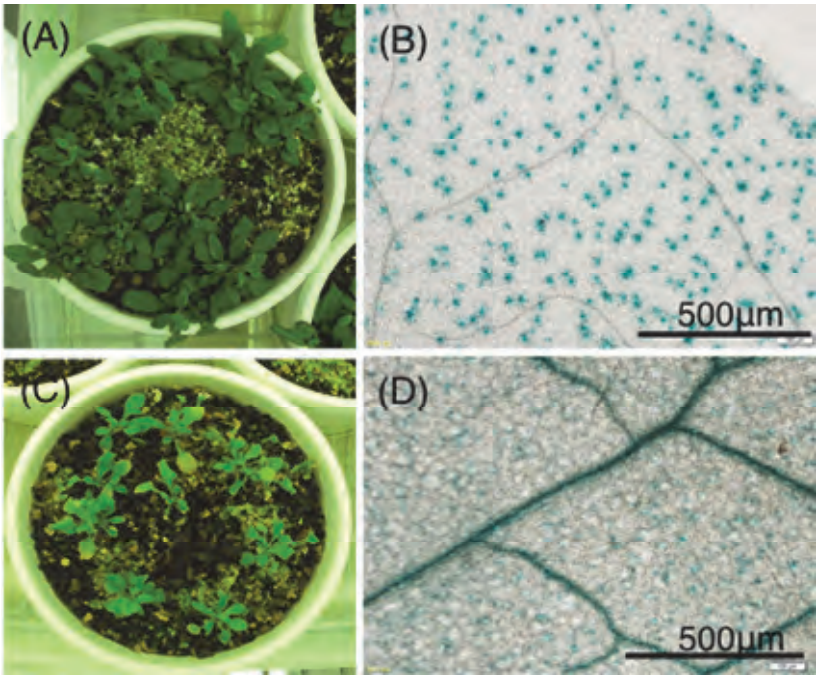


Fig. 4
Dehydration tolerance and histochemical localization of GUS activity in Col-0 and Ws-2 accessions of *Arabidopsis*. Plants were grown on soil for 14 days and then deprived of water for 28 days. Photos show Col-0 (A) and Ws-2 (C) after 28 days of water deficiency. The survival rate of Col-0 was 100% (143/143), whereas that of Ws-2 was 71.7% (71/99). Also shown are SLAC1 localization patterns in a Col-0 leaf (B) and a Ws-2 leaf (D).

2.2 Effects of awareness of ecosystem services on people's intentions to behave in ways that conserve biodiversity

Involvement of a wide range of stakeholders in biodiversity conservation actions is essential for implementing persistent conservation activities at large spatial scales; this implementation is one of the main goals of the Aichi Biodiversity Targets adopted at the COP10 Convention on Biological Diversity. Public participation is particularly important given its potential to cover a wide spectrum of biodiversity conservation issues. To facilitate participation, it would be helpful to understand how people's intentions to behave in ways that conserve biodiversity are determined and to find out which factors play an important role in this process.

We used social psychology methods to examine how awareness of ecosystem services affects people's behavioral intentions toward conservation actions. We designed a questionnaire in which people were asked to state their awareness of ecosystem services on a scale of one to five. We collected data from 5225 people through an Internet survey in 2011. By using the data and a structural equation analysis, we tested a decision-making model modified from an existing social psychological model to incorporate the causal paths from people's awareness of ecosystem services to their intentions to behave in ways that conserve biodiversity.

Our results demonstrated that, from among the awarenesses of four types of ecological services (supporting, provisioning, regulation, and cultural), only awareness of cultural services significantly facilitated positive intentions to behave in a way that conserved biodiversity (Fig. 5). Two social psychological terms—consciousness of social norms and the cost of the conservation activity—respectively had significant positive and negative effects on behavioral intentions. These results suggest that improving people's awareness of ecosystem services—especially cultural services—is important in facilitating their participation in conservation activities.

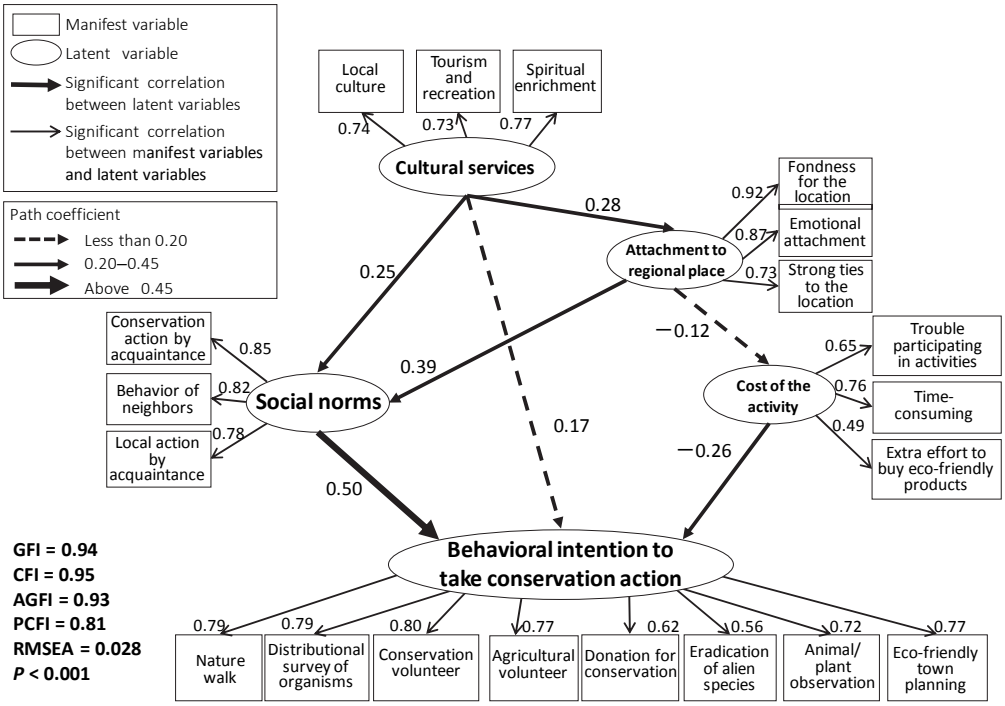


Fig. 5
Path diagram of the relationships between each of the factors affecting people's intentions to behave in ways that conserve biodiversity.

3. Platform of biodiversity databases

3.1 Biodiversity data publication via the Global Biodiversity Information Facility (GBIF)

Sharing scientific data online has become a significant means of support for people engaged in biodiversity studies that cover a broad range of data types. During the current five-year plan we have released a variety of databases on our websites, including those accumulated through lake monitoring, DNA barcoding, and our initiatives for the preservation of biological resources.

To help enhance the international infrastructure for open data, in 2014 CEBES joined the steering committee of JBIF (the Japan Node of the Global Biodiversity Information Facility), thus supporting the activities of a working group to promote the publication of biodiversity data via GBIF. We have also published four datasets on GBIF, namely those on fish monitored in Lake Kasumigaura (743 records); migratory shorebirds (sandpipers and plovers) in Hokkaido (282 records); algae in the Microbial Culture Collection (185 records); and chironomid specimen records in the Chironomid DNA Barcode Database (396 records). All datasets are available at GBIF (http://www.gbif.org/).

3.2 Chironomid DNA Barcode Database

We have adopted DNA barcoding to monitor the biodiversity of insects of the family Chironomidae. DNA barcoding is a molecular methodology for identifying

biological species on the basis of species-specific DNA sequences of the standard barcode region of genome DNA (the “DNA barcode”). The family Chironomidae is the most species-rich and often most abundant group of insects in the freshwater environment. Members of this family are therefore useful indicators of water and environmental quality and play important functional roles in ecosystems.

In the first step of DNA barcoding, we collected voucher specimens of representative species and sequenced the DNA of the mitochondrial CO1 (cytochrome c oxidase subunit 1) gene to generate DNA barcodes. In FY 2013, we built up a chironomid specimen DNA database storing species names, DNA barcodes, and collection records (date, place, and collector’s name) of the voucher specimens in Japanese. In FY 2014, we expanded this database to the size of 400 voucher specimens of 64 species and created an English language version, the Chironomid DNA Barcode Database. We registered these DNA barcodes in the DNA Data Bank of Japan. They have now attracted wide attention both inside and outside Japan, triggering the exchange of chironomid specimens and taxonomic information.

The chironomid database has yielded a number of other outcomes. For instance, we have uncovered several cryptic species. Several pairs of species that were hard to discriminate morphologically have been successfully discriminated by DNA barcoding. Because the cryptic species we have uncovered are encountered frequently during surveys of freshwater environments, detailed descriptions of them are indispensable to develop biodiversity monitoring.

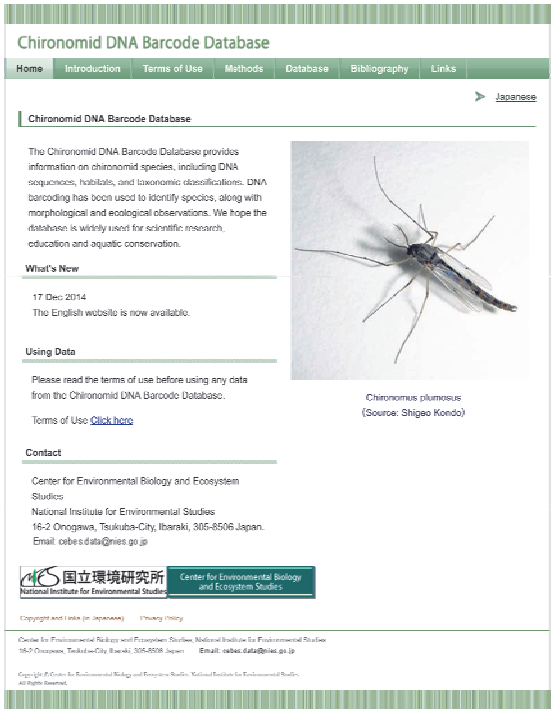
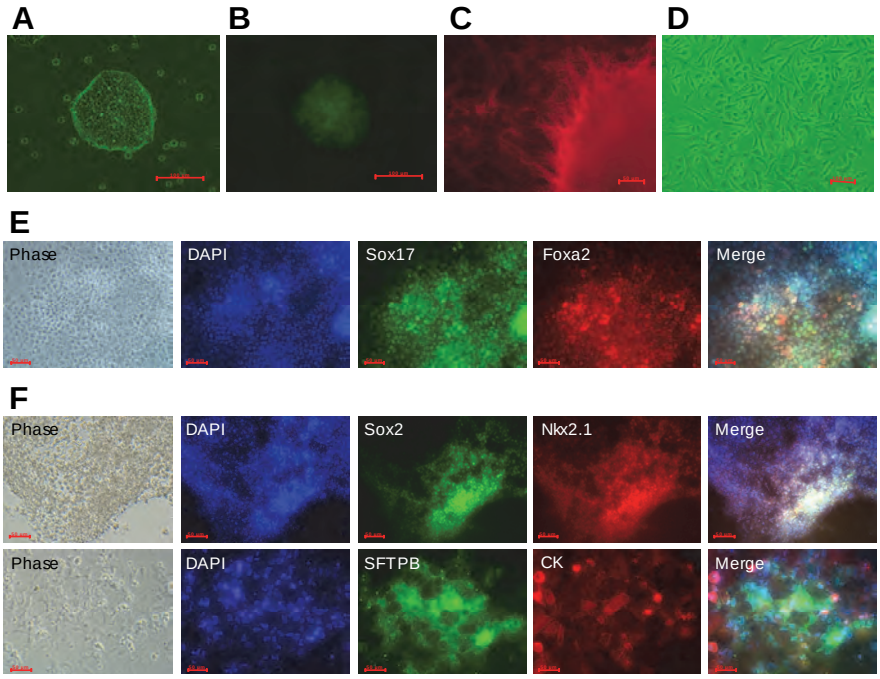


Fig. 6
Home page of the Chironomid DNA Barcode Database website at http://www.nies.go.jp/yusurika/en/index.html

Center for Environmental Health Sciences



Differentiation of mouse induced pluripotent stem (iPS) cells into various target cells
A. Phase-contrast photomicrograph of a mouse iPS cell colony. B. Green fluorescent protein (GFP) fluorescence in mouse iPS cells. This iPS cell line expresses GFP when it maintains pluripotency. C. Immunofluorescence for Map2, a specific marker of neuronal cells. D. Mouse iPS cells differentiated into macrophage-like cells. E. Immunofluorescence for specific markers of definitive endoderm. Mouse iPS cells differentiated into definitive endoderm. Almost all cells were positive for Sox17 and Foxa2 (day 7). F. Immunofluorescence for Sox2, Nkx2.1, surfactant protein B (SFTPB), and pan Cytokeratin (CK). Mouse iPS cells differentiated into lung epithelial–like cells (day 13). These lung epithelial–like cells were positive for SFTPB, Sox2, and Nkx2.1. The cells were also positive for the epithelial marker panCK.

The health impacts of environmental factors such as environmental pollutants have yet to be adequately clarified. To reduce and prevent such health impacts, we need to elucidate them and the mechanisms that underlie them, focusing primarily on fetuses, children, and vulnerable populations.

Our aims are to experimentally investigate and assess the health impacts of environmental factors and their modes of action; develop a simple and fast exposure and impact assessment system; and conduct epidemiological surveys and studies to identify environmental impacts on health and the factors underlying them.

Specifically, we intend to assess the health impacts of environmental factors such as environmental chemicals, metals, atmospheric pollutants, and nanomaterials, and to establish, improve, and verify methods of assessing these impacts. We also intend to clarify their mechanisms of action, with a focus on genomics and epigenetics. In addition, we aim to integrate, systematize, improve, and refine the epidemiological assessment of these health impacts.

Finally, as the National Center for **JECS (the Japan Environment and Children's Study)**, we aim to plan and coordinate studies, manage the work of participating institutions, organize and manage data, and analyze and preserve materials.

The National Center for JECS conducts studies in cooperation with regional Unit Centers recruited or selected through public advertising. Regional Centers have been established by universities or research institutions at 15 locations nationwide. The Centers provide local recruiting grounds and are responsible for conducting follow-up for enrolled children.

We are promoting a study program, namely the **Research Program on Environmental Health for Children and Future Generations** to be used by JECS.

We are in the process of obtaining a wealth of information from JECS. We will need to follow up on the survey results, for example, by biologically validating the epidemiological findings. To do this, we will elucidate the health impact mechanisms, or suggest target substances or impact indexes, that should be considered epidemiologically from among the enormous numbers of environmental pollutants and other health impact factors.

For this reason, we aim to comprehensively investigate, assess, and elucidate the impacts of environmental factors, beginning with environmental pollutants, on children and future generations and by using the epidemiological and experimental approaches described below. We aim to achieve the following:

- We will develop a model for exposure assessment of environmental pollutants that takes into account various factors, and simultaneously a method for measuring the multiple chemical components in human samples, and establish a comprehensive exposure assessment system that can be applied to epidemiologic research. This will enable more efficient and accurate exposure assessment.

- We will upgrade the epidemiological health impact assessment methods and biostatistical techniques used to evaluate the growth and development of children. We will apply the knowledge we gain to real-life epidemiological research measures, such as prevention.

- We will clarify the impacts of environmental chemical exposure during the fetal period and childhood on biological functions. We will also elucidate the epigenetic changes that accompany these impacts. Furthermore, we will provide biological grounds for epidemiological research by elucidating the contributions of epigenetic changes, and their induction mechanisms, to impacts on organisms.

- We will elucidate the impacts of environmental pollutants on immunological and allergic diseases by using animal disease models and cell lines, with children and the future generation as the primary targets. In addition, by constructing an assessment system that covers both simple screening and detailed assessment, we will supplement the JECS study data and suggest target substances or biological markers that should be preferentially investigated.

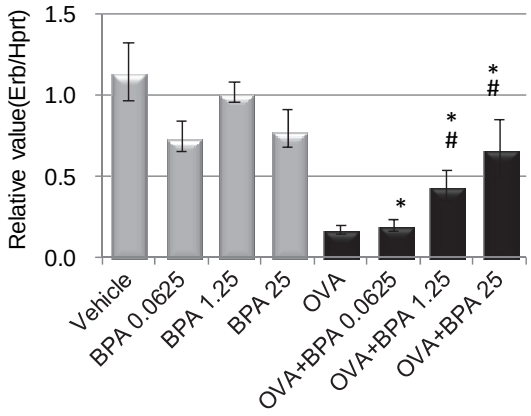
Our main research outcomes in FY 2014 were as follows.

In the **Biological Impact Research Section**, we have been studying the effects of environmental pollutants on the immune system and the central nervous system.

We investigated the mechanisms of the effects of intratracheal exposure to bisphenol A (BPA) on the immune system and central nervous system in a murine model of allergic asthma. Airway inflammation and Th2 immune responses were significantly greater after combined treatment with BPA and ovalbumin (OVA) than after OVA treatment alone. In contrast, a high dose of BPA reduced allergic airway inflammation. We evaluated gene expression in the lung by using RT-PCR to determine the effect of BPA exposure on allergic asthma. BPA exposure increased the mRNA levels of estrogen receptor-β in a dose-dependent manner in the presence of OVA (Fig. 1A). These results suggest that BPA exposure regulates allergic responses via disruption of the endocrine system. In addition, high-dose BPA exposure suppressed the proliferation and IL-4 production of splenocytes in the presence of OVA. We also investigated the effects of BPA on inflammatory markers in the hypothalamus of OVA-immunized allergic asthmatic mice. We

found that expression of the mRNAs of the proinflammatory cytokine IL-1β and the potent inflammatory marker COX2 was significantly decreased in mice exposed to moderate or high doses of BPA (Fig. 1B). These results suggest that exposure to BPA dysregulates neuroinflammatory markers in allergic asthmatic mice.

(A)



(B)

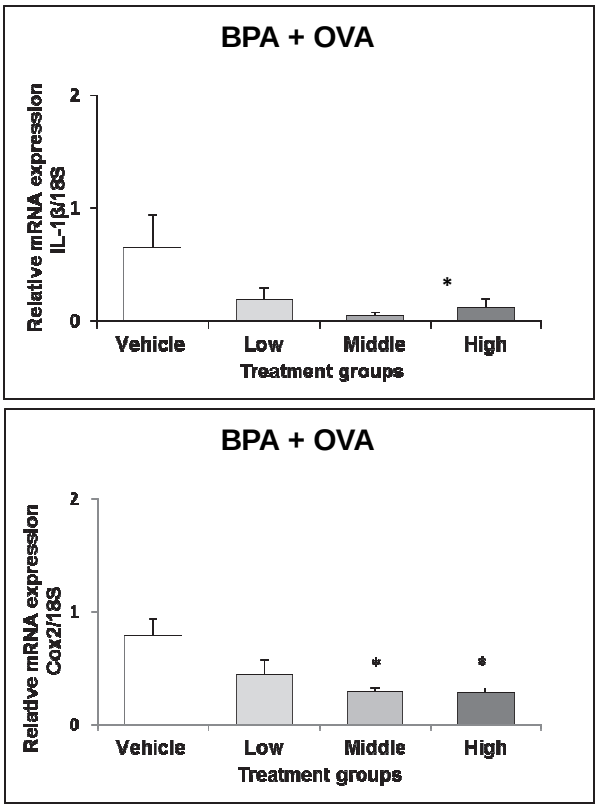


Fig. 1 (A) mRNA levels of estrogen receptor-β (Erb) in the lung following exposure to bisphenol A (BPA) in the absence or presence of OVA. The relative intensity was normalized to an endogenous control gene (hypoxanthine phosphoribosyltransferase 1; Hprt1). Data are means ± SE (n = 3 to 6; *P < 0.05 vs. vehicle group; # P < 0.05 vs. OVA group). (B) Expression levels of IL-1β and COX2 mRNAs in the hypothalamus of mice exposed to BPA with OVA immunization. Data are presented as means ± SE (n = 5 or 6; *P < 0.05 vs. vehicle group).

We investigated the effects of oral exposure to the brominated flame retardants decabromodiphenylether (DecaBDE) in C57BL/6J mice fed a high-fat diet (HFD) or a normal diet (ND). We observed no alterations in body or liver weight with or without DecaBDE treatment. However, a high dose of DecaBDE enhanced fasting blood glucose levels in both diet groups; this increase was more prominent in the HFD-fed mice. These results suggest that DecaBDE contributes to glucose metabolic dysfunction, resulting in hyperglycemia.

We investigated the effects of gestational and lactational exposure (from gestation day 13 to postnatal day 21) to diesel-exhaust-origin secondary organic aerosol (DE-SOA) on social behavior and related gene expression in mature mice (Fig. 2). Sociability, social novelty preference, and social interaction were markedly impaired, and expression of the mRNAs of estrogen receptor-alpha and oxytocin receptor was significantly decreased, in mice exposed to DE-SOA. Our results suggest that a constituent or constituents of DE-SOA may trigger late-onset neurotoxicity after early life exposure and may affect social behavior and related gene expression in the mouse hypothalamus.

We also investigated whether maternal gestational and lactational exposure to DE-SOA affects allergic airway inflammation in offspring. Maternal exposure to DE-SOA reduced allergic airway inflammation in both male and female offspring. In addition, levels of the mRNAs of the aryl hydrocarbon receptor (AhR) and Cyp1a1 (a member of the cytochrome P450 superfamily of enzymes) decreased in female lungs but not in male lungs. These results suggest that maternal exposure to DE-SOA contributes to dysfunction of immune responses in the offspring by reducing the levels of AhR and Cyp1a1.

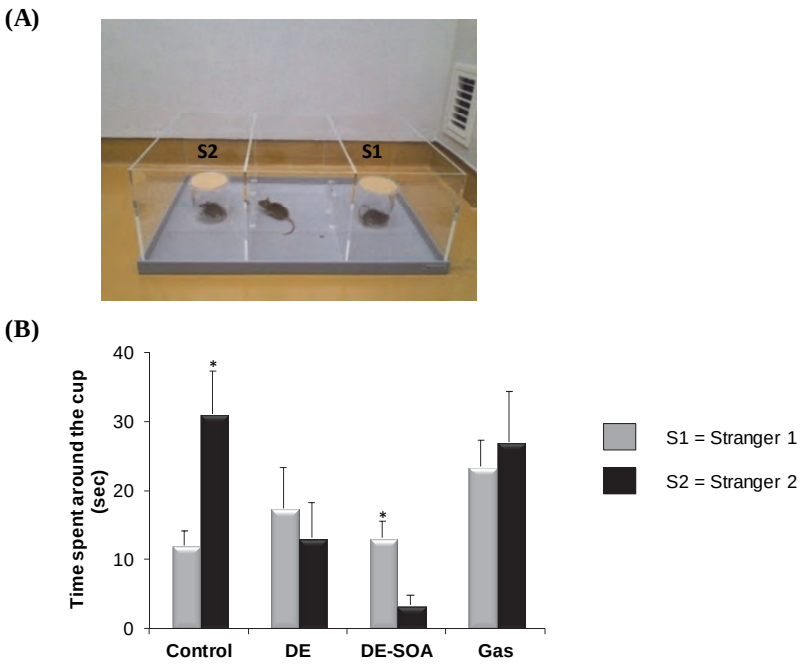


Fig. 2 (A) Social novelty preference test. (B) Time spent around the cup following maternal gestational and lactational exposure to DE (diesel exhaust), DE-SOA (diesel-exhaust-origin secondary organic aerosol), or gas without particles. Data are presented as means ± SE (n = 12; *P < 0.05, Stranger 1 vs. Stranger 2).

To explore the embryotoxicity of environmental chemicals, we used induced pluripotent stem (iPS) cells, which can differentiate into various somatic cells under suspension culture. Last year, when we exposed mouse iPS cells to di(2-ethylhexyl) phthalate (DEHP), a representative phthalate ester, differentiation was skewed toward the generation of ectoderm and neural cells, whereas DEHP suppressed the emergence of endoderm, mesoderm, and hematopoietic progenitor cells. This year, we examined the developmental toxicities of other phthalate esters, such as diisononyl phthalate (DINP), dibutyl phthalate (DBP), diethyl phthalate (DEP), and benzyl butyl phthalate (BBP). Exposure of iPS cells to these phthalate esters at 10 μM gave results similar to those with DEHP, but the levels of these effects were smaller than with DEHP (Fig. 3). DEHP thus had the greatest capacity for embryonic toxicity among the various phthalate esters.

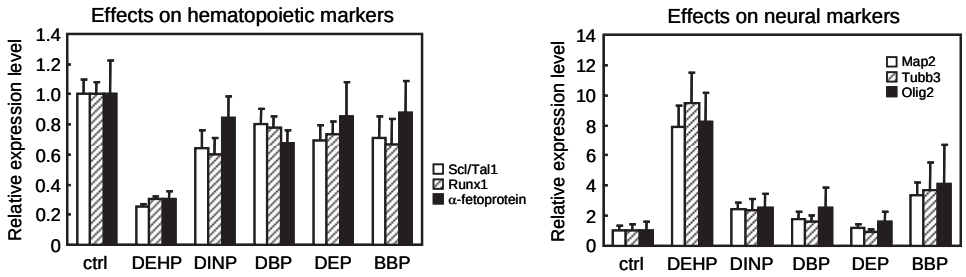


Fig. 3 Effects of various phthalate esters on the development of iPS cells

We also studied the experimental protocols used to differentiate mouse iPS cells into lung epithelial cells and macrophages as part of the development of a novel *in vitro* assay tool for assessing the toxicities of ambient pollutants. We were able to develop mouse iPS cells into $Nkx2.1^{+}SFTPB^{+}$ lung epithelial–like cells. Also, we obtained a relatively pure population of $CD11b^{+}F4/80^{+}$ monocyte-like cells, which then matured into macrophage-like cells.

In the **Molecular Toxicology Section**, we have been studying the effects of environmental chemicals on biological and physiological functions and molecular mechanisms. Recently, our particular focus has been on the effect of inorganic arsenic on cancer development and the central nervous system.

Previous studies have reported that gestational arsenite exposure of mice F0 females surprisingly increases the incidence of hepatic tumors, even in the F2 male in adulthood. This year, we demonstrated that expression of the genes encoding the hepatocellular carcinoma markers β-catenin (CTNNB1) and interleukin-1 receptor antagonist in tumors was significantly upregulated in F2 males born to F1 male progeny of females exposed to arsenite compared with those born to control F1 males. The mechanism behind this transgenerational effect needs to be clarified if we are to understand and prevent the transgenerational hazardous effects of environmental chemicals.

Chronic arsenite exposure also induces immunosuppression, but the precise mechanisms remain elusive. In this study, we investigated the consequences of long-term exposure of mouse B lymphoma A20 cells to arsenite. The results demonstrated that long-term arsenite exposure induced characteristics of senescence such as the appearance of enlarged and flattened cells (Fig. 4A top panels) and SA-beta gal positive cells (Fig. 4A bottom panels; arrows) through an increase in damage to DNA and accumulation of the Rb (retinoblastoma) family protein p130 (Fig. 4B) in lymphoid cells.

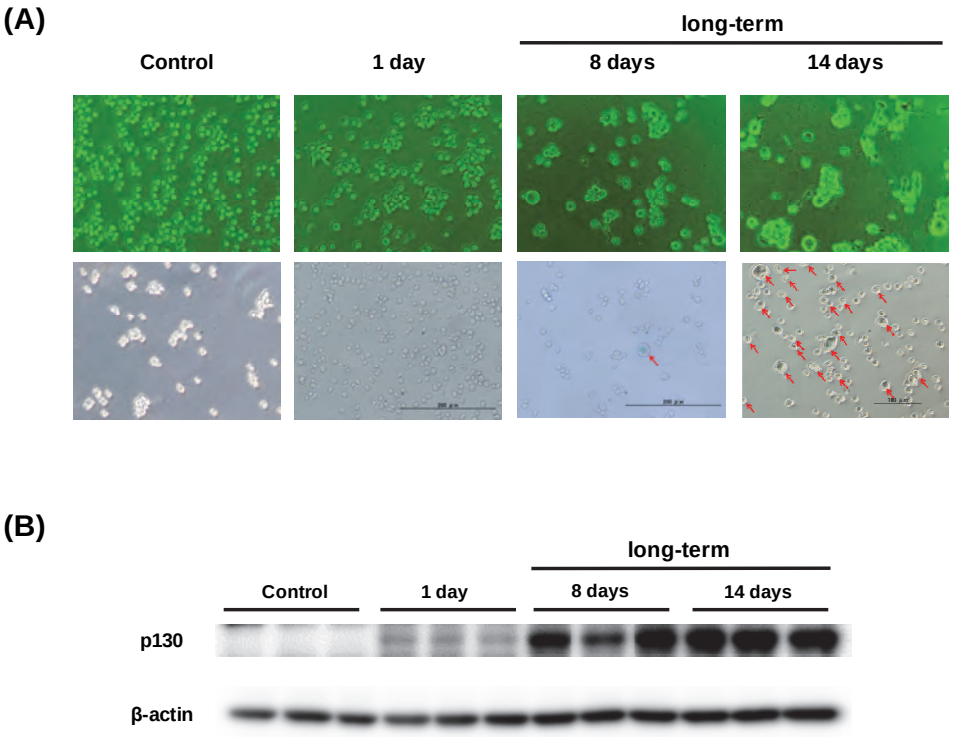


Fig. 4 (A) Morphological changes (top panels) and SA-β gal (senescence-associated β-galactosidase) activity (bottom panels; arrows) in A20 cells after long-term (up to 14 days') arsenite exposure.
(B) Levels of p130 protein examined by Western blotting after arsenite exposure. The housekeeping gene β-actin was used to confirm equal loading.

We performed experiments to assess whether developmental exposure to environmental chemicals impairs the central nervous system. The effects of a pesticide and a flame retardant were investigated by behavioral and physiological analyses in a mouse model. We found that developmental exposure from gestational to lactational period to a pesticide led to abnormal sexual and emotional behaviors.

In addition, developmental exposure to a flame retardant was found to impair the regularity of the estrus cycle. These results suggest that the development of neuroendocrine processes is sensitive to exposure to these chemicals in the environment.

We investigated metabolic interactions between arsenic (As) and selenium (Se) in rats co-administered arsenate and selenite. Male Sprague-Dawley rats were injected intravenously with arsenate or selenite alone or co-administrated with As

and Se, at a dose of 1.0 mg As or 1.0 mg Se/kg body weight. Twenty-four hours after administration, selenite significantly reduced the concentration of As in red blood cells (RBCs) and arsenate significantly increased the concentration of Se in RBCs. As and Se significantly increased the distribution of Se and As, respectively, to the kidney and increased biliary, urinary, and fecal excretion of Se and As, respectively, when these metalloids were co-administered. These results suggest that arsenate interacts with selenite and affects the tissue distribution and excretion of these metalloids in rats.

Naturally occurring inorganic arsenic has been causing serious health problems, such as cancer, in many Asian countries and other areas of the world. We aim to establish epigenetic markers to detect adverse biological effects of arsenic by analyzing the DNA methylation levels of affected genes. This year, we used pyrosequencing to analyze the DNA methylation level of the LINE1 region in the blood DNA of people who live in arsenic-endemic and non-endemic areas of Bangladesh. The pyrosequencing analysis revealed that DNA methylation levels in the LINE1 region were significantly lower in arsenic-endemic areas than in non-endemic areas. These results suggest that the LINE1 region may be useful as a DNA methylation marker to diagnose arsenic exposure.

The **Environmental Epidemiology Section** is involved in developing epidemiological methods and applications for estimating and assessing the health impacts of harmful environmental exposure. Listed below are the projects with which we have been involved, along with selected findings from our analyses.

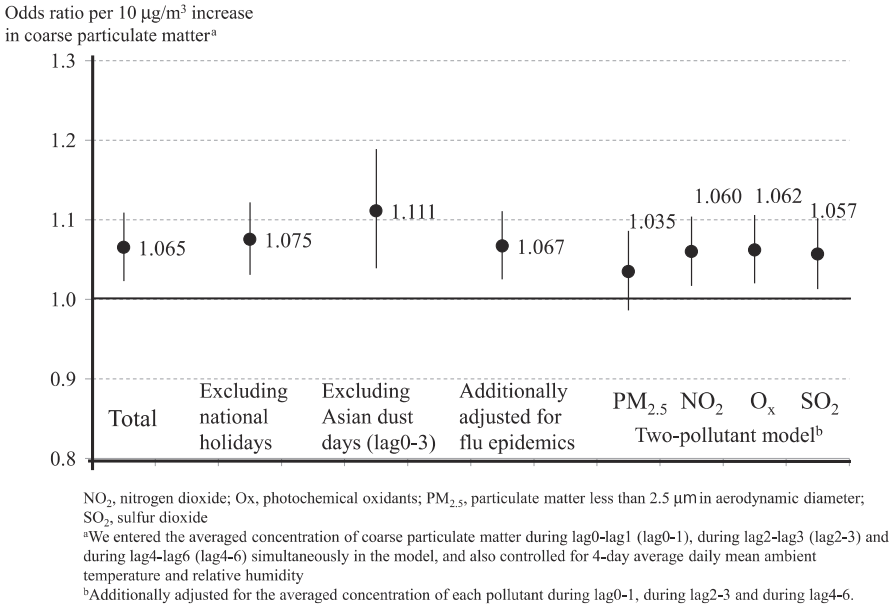


Fig. 5 Sensitivity analyses of the association between coarse particulate matter (lag 0 to 1) and emergency ambulance dispatches due to respiratory disease (*n* = 9716) in older adults (≥65 years). Error bars indicate 95% confidence intervals.

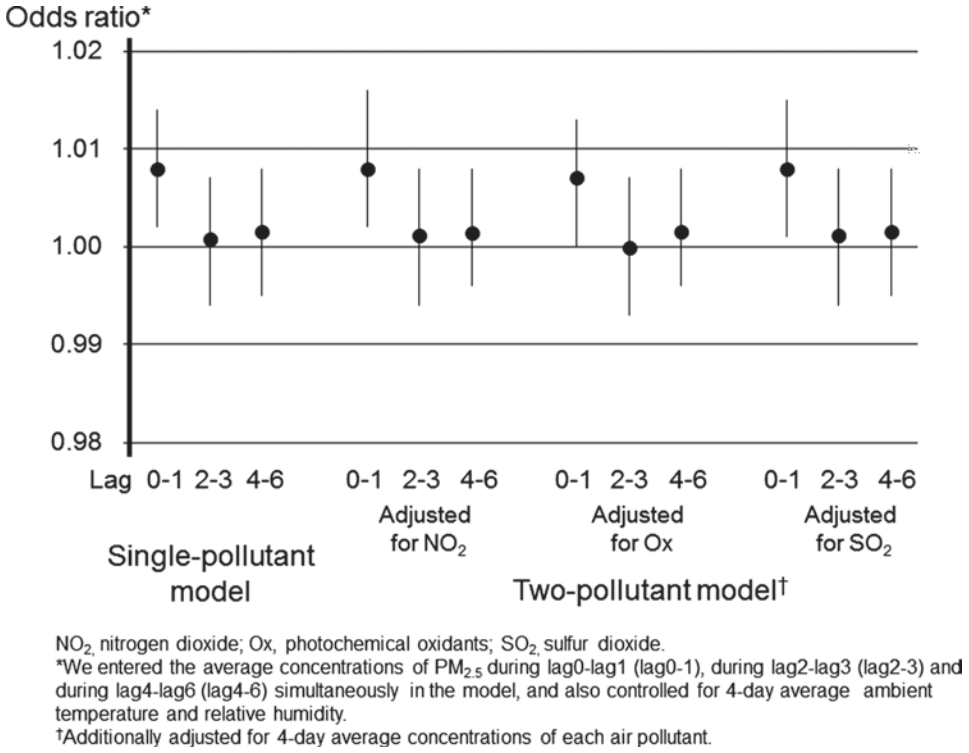
NO_2, nitrogen dioxide; Ox, photochemical oxidants; $PM_{2.5}$, particulate matter less than 2.5 μm in aerodynamic diameter; SO_2, sulfur dioxide

[a]We entered the averaged concentration of coarse particulate matter during lag0-lag1 (lag0-1), during lag2-lag3 (lag2-3) and during lag4-lag6 (lag4-6) simultaneously in the model, and also controlled for 4-day average daily mean ambient temperature and relative humidity

[b]Additionally adjusted for the averaged concentration of each pollutant during lag0-1, during lag2-3 and during lag4-6.

- There is no conclusive evidence of adverse health effects from short-term exposure to coarse particulate matter, so in this case-crossover study we looked for an association between exposure and emergency ambulance

dispatches (as a proxy for acute health outcomes). We found weak evidence of adverse effects of short-term exposure to coarse particulate matter on human health (Fig. 5).



NO_2, nitrogen dioxide; Ox, photochemical oxidants; SO_2, sulfur dioxide.
*We entered the average concentrations of $PM_{2.5}$ during lag0-lag1 (lag0-1), during lag2-lag3 (lag2-3) and during lag4-lag6 (lag4-6) simultaneously in the model, and also controlled for 4-day average ambient temperature and relative humidity.
†Additionally adjusted for 4-day average concentrations of each air pollutant.

Fig. 6 Odds ratios of emergency ambulance dispatches per 10-μg/m^3 increase in fine particulate matter ($PM_{2.5}$) concentration. Error bars indicate 95% confidence intervals.

- Providing further evidence of the short-term health effects of $PM_{2.5}$ exposure, we found that exposure was associated with an increased number of emergency ambulance dispatches. The effect was, however, relatively small. (Fig. 6).

- Recently, there has been increasing concern about the adverse health effects of exposure to desert dust events. However, the association between dust and the incidence of ischemic heart diseases is unknown. The aim of this study was to determine whether Asian Dust (AD), a windblown sand dust originating from mineral soils in China and Mongolia, was associated with the incidence of acute myocardial infarction (AMI). We found that exposure to AD a few days before symptom onset was associated with an increased incidence of AMI (Fig. 7).

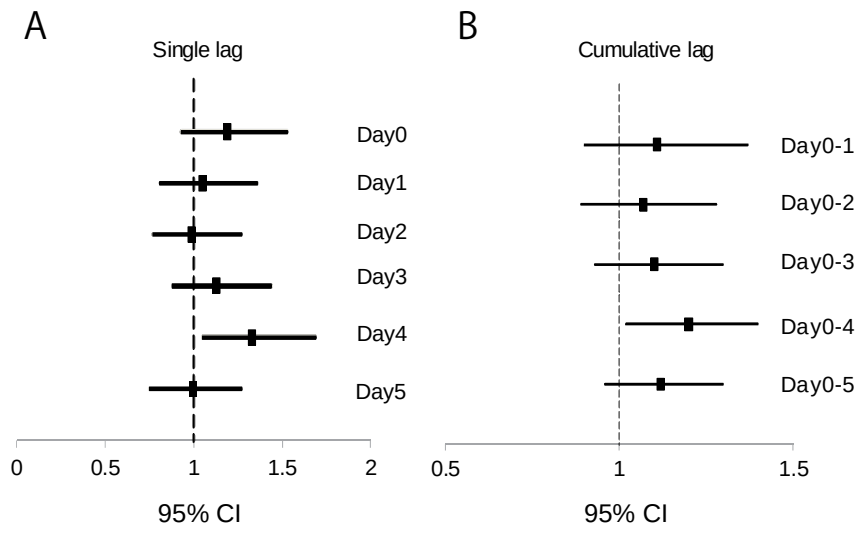


Fig. 7 Odds ratios with 95% confidence intervals (CIs) of acute myocardial infarction on Asian Dust (AD) days compared with non-AD days for single lag (A) and cumulative lag (B), adjusted for ambient temperature and relative humidity

- We compiled guidelines on epidemiologic statistics for summarizing and analyzing the JECS data mentioned earlier. We are continuing to upgrade our methods of assessing epidemiological health impacts and the biostatical methods used to evaluate the growth and development of children under continuous environmental exposure.

The **Integrated Health Risk Assessment Section** has developed high-throughput analytical methods for human biomonitoring. The methods have been tailored to enable the analysis of multiple compounds by using minimum amounts of biological samples in large-scale birth cohort studies. These methods are also "greener" and require minimum solvent use. To name but a few of the tests, we developed a method for analyzing elemental metals (including lead, cadmium, mercury, selenium, and manganese) by using only a dilution step followed by inductively coupled plasma mass spectrometry analysis. This eliminated the need for complex extraction procedures, saved on the use of hundreds of milliliters of solvents, and markedly shortened the analytical time. Another test we developed was for the analysis of perfluorinated compounds in drinking water. This method requires only 10 mL of sample, whereas conventional methods need at least 0.5 L.

We also developed a bioanalytical method for dioxins and dioxin-like compounds. Instrumental methods require tens of milliliters of blood samples—volumes that would unlikely be tolerated in large-scale birth cohort studies such as JECS. Our bioanalytical method can achieve optimal sensitivity by using a sample volume of 1 mL or less. We analyzed house dust samples for multiple compounds so that we could prioritize target compounds in cohort studies. An exposure model that we developed for radiological dose assessment is described in the Environmental Emergency Research Section.

The **Planning and Coordination Office** and the **Data Management and Analysis Office of the Children's Environmental Health Study** play key roles in JECS. JECS is a nationwide newborn cohort study that involves the recruitment of women in early pregnancy and the follow-up of their children until age 13. The goal of the study is to help us to understand the roles of various environmental factors in children's health and development. Recruitment started in 2011 and is now complete; the number of participants enrolled now exceeds 100,000. The number of biological samples collected from participants exceeds 200,000.

Center for Social and Environmental Systems Research

Stocktaking Plenary during UNFCCC COP20, held in Lima, Peru, in December 2014. The Lima Call for Climate Action agreement was reached at this conference.

The Forum on Eco City Bogor through Green Innovation was held in March 2015 in the city of Bogor in Indonesia through the collaborative efforts of Japan and Indonesia.

The Center for Social and Environmental Systems Research targets linkages between human activities and the natural environment in order to identify the relationships among socioeconomic systems and environmental issues. The work of the Center results in significant academic findings as well as proposals for environmental policies and a sustainable society covering a broad area, from global environmental issues such as global warming, to local issues such as recycling and lifestyles.

There are five research sections:

1. The **Environmental Economics and Policy Section** studies the economic and policy aspects of environmental conservation and analyzes the economic and political effectiveness of environmental policies.
2. The **Environmental Planning Section** works on new methodologies for understanding and assessing regional environments and investigates the current status of public environmental awareness and the promotion of voluntary action by individuals.
3. The **Integrated Assessment Modeling Section** develops integrated environment–economy models to assess environmental policies, such as those on global warming mitigation and adaptation, and sustainable development policies.
4. The **Sustainable Social Systems Section** studies sustainable futures for our society (i.e. a low-carbon society, LCS) and ways of achieving such a society in the long term without negative economic repercussions.
5. The **Environmental Urban Systems Section** analyzes urban and regional environmental options such as low-carbon cities and sustainable transportation systems.

Two research programs are conducted in collaboration among these five sections and other research centers at NIES: (1) Sustainable Social Systems and Policy Research Program; and (2) Eco-city Systems Research Program (Fig. 1). The main research outcomes of these two programs in FY 2014 were as follows.

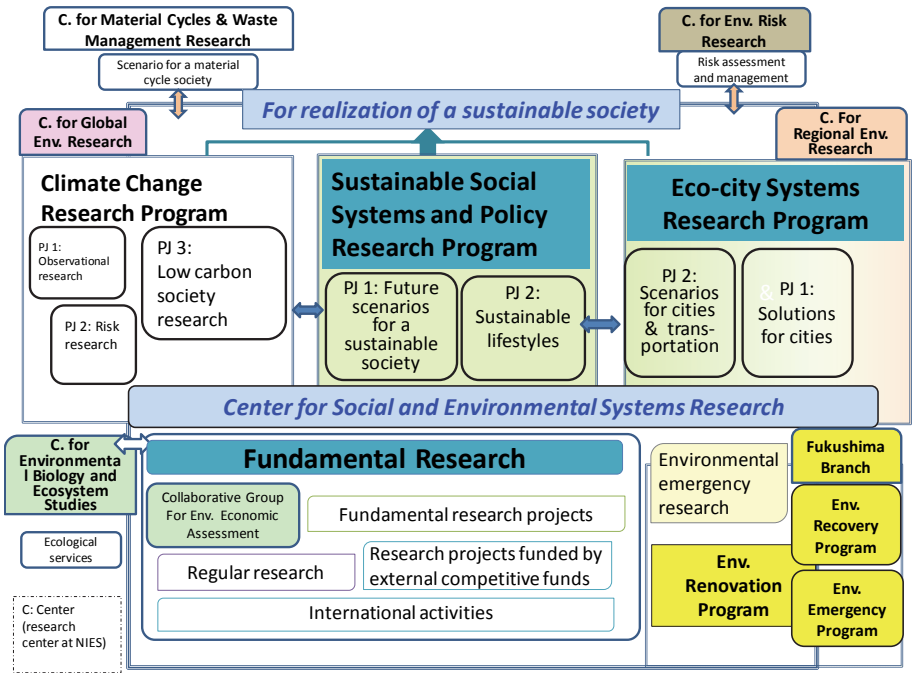


Fig. 1 Structure of research at the Center for Social and Environmental Systems Research

1. Sustainable Social Systems and Policy Research Program

We are tasked with the development of medium- and long-term visions for Japan; formulation of scenarios to achieve these visions; creation of policy roadmaps;and elucidation of specific strategies to promote social transformation. From the perspective of future scenarios for a sustainable society, descriptive socioeconomic scenarios based on sustainable development goals are being developed with an emphasis on the driving forces underlying environmental issues, as well as the concepts and trends of indicators of sustainability. In addition, as transformation strategies, sustainable development indicators and a comprehensive plan within a municipality are provided and the attendant issues are clarified. The consistency of models for socioeconomic activities in nine subregions of Japan has been verified on the basis of quantitative evaluations of the scenarios.

From the perspective of sustainable lifestyles and consumption patterns, the Sustainable Lifestyle Scenario 2030 (Fig. 2) has been developed as part of this research, and this scenario has been verified to be compatible with everyday lifestyles. This has been achieved by means of focus group interviews, a questionnaire survey, and workshops. Moreover, we have published a series of interviews with experts in fields related to our scenario, including social design, labor economics, social welfare, and family sociology, in an online magazine with a young readership that has a high degree of awareness of environmental issues.

The aim of these activities is to realize a vision for actions by individuals and households to construct a sustainable society from the perspective of consumption. Our scenarios, indicators, and models for the advancement of sustainability and the achievement of sustainable development are expected to contribute to policies for basic and comprehensive environmental plans and to the establishment of new research fields.

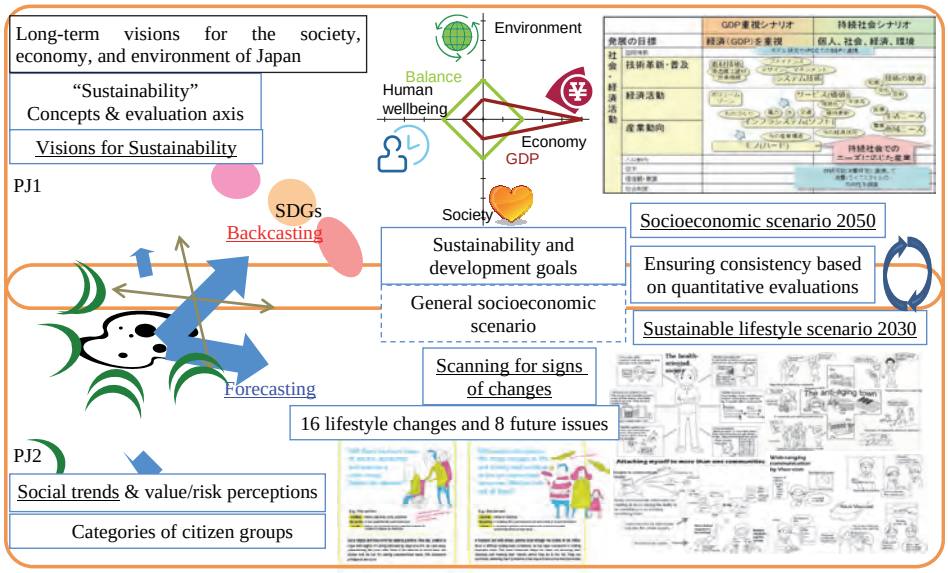


Fig. 2 Future scenarios for a sustainable society (Project 1 of the Sustainable Social Systems and Policy Research Program) and lifestyle scenarios (Project 2)

2. Eco-city Systems Research Program

We develop the theory and methodologies for planning and evaluation system to realize effective environmental technologies and policies at the regional and city levels. The system is being applied to domestic and international cities and regions, and the theory and methodologies are being generalized through verification of their implementation in places such as the Fukushima coastal area, National Eco-Model cities and green cities in Asia, and the city of Bogor in Indonesia. The program consists of two projects: Project 1 (Development of evaluation methods for, and social implementation of, environmental technologies and policies for cities); and Project 2 (Development of scenarios for the environmentally sustainable evolution of cities and regions).

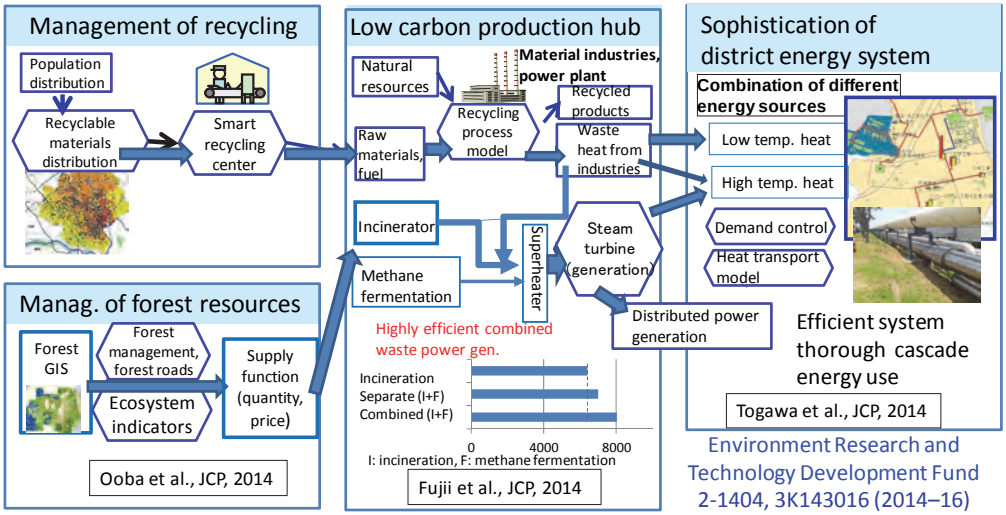


Fig. 3 Framework of a model for the planning and evaluation of cobenefit-type alternative technologies

Environment Research and Technology Development Fund 2-1404, 3K143016 (2014–16)

In Project 1, to efficiently promote a reduction in emissions of CO_2 from spatially distributed emission sources, we are developing a prototype system that will facilitate planning for low-carbon cities. The system will also verify the resulting CO_2 reduction effect through the monitoring of energy consumption. The system has been applied to the city of Bogor in Indonesia and the town of Shinchi in Fukushima Prefecture, Japan. To promote further CO_2 reductions in the industrial sector, one effective solution is the construction of hybrid industries that utilize (to the extent currently possible) wastes, waste heat, and renewable resources as alternative raw materials and energy sources (Fig. 3). The supply and demand potential for such alternative resources is being investigated in cities in Japan and other Asian countries. An energy-saving sewage treatment system has been developed, and the associated technology has been demonstrated in Thailand. Experiments using an advanced trickle filter system yielded satisfactory effluent quality.

In Project 2, we used a factorial analysis of changes in the spatial distribution of populations to develop a method for creating feasible spatial distribution scenarios. The results, in the form of a mesh, revealed a trend toward further decreases in population in areas of Japan with previously low populations. We developed population spatial distribution scenarios with a high degree of feasibility of application on the basis of a simulation of future distributions. The results were published online (Environmental GIS) and have been used in several important studies. Our next step was to develop a formula expressing, in the form of a mesh, the relationships between populations and CO_2 emissions from motor vehicles. The formula indicated, for example, that CO_2 emissions in future scenarios with different population spatial distributions could differ by around 10%. These results were used in a model developed by the Ministry of the Environment, Japan, to elucidate transportation under different land-use patterns.

3. Other research outcomes

3.1 Quantification of long-term global socioeconomic activities

Shared socioeconomic pathways (SSPs) are socioeconomic scenarios designed primarily to be used by the climate-modeling and impact, adaptation, and vulnerability (IAV) communities. SSPs are a set of five representative scenarios (SSP1 to SSP5) that are quantified by using integrated assessment models (IAMs). In this study, we quantified SSPs by using the global computable general equilibrium model AIM/CGE[Global]. We chose to use AIM/CGE[Global] to quantify the SSP3 marker scenario, which illustrates a particular storyline in the IAMs used to quantify SSPs. The design of SSP3 has taken into account tough challenges for both mitigation and adaptation. The quantified results of SSP3 have two unique characteristics. One is strong deforestation due to a large population increase and slow agricultural development. The other is high aerosol emission rates associated with slow air-quality-control legislation (Fig. 4). These characteristics provide fundamental information for the IAV and climate-modeling communities.

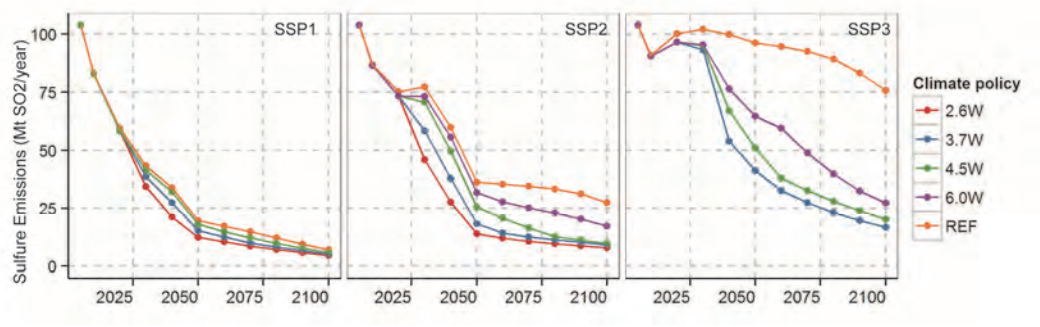


Fig. 4 Global sulfur emissions under the SSP1, SSP2, and SSP3 scenarios associated with mitigation. Series 2.6, 3.7, 4.5, and 6.0 W represent radiative forcing in W/m^2 in 2100. "REF" is the reference scenario.

3.2 Assessment of Japan's mitigation targets in 2030

On April 30, 2015, Japan's greenhouse gas (GHG) mitigation target for 2030 was proposed as –26.0% compared with the value for 2013. Accordingly, the potential reduction in GHGs in Japan was assessed by using the AIM/Enduse and AIM/CGE models. AIM/Enduse was used to assess the feasibility of an 80% reduction in GHGs by 2050. This long-term target is feasible, and in this pathway, emissions in 2030 will be more than 40% below the 2013 level. The results were introduced as a chapter of the interim report of the DDPP (Deep Decarbonization Pathways Project) at the Climate Summit. AIM/CGE was used to assess the impact of the new mitigation target. Gross domestic product (GDP) loss in 2030 will be about 1.4% of that under the reference case, and this path could achieve a 1.6% annual economic growth rate after 2014. If our emission-mitigation capacity can be extended through deeper penetration of efficiency-improvement and emission-reduction options in different sectors, the GDP loss in 2030 will be mitigated further.

3.3 Adaptation pathways to maintain global wheat production through the 21st century

By modeling the sequential introduction of the minimum adaptation measures needed to maintain current wheat yields through the 21st century, we developed adaptation pathways for the current major wheat-producing countries (Fig. 5). Adaptation pathways are temporal sequences of adaptations that show the timing and intensity of the necessary adaptations. We considered two adaptation options, each with multiple intensity levels: (i) expanding irrigation infrastructure, and (ii) switching crop varieties and developing new crop varieties. We found that the adaptation pathways differed markedly among countries. The results showed that a large expansion of irrigation and the development of new heat-tolerant varieties will be required in several countries. We also showed that the wheat yield attainable by adaptation was notably dependent on whether or not forecasts of the necessary adaptation were available; the negative impacts of climate change could be moderated by implementing adaptations based on forecasts, as compared with failing to implement them.

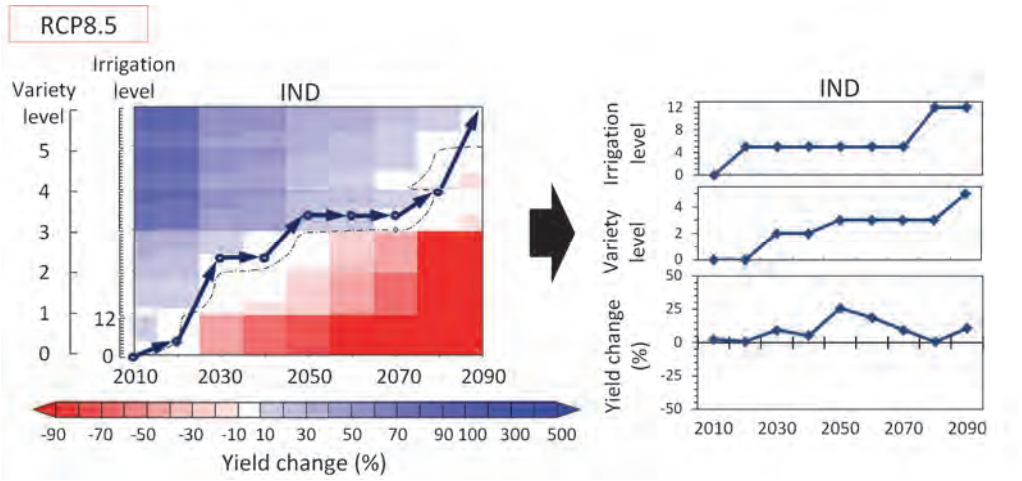


Fig. 5 Adaptation pathway and yield change from the current level (1991–2000) in India. "Variety level" and "irrigation level" indicate the intensity level of each adaptation option. We developed the adaptation pathways on the basis of the climate under the RCP8.5 scenario of the MIROC-ESM (an earth system model) projection.

3.4 Comprehensive research into impact assessment and adaptation for climate change in Japan

This research systematically predicts climate change impacts on Japan on the basis of the new RCP (Representative Concentration Pathways) GHG concentration scenarios. It has identified projections relevant to GHG concentration pathways and climate scenarios, and we have projected the impacts of these scenarios on Japan during the mid-21st century (2031–2050) and at the end of the century (2081–2100). The modeling predicted that global warming would affect a variety of Japan's social and environmental spheres throughout the 21st century. The impacts of disasters related to extreme weather, health effects such as heat stress, impacts on water resources and agriculture, and ecological

changes are expected to be wide in scope and severity, affecting 1) national health, safety, and security; 2) national life quality and economic activity; and 3) ecosystems. Climate change impacts will depend on the degree of warming, as measured in temperature rise. If mitigation measures are advanced on a worldwide scale, then the adverse impacts on Japan can be largely prevented. However, adverse impacts will likely occur if adaptation measures are not implemented.

3.5 Low-carbon research network in Asian countries to promote capacity-building in model and scenario development: the case of Iskandar Malaysia

Particularly in developing countries with rapid population growth and economic development, cities are consuming vast quantities of fossil fuels and natural resources, generating enormous amounts of waste, and producing large amounts of GHGs. There is an observable lack of knowledge, experience, and urgency in mitigating climate change at the city and subnational levels. Iskandar Malaysia set out to be the first urban region in Malaysia to formulate and implement a city-regional-level climate change action plan-the Low-Carbon Society Blueprint for Iskandar Malaysia 2025-by using the Asia-Pacific Integrated Model (AIM) methodology. The Blueprint is based on scientific and quantitative modeling, with improved policymaker adoption and public acceptance. The holistic and integrated features of the Blueprint are shaped by six interrelated multidisciplinary expert groups, namely, Land Use and Scenario Integration, Transportation and Air Quality, Energy Systems, Solid Waste Management, Socioeconomic sectors of both Malaysia and Japan, and Iskandar Regional Development Authority (IRDA) officials. Ten projects have been prioritized for implementation on the basis of their institutional readiness (e.g. continuation or extension of existing initiatives) as well as their relatively high CO_2 reduction potential and low implementation barriers, which include aspects of economic and social cost, human capital, institutional and legislative frameworks, social readiness (public acceptance), private sector buy-in, and technology availability.

3.6 Design and demonstration of an innovative low-carbon monitoring system

To address the challenges of climate change and sustainable urban development, the need to promote a low-carbon society and eco-city transformation is important. Innovative monitoring systems will help to stimulate energy-consumption activities and track the energy-saving actions of members of the public and businesses; moreover, they will help to verify the demand-side response. Such systems will also support the verification of carbon-reduction policies on both city and national scales. The use of monitoring systems can currently be characterized as an emerging concept. Under these circumstances, the aim of this research is to develop an innovative low-carbon monitoring system and

demonstrate it in the commercial and residential sectors. The functions of the system and the monitoring sites have been designed on the basis of reviews of internationally advanced practices and local energy consumption pattern analysis. A demonstration project has been set up in the city of Bogor, Indonesia, which is promoting eco-city initiatives (Figs. 6 and 7). The newly designed monitoring system is expected to serve as a support tool for users to promote energy-saving actions and share information with others through the visualization of real-time energy consumption. The system will also help to promote the transformation of lifestyles and business patterns and support improvements in demand-side management. The monitoring data and knowledge database will provide enhanced local parameters for modeling approaches, further facilitating the transformation to a low-carbon society.

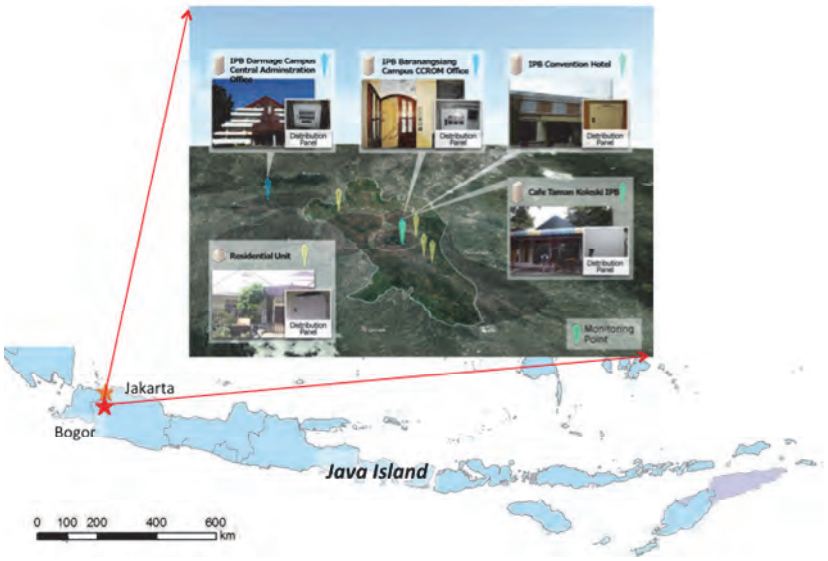


Fig. 6 Locations of the monitoring sites in the city of Bogor, Indonesia

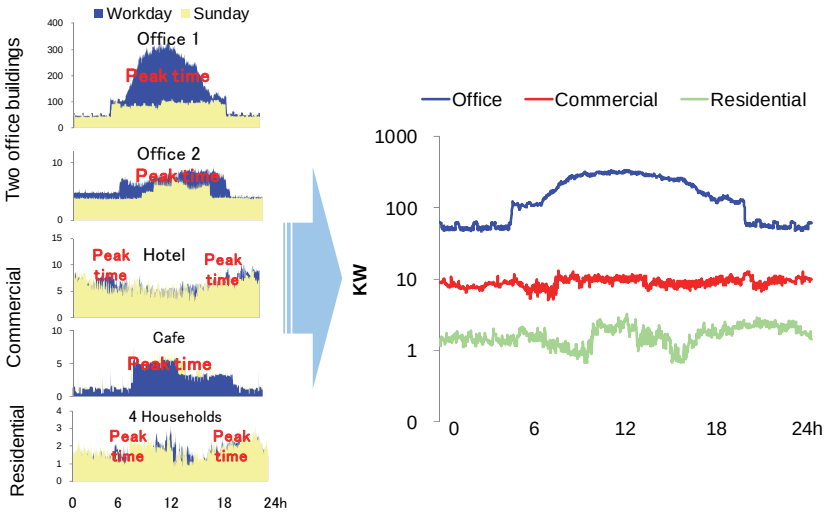


Fig. 7 Energy-consumption patterns of the sites monitored in Bogor

3.7 Urban population density scenarios for low-carbon transportation

The aim of this research is to quantify the potential reduction in CO_2 emissions from passenger vehicles over the long term through the introduction of compact cities. We determined the correlation between population distribution and passenger vehicle CO_2 emissions from 1980 to 2005 and simulated passenger vehicle CO_2 emissions in 2030 under both compact and dispersed scenarios. We conducted a correlation analysis and scenario analysis by using data sets of municipal CO_2 emissions from passenger vehicles, national population census figures, and future population distribution scenarios. Annual CO_2 emissions from passenger vehicles per capita by each cell-density category were then estimated. The difference in emissions per capita between the compact and dispersed scenarios was roughly 10% in most Japanese municipalities (Fig. 8).

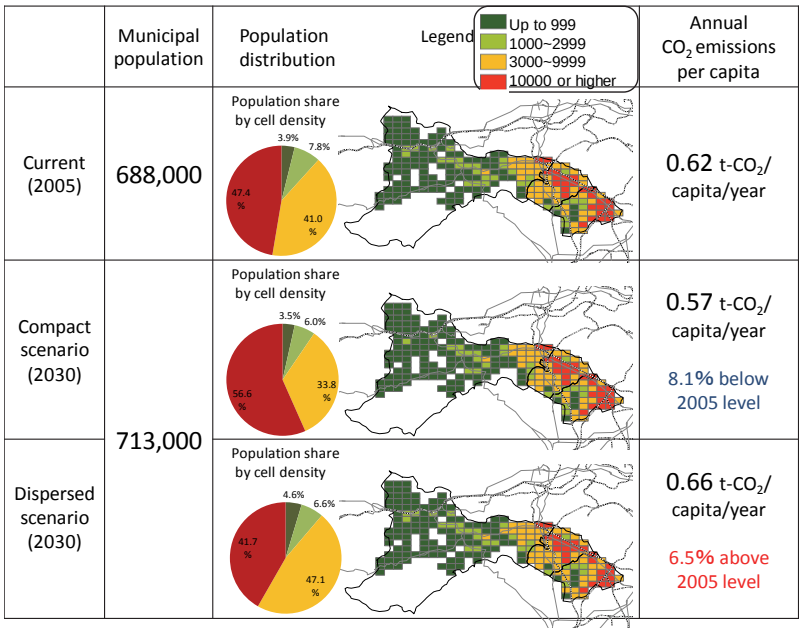


Fig. 8 Example of scenario analysis of passenger vehicle CO_2 emissions (in the city of Sagamihara in Kanagawa Prefecture)

3.8 Future technology and policy system analysis for eco-cities: Case study of the development of low-carbon industries through urban symbiosis in Asian cities

Energy and resource consumption has greatly expanded alongside the rapid growth of Asian cities, resulting in increased GHG emissions and waste generation. The need to promote low-carbon industries is an urgent global issue that also applies to Asia. We have proposed the concept of “hybrid industries”—that is, industries in which the processes utilize not only fossil resources but also recycled and renewable resources to the extent possible. This study examined the feasibility of hybrid industries by promoting urban symbiosis in cities in three Asian countries with different circumstances: Kawasaki in Japan, Ulsan in Korea, and Shenyang in China. Asian cities are in the midst of a shift from waste dumping to incineration. However, in view of the carbon-reduction

effect of recycling, as well as the cost of recycling and appropriate treatment of wastes, the potential for hybrid industries that use combustible municipal wastes as input should be considered. We evaluated the potential for CO_2 reduction, as well as the costs of promoting hybrid industries. The results show that promoting hybrid industries will generate marked environmental benefits for the three cities, and that there are important factors that affect cost-effectiveness, including the spatial density of waste generation and labor costs.

3.9 Sustainable consumption and behavior research

This field of research consists of the following three parts:
1) Public opinion research, focusing on the role of mass media as a catalyst for social change. This includes research on public awareness of environmental issues, public support for various environmental policies, people's actions toward sustainable lifestyles, and mass media coverage of environmental issues.

2) Model development to estimate the generation of environmental loads on the basis of household-sector demand. We are using various statistics published by the Statistics Bureau of the Ministry of Internal Affairs and Communications, Japan, to investigate how changes in household-sector demand bring about changes in impacts with regard to environmental issues.

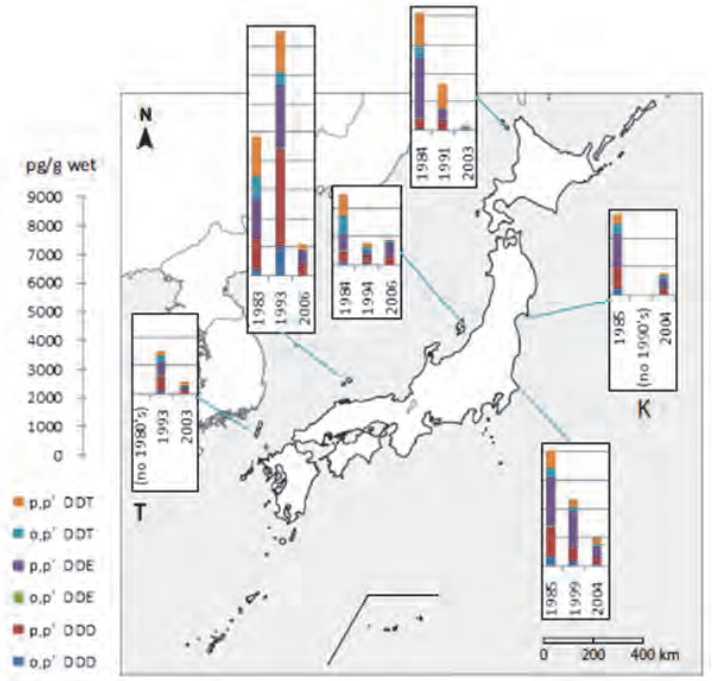
3) Research into building scenarios for lifestyle change toward 2030. This study is comparable to the EU-funded SPREAD Sustainable Lifestyles 2050 Project and other scenario-building work in the sustainable lifestyle research field. We are considering people's lifestyles in terms of not only environmental aspects but also more general social changes such as globalization.

3.10 Institutional dimension of environmental policy research

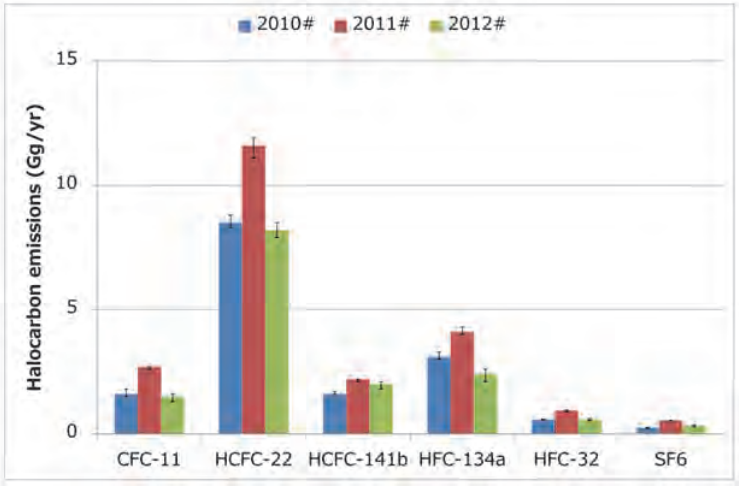
We have been using legal and political science–based methodologies to conduct research into the institutional aspects of environmental policies. Although research staff specializing in international law and social science are in a minority at NIES, they can benefit from conducting interactive studies with researchers in other fields of study, both inside and outside NIES. This research topic covers five to ten different themes and research projects, three of which are:
1) Study on an Agreeable and Effective International Institution Concerning Climate Change for the Years after 2020; 2) Qualitative Analysis of Various Funding Schemes Targeting Climate Change Adaptations; and 3) Study on Sustainable Development Indicators (SDIs) and Investigation of a Plausible Sustainable Vision and Scenario for Japan's Future, focusing on the connections among food, water, and energy.

Center for Environmental Measurement and Analysis

Liquid N_2 vapor-phase storage tanks installed in the Environmental Specimen Time Capsule Building



Decadal changes in DDT levels in bivalves collected from remote sites around Japan. Sampling years are shown. No samples were available at Tsushima in the 1980s (*T*) or at Kinkazan in the 1990s (*K*).



Estimated halocarbon emissions in Japan using the inversion method.

Halocarbon emissions in Japan estimated by using the inversion method

The goals of the **Center for Environmental Measurement and Analysis** are to contribute to the quality assurance and quality control (QA/QC) of chemical analyses of environmental samples, develop better scientific methodologies to improve our understanding of environmental issues, and demonstrate the effectiveness and advantages of these new or improved methodologies.

To achieve these goals, the seven sections of the Center have been conducting a variety of studies. The Fundamental Chemical Analysis Section has been developing environmental Certified Reference Materials and studying their analytical application to QA/QC. The Advanced Organic Analysis Section has been developing techniques for comprehensive analysis of organic pollutants. The Isotope and Inorganic Analysis Section has been investigating precise measurement of the abundance of stable isotopes of heavy metals and sensitive measurement of radiocarbon (^{14}C) in a variety of environmental samples. As part of Environmental Emergency Research and research on radioactive materials at NIES, this section has also been studying the dynamics of radioactive materials emitted as a result of the accident at the Fukushima Daiichi Nuclear Power Plant. The Environmental Chemodynamics Section has been investigating the chemodynamics of natural and anthropogenic volatile organic compounds, as well as carbon cycles in the ocean. The Biological Imaging and Analysis Section has been pursuing the development of techniques for detecting and analyzing the *in vivo* responses of biological systems to various environmental factors. The Advanced Remote Sensing Section has been developing advanced techniques for remote sensing, such as lidar (laser radar), and the Environmental Information Analysis Section has been devising new methods of analyzing the large quantities of data gathered by using space- and ground-based remote-sensing techniques.

Following are brief accounts of some of the most important results of our research in FY 2014.

Retrospective analysis by using data-processing tools for GC×GC-HRTofMS: application to a sediment core sample from Tokyo Bay

Data-processing tools for non-target analysis using comprehensive two-dimensional gas chromatography coupled with high-resolution time-of-flight mass spectrometry (GC×GC-HRTOFMS) were developed and applied to a sediment core from Tokyo Bay, with a focus on chlorinated compounds. Two different methods were used for processing: (1) consecutive use of a mass defect filter followed by artificial neutral loss scan (MDF/artificial NLS) as a qualitative non-target screening method; and (2) Entire Domain Combined Spectra Extraction and Integration Program (ComSpec) and two-dimensional peak sentinel (T-SEN) as a semi-quantitative target screening method. Non-target screening using MDF/artificial NLS revealed that polychlorinated biphenyls (PCBs), followed by polychlorinated dibenzo–*p*–dioxins and polychlorinated dibenzofurans (PCDD/Fs), were the main chlorinated compounds (most were internal standard (IS) spiked) in all sediment layers (Fig. 1). Furthermore,

unknown peaks thought to be chlorinated compounds were found in increasing numbers with time, some in increasing amounts. Adaptation of T-SEN, together with ComSpec as a target screening approach, for automatic semi-quantitative analysis showed that, in decreasing concentration order, PCBs, PCDD/Fs, and dichlorodiphenyltrichloroethane (DDT) and its metabolites (DDEs, DDDs) were the main chlorinated pollutants in the sediments. Complementary use of the two techniques allowed us to extract important chlorinated pollutants, including non-targeted compounds. Retrospective analysis by this approach performed well—even on matrix-rich sediment samples—and offered interesting insights into the historical trends of pollution in Tokyo Bay.

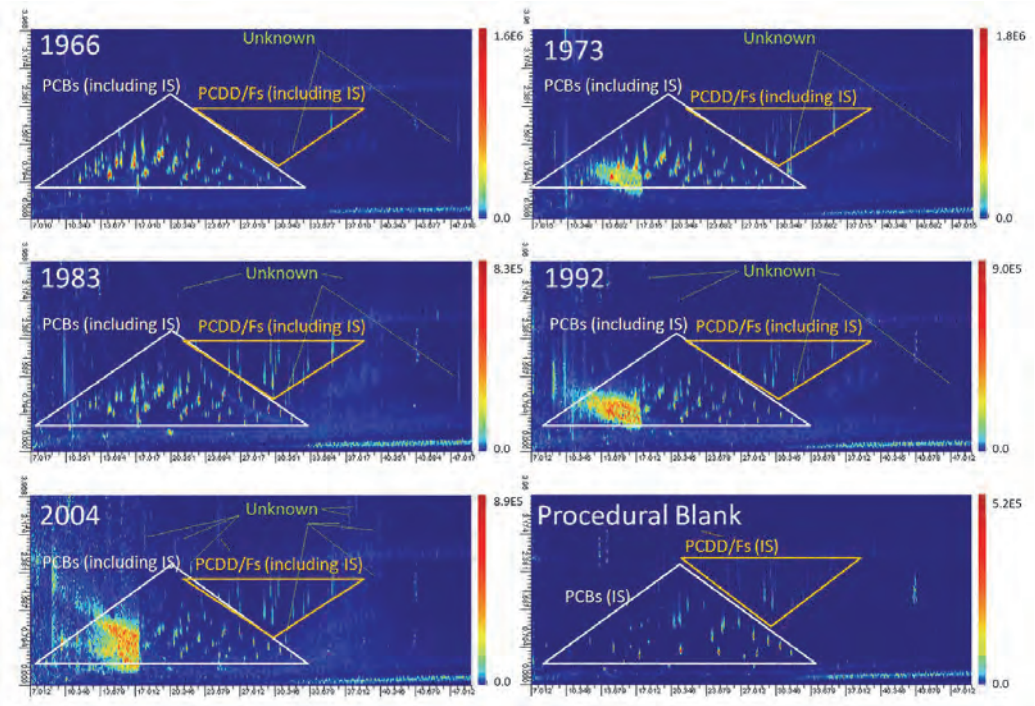


Fig. 1 GC×GC chromatogram of each layer of the sediment core from Tokyo Bay after consecutive use of a mass defect filter (MDF) followed by artificial neutral loss scan (MDF/^{35}Cl-NLS). NLS was performed with a setting of *m/z* 34.969 after MDF; the mass defect was set at 0.2. Estimated sedimentation dates are in the top left of each chromatogram.

Three decades of environmental specimen banking at the National Institute for Environmental Studies, Japan

After two decades of operation of the initial environmental specimen bank, a new program, the Environmental Specimen Time Capsule Program, was started in 2002 as a government-supported long-term repository aimed at building a firm scientific basis for various environmental studies. The program consists of long-term environmental specimen banking and collection of specimens of endangered wildlife species. It is based in a cryogenic sample preservation facility called the Environmental Specimen Time Capsule Building, construction of which was completed in 2004. As part of the program, bivalve samples were collected from around the Japanese coastline (Fig. 2). Analysis of pollutants in bivalve samples reveals long–term changes of pollutants levels. For example, it is shown that DDT related compounds in seawater around Japan have been

decreasing gradually in recent decades. After 9 years of extensive research, research foci were selected and the program was reorganized in 2011 into environmental sample collection and an endangered wildlife collection components. In response to the massive and composite environmental disaster accompanying the Great East Japan Earthquake, the tsunami, as well as the subsequent accident at the Fukushima Daiichi Nuclear Power Plant, a new sampling and monitoring program was started in the affected areas in collaboration with the reorganized environmental sample collection and archiving program.

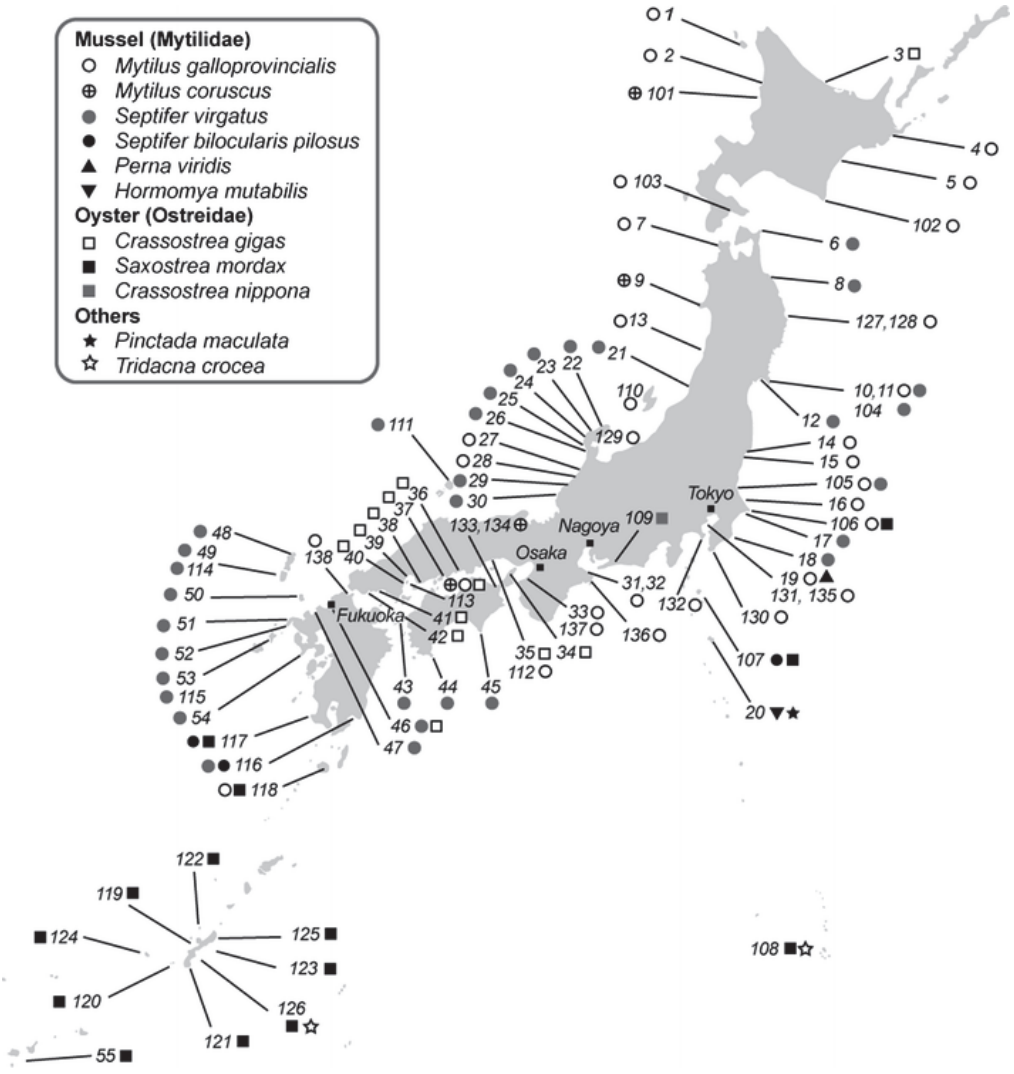


Fig. 2 Bivalves have been sampled at a total of 126 sites as part of the Environmental Specimen Time Capsule Program.

Extraordinary halocarbon emissions initiated by the 2011 Tohoku earthquake

We have been conducting *in situ* high-frequency atmospheric monitoring of halocarbons at two Japanese stations, Hateruma Island (24.1°N, 123.8°E) in Okinawa and Cape Ochiishi (43.1°N, 145.3°E) in Hokkaido, as part of CGER's global environmental monitoring. The Tohoku earthquake of March 11, 2011 and

the subsequent tsunami wreaked catastrophic damage, including destruction of buildings. As a result, chlorofluorocarbons (CFCs) and other anthropogenic halocarbons present in the buildings could have been released into the atmosphere. We carefully analyzed monitoring data to check whether a significant halocarbon emission footprint was triggered by the earthquake. We found that substantially enhanced mixing ratios of CFCs, hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), and SF_6 were indeed detected at Ochiishi station. Figure 3a maps the locations of the atmospheric monitoring stations and the distribution of seismic intensity of the Tohoku earthquake. Backward trajectory calculations showed that air observed to contain halocarbons in markedly increased concentrations at Ochiishi (Fig. 3b) had traveled over the affected regions 1 or 2 days after the earthquake. By combining the atmospheric monitoring data with an atmospheric transport model and an inversion method, we estimated annual mean halocarbon emissions in Japan. Estimated emissions in March to February 2010–2011, 2011–2012, and 2012–2013 are summarized in Table 1. The estimated sum of earthquake-related emissions of halocarbons was 6.6 Gg, which is equivalent to ozone depletion potential–weighted emissions of 1.3 Gg and a global warming potential of 19.2 Tg of CO_2.

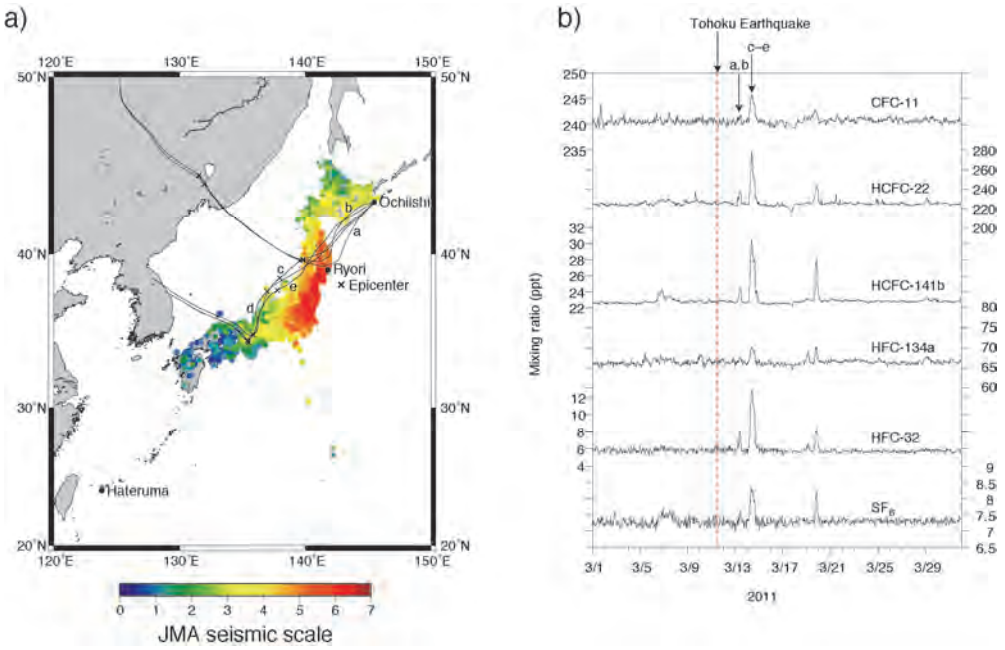


Fig. 3 (a) Map showing the locations of atmospheric monitoring stations and the distribution of seismic intensity of the March 11, 2011 Tohoku Earthquake. The lines represent 3-day back trajectories for air masses arriving at 500 m altitude over Cape Ochiishi on March 13 at a. 06:00 local time (LT) and b. 09:00 LT and on March 14 at c. 06:00 LT, d. 09:00 LT, and e. 12:00 LT. The 24 h intervals are labeled with “cross” symbols. (b) Time series of six halocarbons measured at Ochiishi in March 2011. Arrows indicate starting times of the back trajectories in (a).

Table 1 Estimates of emissions in Japan from March to February 2010–2011 [2010#], 2011–2012 [2011#], and 2012–13 [2012#] and emissions caused by the Tohoku earthquake

	Halocarbon emissions (Gg/yr)			Relative increase[1] (%)	Tohoku earthquake emissions (Gg)	ODP-weighted Tohoku earthquake emissions (Gg)	GWP-weighted Tohoku earthquake emissions (Tg CO_2-eq)
	2010#	2011#	2012#				
CFC-11	1.6 (1.5–1.8)	2.7 (2.6–2.7)	1.5 (1.3–1.6)	72 (53–91)	1.1 (0.9–1.3)	1.1 (0.9–1.3)	5.3 (4.3–6.2)
HCFC-22	8.5 (8.3–8.8)	11.6 (11.1–11.9)	8.2 (7.9–8.5)	38 (29–47)	3.2 (2.5–3.8)	0.2 (0.1–0.2)	5.8 (4.5–6.9)
HCFC-141b	1.6 (1.6–1.7)	2.2 (2.1–2.2)	2.0 (1.8–2.1)	21 (10–30)	0.4 (0.2–0.5)	0.04 (0.02–0.06)	0.1 (0.0–0.1)
HFC-134a	3.1 (3.0–3.3)	4.1 (4.0–4.3)	2.4 (2.1–2.6)	49 (35–65)	1.4 (1.1–1.7)	0 (0–0)	1.9 (1.5–2.4)
HFC-32	0.57 (0.56–0.59)	0.94 (0.89–0.96)	0.58 (0.54–0.62)	63 (46–76)	0.4 (0.3–0.4)	0 (0–0)	0.2 (0.2–0.3)
SF_6	0.24 (0.22–0.26)	0.54 (0.53–0.55)	0.32 (0.29–0.36)	91 (73–111)	0.3 (0.2–0.3)	0 (0–0)	5.8 (5.2–6.6)
Total					6.6 (5.1–8.0)	1.3 (1.1–1.6)	19.2 (15.8–22.4)

1 "Relative increase" is the factor by which *a posteriori* emissions estimated from inversions for 2011# are larger than the average of values from inversions for 2010# and 2012#.

Different behavioral-effect dose-response profiles in mice exposed to two-carbon chlorinated hydrocarbons: influence of structural and physical properties

We examined whether the dose-response profiles of the acute behavioral effects of two-carbon chlorinated hydrocarbons such as 1,2-dichloroethane (DCE), 1,1,1-trichloroethane (TCE), trichloroethylene (TRIC), and tetrachloroethylene (PERC) differed. A test battery involving six behavioral endpoints [lethality; righting reflex; bridge test performance; response rate of operant behavior (lever-pressing) sustained by a fixed ratio schedule of food reinforcement, with reinforcement for every 20 lever operations (FR20); and response rate of operant behavior (lever-pressing) during safe and alarm periods sustained by a multiple schedule (FR20/FR20-punishment) of food reinforcement (MULT safe, MULT alarm)] was applied to evaluate the effects of DCE, TCE, TRIC, and PERC in male ICR-strain mice under the same experimental conditions.

Figure 4 shows dose-response relationships of DCE (Fig. 4 (a)), TCE (Fig. 4 (b)), TRIC (Fig. 4 (c)) and PERC (Fig. 4 (d)) for each of the 6 behavioral indices in mice. The behavioral-effect dose-response profiles of these compounds differed. The best-fit modified Hill equations for each of five behavioral effects were determined by using the maximum-likelihood method, and the equations provided lethal dose 50 (LD_{50}) and effective dose 50 (ED_{50}) values for those behavioral effects. In the case of response rates during the alarm period of the MULT operant test, the results were analyzed by using 1-way ANOVA that provided least-observed-effect levels (LOELs) for the behavioral effects. Multiple regression analysis was used to evaluate the relationship between behavioral effect indices constructed by using the ED_{50} values and LOELs for the behavioral effects and the structural and physical properties of the compounds, such as number of double bonds; number of chlorines; maximum number of chlorines/carbons; molecular weight; melting point; boiling point; specific gravity; vapor pressure; water solubility; and octanol–water partition coefficient. The regression analysis revealed significant relationships between melting point and bridge test ED_{50}/LD_{50}, MULT alarm LOEL/LD_{50}, MULT alarm LOEL/righting reflex ED_{50}, FR20 ED_{50},

bridge test ED_{50} and MULT alarm LOEL; between (octanol–water partition coefficient)/(molecular weight)$^{1/2}$ and LD_{50}; between boiling point and LD_{50}; between vapor pressure and FR20 ED_{50}/LD_{50}; between the number of double bonds and FR20 ED_{50}/LD_{50}; and between the maximum number of chlorine atoms per carbon atom and FR20 ED_{50}. Thus, dose-response profile differences were correlated significantly with differences in specific structural and physical properties. These results suggest that differences in the specific structural and physical properties of DCE, TCE, TRIC, and PERC are responsible for differences in behavioral effects that lead to a variety of dose-response profiles.

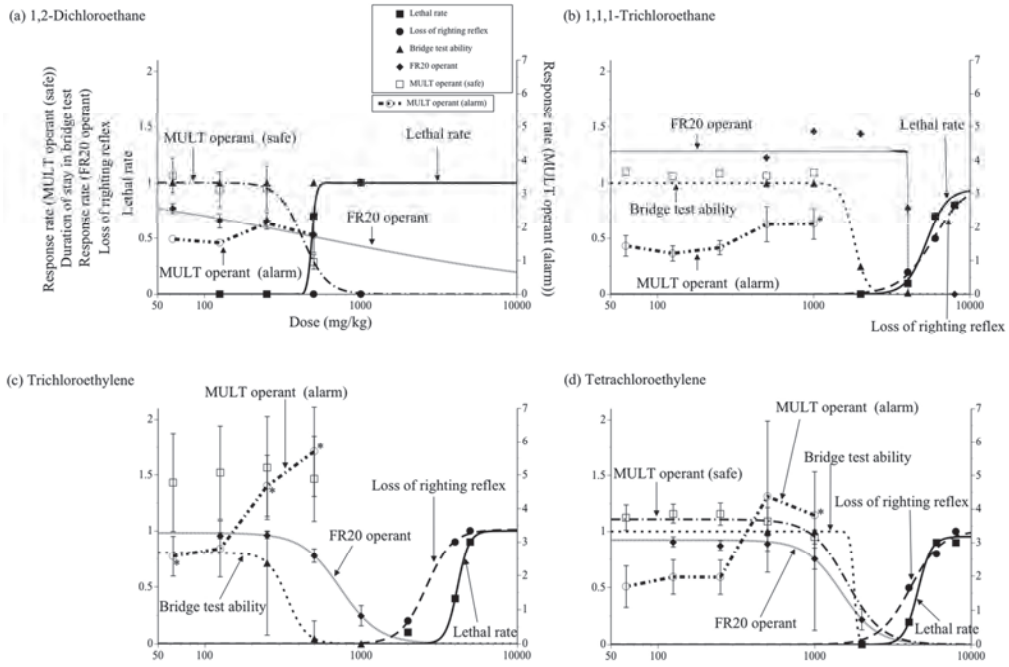


Fig. 4
Behavioral-effect dose-response profiles of (a) DCE, (b) TCE, (c) TRIC, and (d) PERC in mice. Normalized measurements for each of six behavioral indices are plotted relative to the administered dose. Curves are those of the best-fit modified Hill equation for each of five behavioral effects. Plotted data are connected by straight lines in the case of response rates during the alarm period of the MULT operant test.

Detection of Asian dust internally mixed with air pollution aerosols by using a polarization optical particle counter and polarization-sensitive two-wavelength lidar

East Asia is a unique region in which mineral dust (“Asian dust”) sources are located near urban and industrial areas. During its transportation, Asian dust is often mixed with air pollution aerosols. Some epidemiological studies of the effects of Asian dust on human health suggest that these effects can be enhanced when dust particles are mixed with air pollution aerosols. Moreover, because the effects can depend on the mixing state (i.e. external mixing, in which the particles of dust and their contaminants remain separate, or internal mixing, in which the contaminants condense onto the dust particles), it is important to determine the mixing state. We operate a network of polarization-sensitive two-wavelength lidars (AD-Net) in the East Asian region (http://www-lidar.nies.go.jp/AD-Net/). We sometimes observe Asian dust signals with a low depolarization ratio and high backscattering color ratio (1064 nm/532 nm), suggesting that the dust is internally mixed and polluted. However, the information derived from volume scattering

measurements obtained through such means as lidar is limited, and validation was required. To study the optical characteristics of mixed particles in detail, we introduced a polarization particle counter (POPC), which measures the forward scattering (representing particle size) and the backscattering depolarization ratio (representing non-sphericity) of single particles. We conducted simultaneous observations with a POPC and the AD-Net lidar in Seoul, Korea, and we captured the characteristics of pure Asian dust, internally mixed Asian dust, and externally mixed Asian dust particles.

The results of the POPC measurements are shown in Figure 5 for pure dust (case A), internally mixed polluted dust (case B), and externally mixed dust (case A′). Backward trajectories for case A and case B are shown in Figure 6. In case B, Asian dust was transported slowly through the polluted areas. The number of large particles was smaller than that in case A, and the depolarization ratio was smaller in the large particle mode. The difference clearly indicates the characteristics of internally mixed polluted Asian dust. The decrease in the depolarization ratio is explained by the increase in the imaginary part of the refractive index in the polluted dust. In externally mixed dust (case A′), a distribution peak of air pollution particles appears in the scatter plot.

The lidar data for the same events (a scatter diagram between the particle depolarization ratio (PDR) and the backscattering color ratio) are shown in Figure 7. If case A represents pure dust, the data for an external mixture of pure dust and air pollution aerosols should fall on the curve connecting case A and the air pollution aerosols in the scatter diagram. In fact, the external mixture (case A′) does fall on the curve. However, case B is different. The PDR for case B is smaller than that for case A, but the color ratio is similar to that in case A. This result demonstrates that internally mixed Asian dust can be detected successfully with polarization-sensitive two-wavelength lidar.

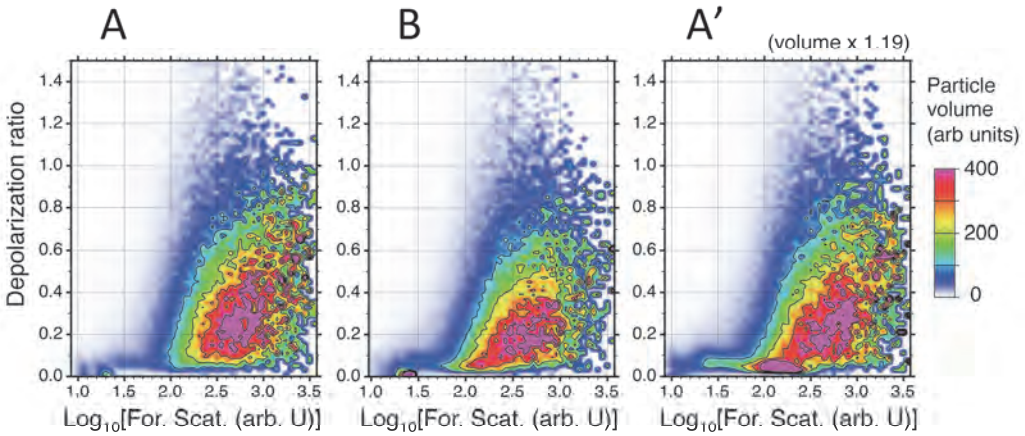


Fig. 5 Scatter plots between the common logarithm of the forward-scattering intensity (representing particle size) and the backscattering depolarization ratio measured with a polarization particle counter in the cases of pure dust (case A), polluted dust (case B), and externally mixed dust (case A′). The total particle volume in each sampling grid is indicated. The plots are scaled in such a way that similarities and differences are best seen.

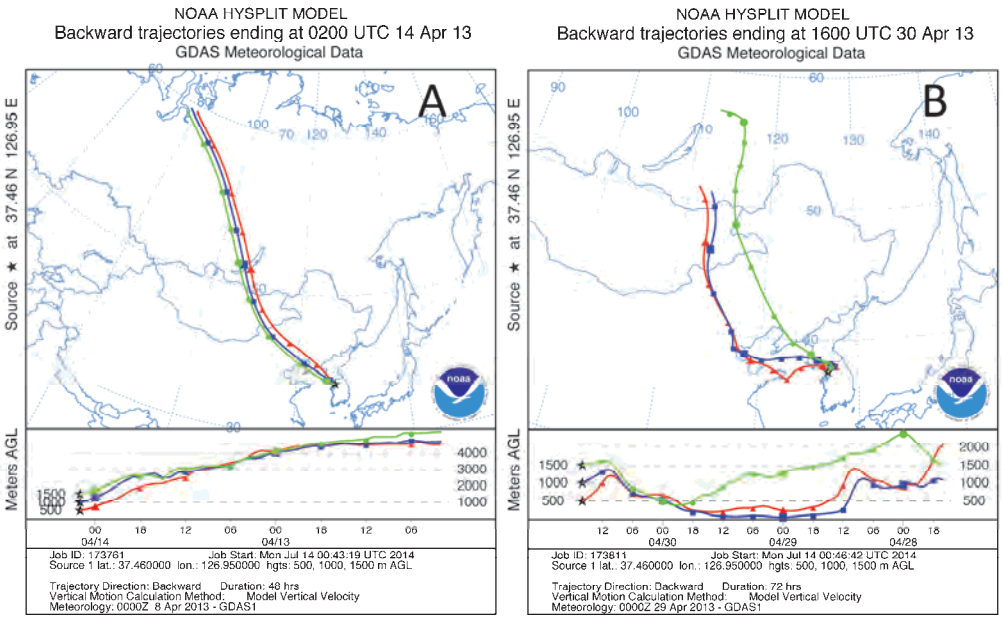


Fig. 6 Back trajectories obtained with NOAA HYSPLIT (the National Oceanic and Atmospheric Administration's Hybrid Single Particle Lagrangian Integrated Trajectory model) for cases A and B. (See caption to Fig. 5.) The length of the back trajectories is two days in case A and three days in case B.

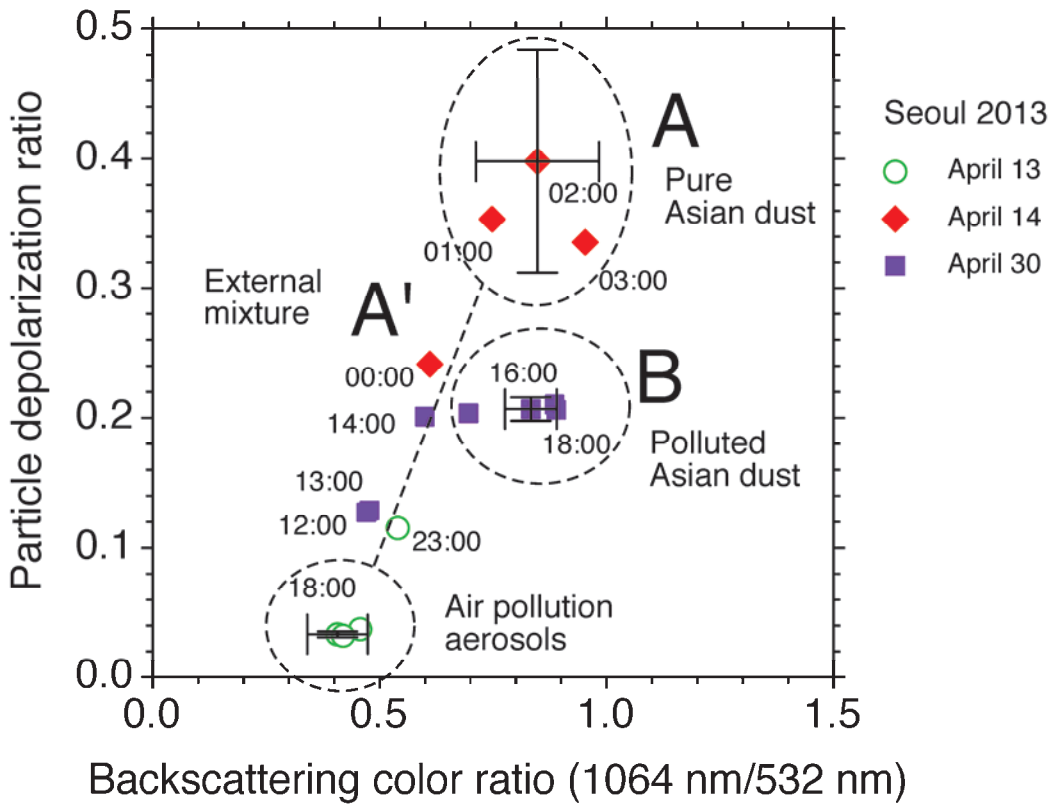
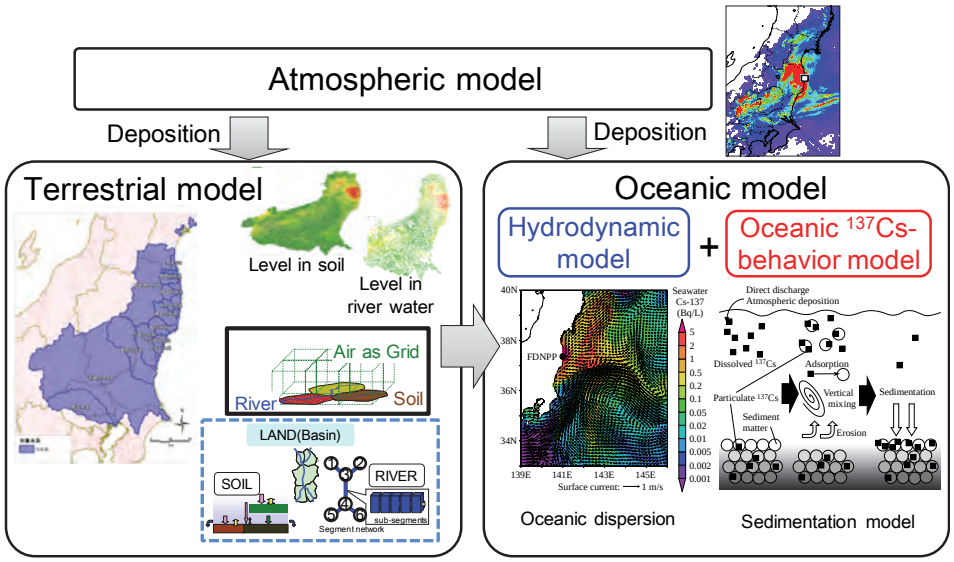


Fig. 7 Scatter diagram of the backscattering color ratio (1064 nm/532 nm) plotted against the particle depolarization ratio at a wavelength of 532 nm for pure dust (case A), polluted dust (case B), and air pollution aerosol. Hourly medians at heights of 120 to 500 m were used in this plot. Times of day are indicated to depict temporal variation. Error bars indicate estimates of statistical error.

Environmental Emergency Research



Schematic diagram of a multimedia model for simulating the fate of ^{137}Cs

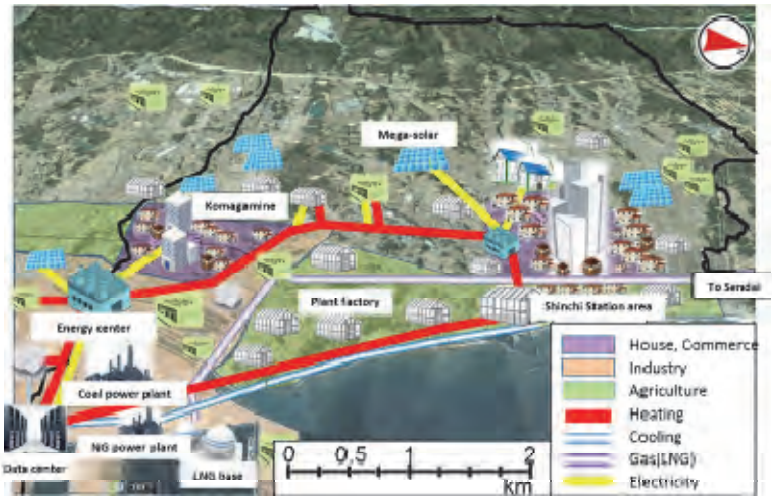


Illustration of urban revitalization planning by using regional energy, liquefied natural gas (LNG)

1. Environmental Recovery Research Program 1 “Establishment of technologies and systems for managing radioactively contaminated wastes”

Large amounts of disaster waste were generated as a result of the Great East Japan Earthquake in March 2011. Moreover, the Fukushima Daiichi Nuclear Power Plant accident resulted in the grave problem of solid waste contamination by radioactive substances. To help solve these problems as expediently as possible we are performing various types of urgent research into appropriate waste management on behalf of central and local governments.

Our research is reflected in various measures, including technical guidelines from the Ministry of the Environment (MOE), discussions by an MOE panel, and the passing of the *Act on Special Measures Concerning the Handling of Pollution by Radioactive Substances*. With the help of these measures, we expect to make a real contribution to the establishment of techniques for managing radioactively contaminated waste.

Below is a summary of our main research findings.

1.1 Clarification of fundamental properties and behavior mechanisms of radioactive substances

1) Distribution of cesium to ash during incineration of contaminated biomass
We improved a multizonal equilibrium model for predicting the transformation of radioactive cesium (r-Cs) compounds in a stoker-type incineration plant (Fig. 1). With this improvement, two process zones (a boiler and a gas cooling tower) were added and ash formations during these new gas-cooling processes were calculated. Furthermore, the combustion and post-combustion zones in the primary combustion chamber were divided into several zones and the molten phase was taken into account. These improvements enabled us to account for the existence of mineral phases in the bottom ash; these phases were often observed in early works. Our findings demonstrated that the improved model was effective in representing the combustion phenomenon in the primary combustor.

We also continued to investigate the distribution of r-Cs to ash during the combustion of various types of contaminated waste biomass at different temperatures. A series of distribution results revealed that, in the combustion of leaves from broadleaf trees and weeds, relatively large amounts of r-Cs remained in the ash, whereas in the combustion of conifer leaves and twigs, r-Cs tended to vaporize into the air.

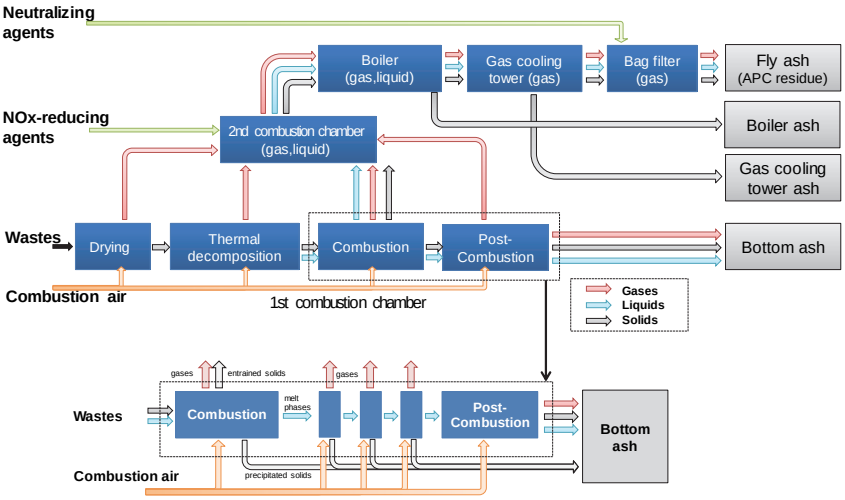


Fig. 1. Schematic of the multi-zonal equilibrium calculations we used to improve stoker-type incineration plants

2) Landfill soil adsorption ability

Although it is well known that soil can adsorb r-Cs, we have previously found that this ability is poor if the landfill leachate is highly saline. In our latest study, we focused on the desorption of r-Cs from soils in which it had accumulated. After preparing a sample soil for use in r-Cs sorption tests, we added one of the following seven solvents: pure water; 10,000 ppm of sodium; 10,000 ppm of sodium and 10 ppm of stable Cs; 10,000 ppm of potassium, 10,000 ppm of potassium and 10 ppm of stable Cs, 10,000 ppm of stable Cs; or uncontaminated leachate from municipal solid incineration fly ash. The r-Cs desorption percentage was highest with the addition of 10,000 ppm of potassium and 10 ppm of stable Cs (Fig. 2). The influence of 10,000 ppm of stable Cs on the desorption percentage was similar to that of 10,000 ppm of potassium.

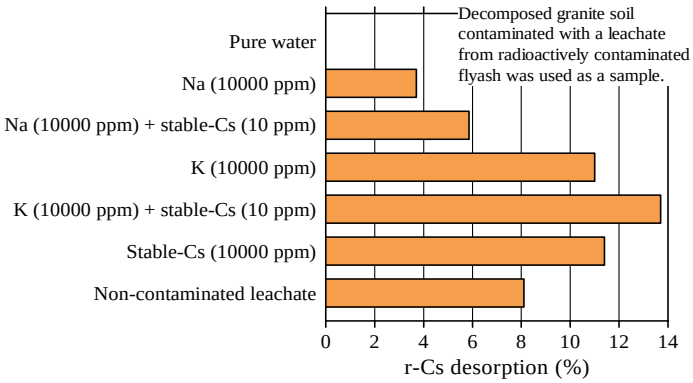


Fig. 2 Desorption of r-Cs from soils containing leachate from radioactively contaminated fly ash

1.2 Development, optimization, and assessment of treatment, disposal, and recycling technologies

1) Waste volume reduction by using thermal technology, and fate assessment of Cs in incineration processes and in refractory brick

To design appropriate strategies for treating and disposing of r-Cs waste from MSW incineration plants, we measured the leachability of r-Cs from different refractory wastes in which it had accumulated. The leachability values for wastes

with Si contents below 10% were scattered, whereas r-Cs scarcely leached from refractory wastes with Si contents of approximately 20%. The Si level may therefore be a key determinant of this leaching.

Furthermore, we characterized the leaching behavior of individual layers obtained from a contaminated refractory (Fig. 3). The layer close to the inside of the furnace had very low r-Cs leachability, but the leachability of the layers increased linearly toward the outside (red arrow). Thus the chemical form of r-Cs differed among layers originating from the same refractory. This difference was likely due to the substantial temperature decrease from the inside surface to the bulk of the brick.

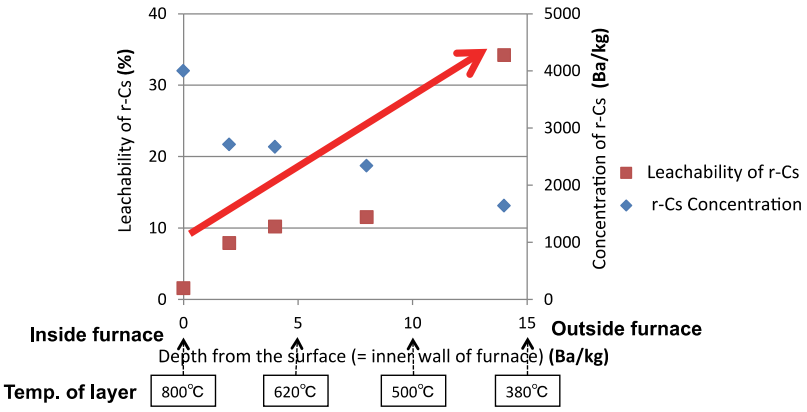


Fig. 3 Leachability of r-Cs from individual waste layers in a contaminated refractory

2) Development of washing and treatment technologies for r-Cs-contaminated ash and leachate

We developed a technology for removing r-Cs from fly ash in FY 2013. r-Cs dissolved in solution was removed by the adsorbent in a bench-scale test plant; the radioactivity of the effluent water was less than 10 Bq/L. We then conducted contamination monitoring during dismantlement of the plant in FY 2014. All equipment such as tanks and filters (Fig. 4) were monitored with a scintillation survey meter and GM (Geiger-Mueller) survey meter after the plant had been decontaminated. The radiation dose rate and surface density were very low at all survey points although there was a little fly ash in the tanks or on the filters. Our results indicated that all equipment could be transported from this plant, and disposed of, safely.

Fig. 4 Intensive monitoring of a bench-scale plant for washing contaminated fly ash

All materials used for r-Cs adsorption were provisionally replaced in a concrete container and packed in appropriate vessels with shielding. We confirmed by survey-meter and smear testing that the floor, walls, and ceiling of the test room contained no contaminants. The building used for fly-ash washing can therefore now be used for other purposes. To our knowledge, this is the first contamination survey of a plant used to wash contaminated fly ash; we intend to use the data we obtained on facility dismantling and radioactive contamination monitoring to compile a guidance document.

3) Application of concrete technologies

We have been studying three aspects of the application of concrete technology to the handling of radioactive wastes, namely the contamination depth of concrete; safe disposal of radionuclide-contaminated incineration fly ash in a concrete pit; and stable Cs immobilization by ferronickel cyanide in a concrete-solidified body. Concrete wastes account for a substantial percentage of contaminated wastes and require decontamination. Contamination depth was evaluated by using beta-ray radiographs (Fig. 5). In a concrete gutter-cover plate, the contamination depth was limited (less than 2 mm), whereas there was deeper contamination (up to 1 or 2 cm) in porous materials such as tuff stone or concrete blocks for architectural usage.

The MOE is proposing to build closed-type final disposal facilities made of reinforced concrete in five prefectures surrounding Fukushima Prefecture but excepting Fukushima Prefecture. In Fukushima Prefecture, a controlled-type final disposal facility and interim sites are used for the same purpose. Because of the nature of incineration fly ash, it is possible that certain rare accidents could cause severe degradation of the encasing concrete in these facilities. Various issues therefore need to be considered in regard to design, construction, and maintenance. We have summarized outlines and examples of countermeasures as a technical report, which has been published on the web (in Japanese).

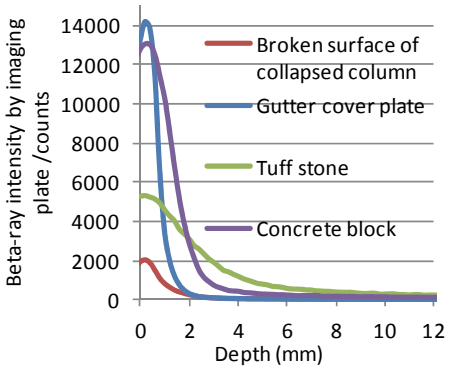


Fig. 5 Depths of penetration of various types of concrete by Cs, as determined by using beta-ray radiographs

4) Landfill and storage technology for contaminated wastes and soil

One aim of cement-solidification of designated waste is to reduce the amount of r-Cs leaching from the waste. Our long-term leaching tests revealed that the rate of leaching of r-Cs from cement-solidified waste decreased with increasing unconfined compressive strength of the solidified waste. The leaching rate depends on the geometry of the solidified waste; we used this characteristic to develop a method for estimating the rate of leaching from large-scale solidified waste. In addition, to ensure safety of land use of a closure landfill site in which the radioactively contaminated wastes had been disposed, we proposed specific cautions for the use of surface, intermediate, and bottom levels of the landfill site (Fig. 6).

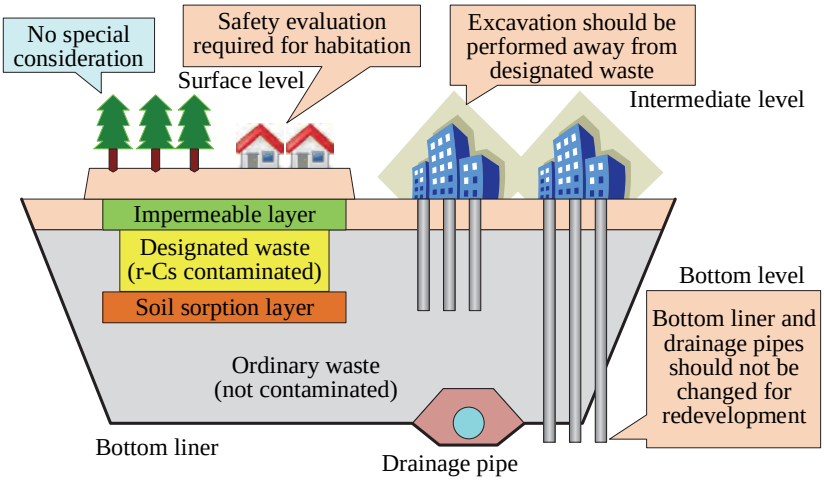


Fig. 6 Proposed specific cautions for the land use of surface, intermediate, and bottom levels of the landfill site in which the r-Cs wastes had been disposed

1.3 Establishment of radioactivity-monitoring technologies and their application to waste management

During two demolition processes in an area with high ambient radiation levels, we conducted a series of investigations into the radiation exposure of workers, the dispersal of particulate matter contaminated by radioactive materials, and the disposal of contaminated demolition waste. The first investigation covered a period in November and December 2014 (34 days) during which four affected buildings were demolished. The ambient dose rate at this site was 0.64 to 0.93 μSv/h. The second investigation took place in January 2015 (17 days) when

another affected building was being demolished. The ambient dose rate at this site was 2.08 to 3.02 μSv/h. In the second investigation, part of demolition work was classified by the "Ionizing Radiation Ordinance for Decontamination" as "Under a designated dose rate work" owing to the high level of ambient radiation.

Personal dosimeters were used to monitor the exposure of the demolition workers to external radiation. A high-volume air sampler collected air near the demolition site for workplace condition evaluation, and deposit gauges were used to monitor adjacent sites. One deposit gauge was placed near the affected building, and others were positioned at four cardinal points away from the building to collect fallout. The collected air filter samples and fallout samples were filtered on membranes and examined with a Ge semiconductor detector to determine the levels of r-Cs activity.

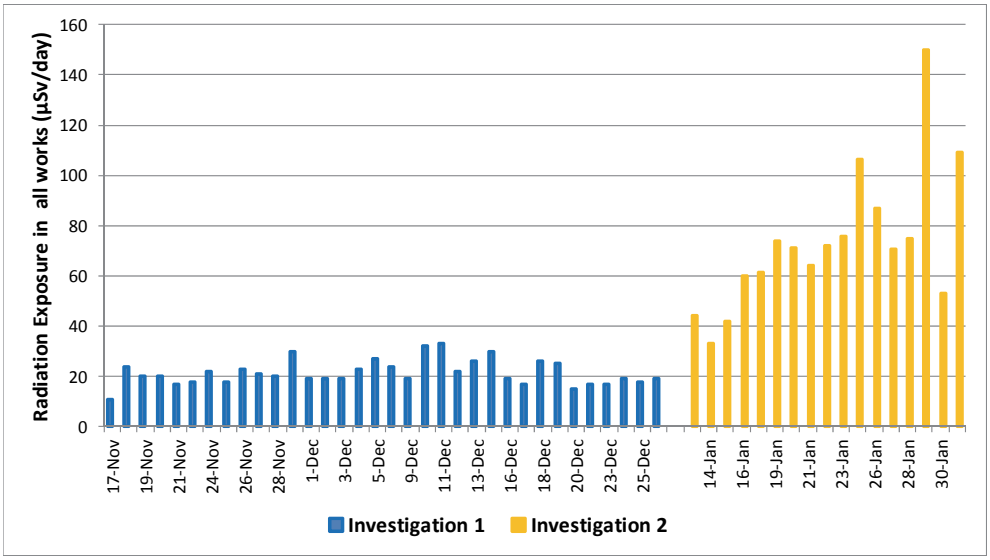


Fig. 7 Daily external radiation exposure levels of demolition workers (left: investigation 1; right: investigation 2)

Daily external radiation exposure levels of demolition workers are shown in Figure 7. Daily exposure levels in investigation 2 were higher than those in investigation 1 owing to differences in air dose rates between the sites. The cumulative external exposure dose through the working period ranged from 11 to 33 μSv (average 21.4 μSv) in investigation 1, and 33 to 150 μSv (average 73.4 μSv) in investigation 2. The length of the work period in investigation 1 was about twice that in investigation 2.

The r-Cs concentration in the air near the demolition workplace was 0.00076 to 0.011 Bq/m^3—almost an order of magnitude higher than the environmental r-Cs monitoring results from November 2014 to February 2015 reported by the Fukushima Prefectural Government in March 2015 (0.00019 to 0.0007 Bq/m^3). r-Cs activity in the fallout in investigation 1 was 0.133 to 1.45 Bq m^{-2} day^{-1} before the demolition and 0.455 to 2.68 Bq m^{-2} day^{-1} during the demolition work. In investigation 2, r-Cs activity was 0.550 to 5.31 Bq m^{-2} day^{-1} before the demolition and 1.68 to 8.59 Bq m^{-2} day^{-1} during the demolition work. These results were similar to those reported by the Fukushima Prefectural Government (1.43 to 15.1 Bq m^{-2} day^{-1}).

1.4 Elucidating r-Cs flows in the anthroposphere to optimize management systems for Cs-contaminated waste

We estimated r-Cs inflows from the environment to municipal solid waste (MSW) incineration and sewage water treatment processes in 16 prefectures in eastern Japan. We estimated that, in the year from July 2011, 0.03% to 0.05% of the total r-Cs deposition flowed into MSW incineration processes and 0.5% to 3% flowed into sewage water treatment processes. We also conducted a case study in which we preliminarily estimated macro flows of r-Cs through MSW incineration processes (Fig. 8). A large fraction of the r-Cs entering MSW incineration processes ended up in landfills of incineration residues with r-Cs concentrations not exceeding 8000 Bq/kg (the limit for landfilling at ordinary landfill sites) or was sent to temporary strage saites for incineration residues with r-Cs concentrations exceeding 8000 Bq/kg; the latter residues were intended for processing by the government as specified Cs-contaminated wastes. Our preliminary estimate showed that only a small fraction of the r-Cs entering MSW incineration processes later entered recycling processes such as the production of construction materials, cement, and non-ferrous metal materials.

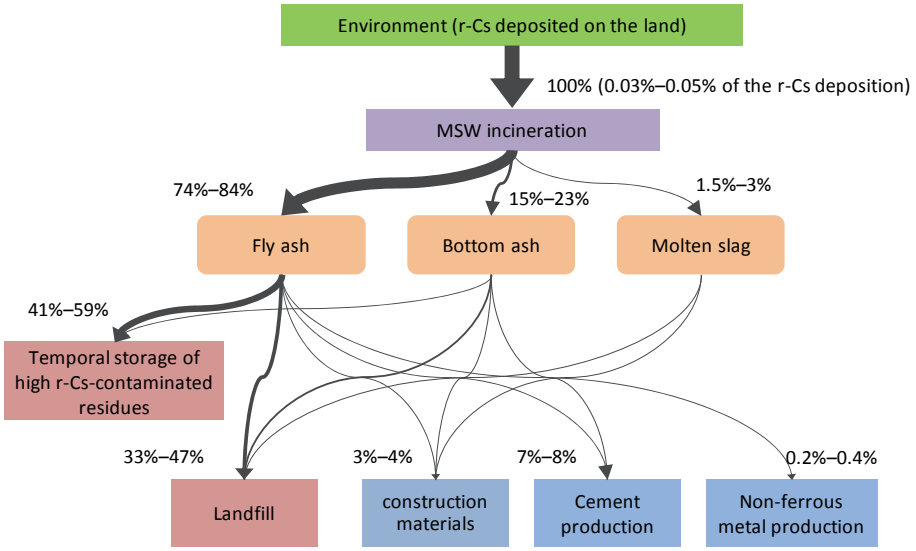


Fig. 8 Preliminary estimates of r-Cs flows through municipal solid waste (MSW) incineration processes

1.5 Risk communication

1) Web questionnaire

We conducted a web questionnaire on “trustability of scientific information” and reported part of the results. In the questionnaire, we studied the respondents’ rates of use of scientific information and their trustability ratings and general impressions of this information. We selected 15 information sources and collected 2099 samples.

TV and the Internet were rated very highly as “use always” (exceeding 55% of respondents). In contrast, the percentages of participants who responded “use

always" for researchers, research organizations, government publications, or local government publications were all extremely low at less than 40%; they were still low even when we included "use frequently" and "use sometimes."

Trustability of information sources was highest for "family members:" 25.8% of participants responded "highly reliable." Trustability of researchers and research organizations was relatively high, considering the fact that the percentages of respondents who used these sources were extremely low.

Next, we had the participants choose one or more suitable adjectives from among 30 selected ones to describe their daily impressions of the 15 information sources. We then performed a correspondence analysis of the relationships between reliability and impressions.

As a result, the 30 adjectives were allocated to six groups. In regard to the subjects' impressions of newspapers and local government publications, for which the trustability scores were high, adjectives such as "representative," "equitable," "preservable," and "useful" were closely related. From these results, we deduced that the principal determinant of the trustability of information sources was not the speed of information supply or the specialized nature of the information; rather, familiar and fair information sources tended to be trusted more.

2) Public acceptance of temporary storage sites in the city of Date

We performed interview surveys with administrative officers and members of the public in the city of Date in Fukushima Prefecture to analyze the process of siting of temporary storages for wastes contaminated by radioactive substances. We found that a sense of responsibility to the local community acted as a factor that promoted public acceptance of temporary storage sites.

2. Environmental Recovery Research Program 2 "Study of the dynamics of radioactive materials in multimedia environments"

A nuclear accident at the Fukushima Daiichi Nuclear Power Plant (FDNPP) accompanied the Great East Japan Earthquake and tsunami of March 11, 2011. As a result, enormous amounts of radioactive materials were emitted into the atmosphere and the ocean. Radioactive materials adversely affect human health through the contamination of air, water, soil, and food. It is therefore very important to understand the current status of radioactive contamination and the dynamics of radioactive materials in multimedia environments.

From this perspective, to gain a better understanding of the impacts of radioactive contamination on wildlife and ecosystem health, we studied the dynamics of radioactive materials in multimedia environments by using field measurements and multimedia fate modeling. The main results are summarized below.

2.1 Influence of vegetation on r-Cs wash-off associated with soil erosion in forests

For 145 days, from May to October 2013, we assessed the influence of vegetation on the wash-off of ^{137}Cs from forested areas by monitoring the amounts of ^{137}Cs in the eroded soil and surface runoff water from 3-m^2 experimental plots on 37° to 39° slopes in four different types of forest in Fukushima Prefecture. The greatest amount of ^{137}Cs was lost from plots in a Japanese cypress forest, followed by plots in a deciduous broadleaf forest, then a Japanese red pine forest, and then a Japanese cedar forest (Fig. 9). The amount lost from the plots in the Japanese cedar forest was one-tenth of the amount lost from the plots in the Japanese cypress forest. More than 96% of the ^{137}Cs lost by the plots was in the eroded soil, and relatively large amounts of soil were lost from plots in forests that did not have well-developed understories or had small organic horizons, suggesting that the forest-floor covering strongly affected the wash-off of ^{137}Cs. Nevertheless, only up to 1.1% of the ^{137}Cs in the soil was washed off the plots. The ^{137}Cs activity concentrations were positively correlated with the organic matter contents of both the eroded soil and the suspended solids in stream waters, confirming that ^{137}Cs was transferred from the forest floor to stream waters and indicating that the organic horizon was an important source of the washed-off ^{137}Cs.

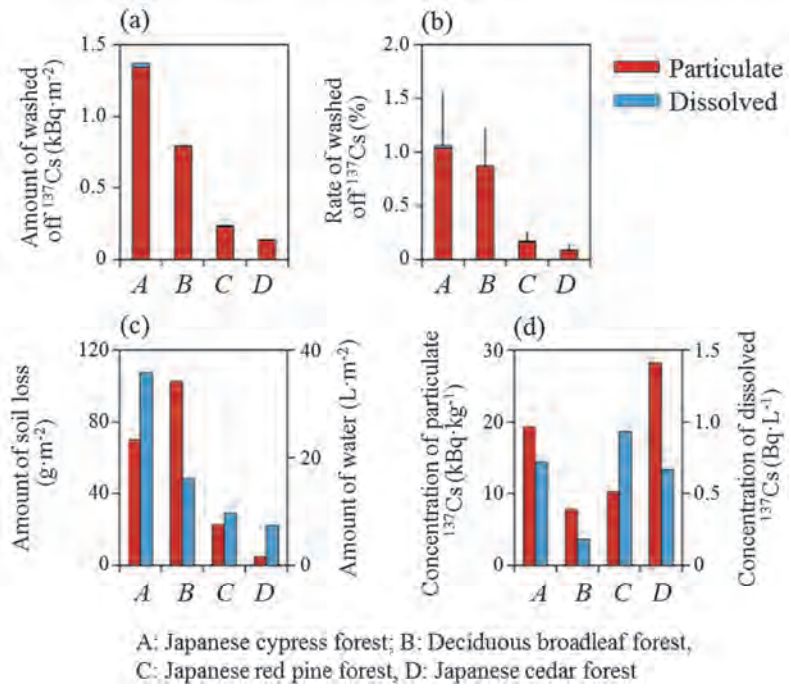


Fig. 9 Amounts (a) and percentages (b) of ^{137}Cs washed off; amounts of soil loss and surface runoff water (c); and ^{137}Cs concentrations in surface runoff water (d). In (a) and (b), bars for dissolved ^{137}Cs values are placed on top of those of particulate ^{137}Cs to show the total values of ^{137}Cs in surface runoff waters. Error bars in (b) indicate standard deviation based on variation in ^{137}Cs deposition in soil.

2.2 Analysis of ^{137}Cs stocks and flows in the Matsukawa-ura Lagoon basin

By interpolating data with a spatial resolution of 100 m, we estimated the average amount of ^{137}Cs accumulated in the sediments of Matsukawa-ura Lagoon, in Fukushima Prefecture, to be 34 kBq m^{-2}. These data were obtained from measurements of ^{137}Cs activity in 20-cm-deep sediment cores taken from 36 points covering the whole of the lagoon. The sediment cores were collected in

July 2013. The average amount of ^{137}Cs accumulated over the entire land area of the basin (172.5 km^2) was calculated by using data from an airborne monitoring survey to be 150 kBq m^{-2}. From observations at a point in the downstream part of the Uda River, which flows into the lagoon, the percentage of ^{137}Cs lost from the land in the basin to runoff each year was estimated to be only 0.12%. By combining these estimates, we estimated that the total amount of ^{137}Cs lost from the entire land area of the basin to runoff was 7.2×10^7 kBq in the 28 months after the FDNPP accident. This corresponded to about 30% of the total amount of ^{137}Cs that had accumulated in the lake sediments after the FDNPP accident; it suggests that the ^{137}Cs concentration in the lagoon might increase in future because ^{137}Cs may accumulate more quickly than it decays. This possibility is further supported by the marked difference between the ^{137}Cs concentrations in the heavily contaminated mountainous upstream region and the moderately contaminated lowland downstream region. Very limited migration of ^{137}Cs through the river basin has been observed so far. More detailed investigations, such as a continuous survey of ^{137}Cs accumulation across the lagoon bed and a quantitative evaluation of ^{137}Cs discharged from the lagoon to the sea, will be required to give us a more accurate understanding of the changes that will occur in ^{137}Cs concentrations in Matsukawa-ura Lagoon.

2.3 Multimedia fate modeling

We have been developing a multimedia fate model for radioactive substances by coupling atmospheric, oceanic, and terrestrial environment models. The atmospheric and oceanic models have been developed at the Center for Regional Environmental Research, and the terrestrial model has been developed at the Center for Environmental Risk Research. We aimed to simulate the multimedia fate of radioactive substances by combining the three models using appropriate geographic resolutions.

In the atmospheric modeling, we evaluated the model's performance in estimating atmospheric ^{137}Cs concentrations in eastern Japan during March 2011 by using new observational data retrieved from filter tapes at operational air-pollution monitoring stations. We compared simulated results by using different emission scenarios and wet deposition modules, and we found that the best model setups differed between the simulations of atmospheric concentrations and those of deposition. Further studies are needed to improve simulation models and thus reproduce consistent atmospheric concentration and deposition fields. We also evaluated the results of simulations of atmospheric ^{137}Cs concentrations over the 4-year period since the Fukushima accident. In a simulation that used reported direct-release rates, the model underestimated the observed ^{137}Cs concentrations in and around Fukushima Prefecture by orders of magnitude of two to four. Models that considered resuspension from the ground better reproduced the observed results, suggesting that resuspension was an important contributor to atmospheric ^{137}Cs in the years after the accident.

In our terrestrial modeling, we have been developing a model for predicting the long-term fate of terrestrial r-Cs in radioactively polluted areas. To do this, we model the processes involved in determining the long-term fate of r-Cs. The model is based on G-CIEMS (Grid-Catchment Integrated Environmental Modeling System), which was originally developed for assessing the risks posed by organic pollutants. This year, we evaluated the model's performance in determining the annual rate of transport of ^{137}Cs from terrestrial areas to the ocean by comparison with another terrestrial model, SACT (Soil and Cesium Transport), which was developed by the Japan Atomic Energy Agency. Although the frameworks of these models and the assumptions adopted were different, the estimates made by the two models were within the same order of magnitude. To provide more accurate predictions, we have been improving our model by incorporating the effects of different species of forest trees and spatiotemporal variations in precipitation and river flow rates on the behavior of ^{137}Cs.

In our oceanic modeling, we simulated oceanic ^{137}Cs behavior for about 10 months after the FDNPP accident. Our aim was to elucidate the dynamic ocean processes causing the heterogeneous sedimentary-^{137}Cs distribution that now remains massively on and around the shelf off Fukushima and adjacent prefectures. Notably, in accordance with recent observations, our simulation revealed significant accumulation of sedimentary ^{137}Cs in a swath just offshore of the shelf break (along the 50- to 100-m isobath). Our simulation suggests that the shape of the swath is due mainly to spatiotemporal variation between the bottom shear stress in the shallow shelf and that offshore of the shelf break. The simulation also revealed that large amounts of sedimentary ^{137}Cs were present in the deeper, as well as the upper, sediments. The total sedimentary ^{137}Cs content of the entire simulation domain was 3.2×10^{15} Bq—more than 10 times that in previous estimations.

2.4 Study of the effects of low-dose environmental radiation on reproductive organs in plants

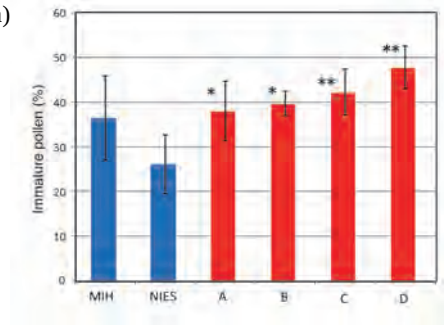
r-Cs emitted at the time of the FDNPP accident spread over an extensive area, including the town of Namie and the village of Iitate. In this area, the high air dose rate has caused concern about adverse effects on ecological communities. One of these potential effects is disordered reproduction in plants. However, there is limited literature available on the effects of low-level γ-ray exposure on plant tissues. We have therefore started monitoring the morphological changes in plant reproductive tissues in the high air dose-rate area of Fukushima Prefecture. We choose cherry trees and Japanese morning glory as monitoring plants. The Somei Yoshino cherry tree is the most popular cultivar in Japan and is useful for monitoring because it is genetically homogeneous among all individuals. We also used two genetically homogeneous cultivars of Japanese morning glory, Scarlet O'Hara and Violet. These cultivars produce an abundance of homogeneous seeds;

changes in seed color and shape could result from environmental stress, and radiation-induced gene expression changes can be identified. We compared the percentages of immature pollen in cherry flowers, along with seed color changes and the expression of stress-induced genes in Japanese morning glory, between a high-dose area (HDA) in Fukushima Prefecture and a low-dose area (LDA) in another area of Japan.

1) Effect on cherry tree pollen development

Flower buds of Somei Yoshino from five individuals were collected in the flowering season in the HDA in Fukushima; low-dose-exposed buds were picked at NIES and at the Mie Prefecture Health and Environment Research Institute. The maximum air dose rate in the HDA was 3.67 μSv/h, whereas that in the LDA was 0.067 μSv/h. Samples were fixed immediately on site and then sent to NIES. Pollens in their anthers were stained and the percentages of immature pollen were counted. The percentage of immature pollen was significantly higher in the HDA than in the LDA (Fig. 10a). However, there was no correlation between the air dose rate and the percentage of immature pollen.

(a)



(b)

Fig. 10 (a) Differences in % of immature pollen between the low-radiation-dose area (blue bars) and the high-dose area (red bars). Vertical lines represent SD. *$P < 0.1$; ** $P < 0.05$ versus the low-dose area by Student's *t*-test. (b) An experimental site in the high-dose area. Six seedlings each of the Japanese morning glory cultivars Scarlet O'Hara (left) and Violet (right) were grown. The seedlings were two months old at the time of this photograph.

2) Effect on gene expression and seed development of Japanese morning glory

Six seedlings of each of the two cultivars of Japanese morning glory were planted at four experimental sites in the HDA (in the town of Namie) and one site in the LDA (at Tsukuba) (Fig. 10b). They were cultivated from the end of June up to the end of October. The maximum air dose rate in the HDA was 6.08 μSv/h (averaged over the cultivation period), whereas that in the LDA was 0.13 μSv/h. Leaves were sampled from three individuals of each cultivar at each site. After three or four samplings, a total of 12 leaves were collected at each site in the HDA; nine leaves were collected at the LDA site. The leaves were immediately fixed by RNA stabilization reagent on site and then sent to NIES, where gene expression was analyzed by quantitative PCR. At the end of the cultivation period, all of the seeds were collected for observation of shape and color. Although no correlation between air dose rate and change in seed color was found, the level of expression of one stress-induced gene was significantly correlated with the air dose rate.

2.5 Assessment of r-Cs contamination of frogs collected from a contaminated area of Fukushima

To assess the impacts of radioactivity from the FDNPP accident on wildlife and ecosystems in the contaminated area, large amounts of research into radioactivity accumulation by, and health effects on, wildlife are needed. To search for possible adverse effects of radionuclides, we investigated their accumulation in frogs inhabiting radioactively contaminated areas around the FDNPP.

In August and September 2012, we collected 135 live individuals of five frog species (*Rana japonica*, *Rana ornativentris*, *Rana tagoi tagoi*, *Pelophylax porosus porosus*, and *Hyla japonica*), as well as soil samples, at nine sites in areas within and outside a 20-km radius of the FDNPP (Fig. 11a). We determined r-Cs concentrations (^{134}Cs and ^{137}Cs) in 125 of the collected frogs. To meet the minimum requirements for determining r-Cs contents, samples from small frogs were combined as composites. We detected r-Cs in 31 composite samples. There was a positive correlation between r-Cs concentrations in the soil samples and those in the frogs (Fig. 11b). The highest concentration in the frogs was 47,278.53 Bq/kg-wet, in *R. tagoi tagoi* at Namie site C.

Although we histologically examined the ovaries and testes of 69 *R. japonica* and the ovaries of seven *H. japonica* by light microscopy to look for the effects of radionuclides on germ cell morphology, there were no clear abnormalities in the gonadal tissues of frogs collected from sites with different contamination levels. No details are known about radiation damage to frogs at the cellular level or about the consequences of long-term exposure to radiation at individual levels. Therefore, it is important to continue investigating the effects of radiation on wildlife.

Most of Japan's frog species inhabit rice paddy fields, where they are important organisms in paddy ecosystems. Although the areas around the FDNPP included many paddy fields, no agriculture has been conducted in the contaminated area since the accident. Therefore, most of these paddy fields have dried up and changed into grasslands. For many amphibians, aridification of paddy fields means a rapid decrease in suitable environments. Rapid environmental changes accompanying this lack of human activity must also be monitored. In addition to radiation impacts on wildlife health in radioactively contaminated areas biodiversity conservation must also be considered.

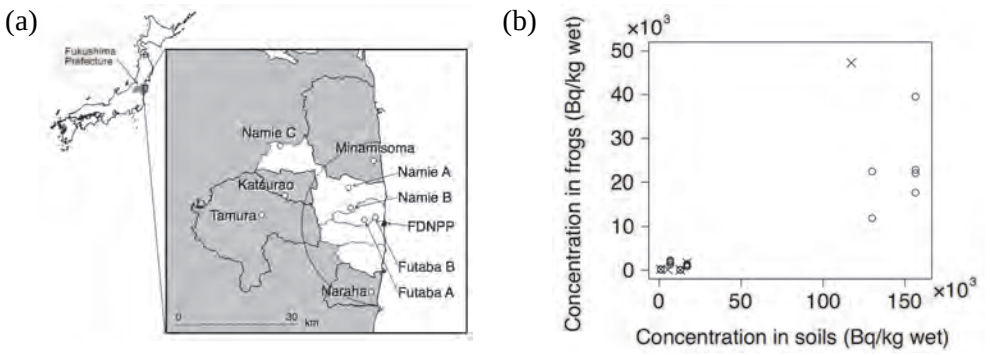


Fig. 11 (a) Map showing nine survey sites around the Fukushima Daiichi Nuclear Power Plant (FDNPP). **(b)** rCs concentrations (the sum of ^{134}Cs and ^{137}Cs) in frogs and soil samples at each site. Open circles, *Rana japonica*; crosses, other frog species.

2.6 Long-term dose estimation by using ambient monitoring and an exposure model

To estimate radiation doses from the Fukushima incident and major radiation sources, we used a combination of environmental measurements and a numerical exposure model.

1) We measured r-Cs concentrations in soils, indoor dust, and diet samples collected in the village of Iitate in Fukushima Prefecture, as well as in an area where we had observed relatively high radiation levels (i.e. a “hotspot”). We then estimated the radiation exposure from each source. The amounts of r-Cs in indoor dust collected in Tsukuba are shown in Figure 12a. The concentration of r-Cs has gradually decreased from soon after the accident to the current level; however, concentrations of several hundred Bq/kg of r-Cs were still being detected even four years after the accident. The concentration in the majority of ambient air samples collected from two sites in Iitate between March 2012 and the present did not exceed 0.001 Bq/m3 (Fig. 12b), meaning that the estimated inhalation dose was <0.001 mSv/year. Peak number 3 in Figure 12b was due to decontamination activities around the area.

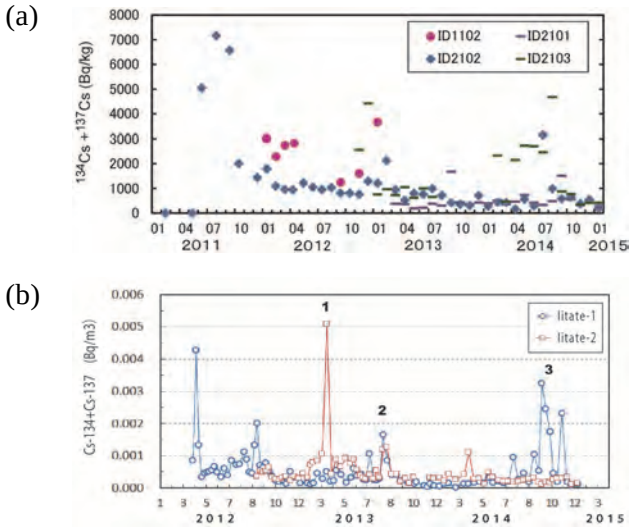


Fig. 12 Temporal change in r-Cs concentrations in indoor dust collected from residences in a “hotspot” area in Tsukuba (a) (different symbols represent different collection sites); and in ambient air collected in Iitate, Fukushima (b).

2) We developed numerical models for both external and internal exposures to estimate the radiation doses of general residents in eastern Japan. Diet samples, indoor air, indoor dust, outdoor air, and soil were considered to be sources of internal radiation. The models were built by using a set of data that we collected, as well as datasets provided by other institutions. The predominant radiation source was external exposure. Most of the model results for the cities in Fukushima Prefecture were overestimated. Our estimation of the median dietary intake was 0.1 mSv/year; however, this estimation was much higher than those of total diet and market basket studies. The major non-dietary source of internal radiation dose was indoor dust, followed by soil, indoor air, and outdoor air. Uncertainties and limitations of these model estimates arose from a lack of

monitoring data on soil deposition, accurate behavioral data, food measurement data, information about food consumption changes after the accident, consideration of land-use bias, consideration of decontamination, and consideration of the shielding effects of snow and soil. We intend to refine the model by using information about decontamination, land use, and shielding by snow and soil.

3. Environmental Renovation Research Program "Promotion of surveys and research towards restoration and environmental creation for the post-disaster regional environment"

Our Environmental Renovation Research Program aims to predict future needs for promoting surveys and research that will restore or create post-disaster regional environments.

3.1 Urban revitalization planning-support system based on regional energy characteristics

From the perspective of efficient use of limited resources and energy, much attention has been focused on distributed regional energy systems. These systems enable the efficient use of both electricity and heat by facilitating the practical use of regional resources and taking advantage of the proximity between supply and demand.

This study aims to develop a framework to support the design of a properly distributed energy system meeting the characteristics of regional supply and demand. The basic framework includes three steps: first, we analyze the energy supply conditions for the area of interest and summarize the potential amounts and costs of different generation technologies; second, we estimate possible variations in the demand for energy (including electricity, cooling, heating, and hot water) on the basis of land-use strategy scenarios; finally, we develop a mathematical programming model to optimize the sharing and operation of alternative energy technologies (Fig. 13). As a case study, we are applying the model to the municipality of Shinchi, in Fukushima Prefecture, which is involved in a revitalization project. A redevelopment project is currently in progress around the station area. We have proposed an optimal energy system along with a district revitalization plan.

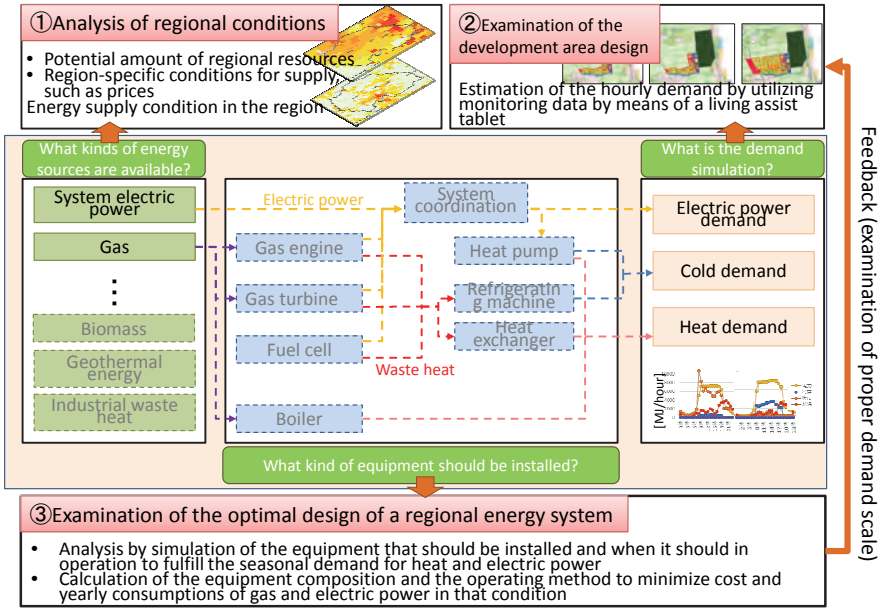
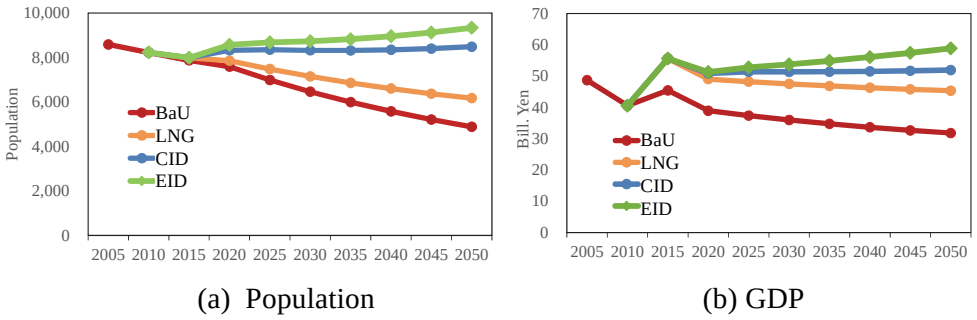


Fig. 13 Basic concept design of a distributed energy system

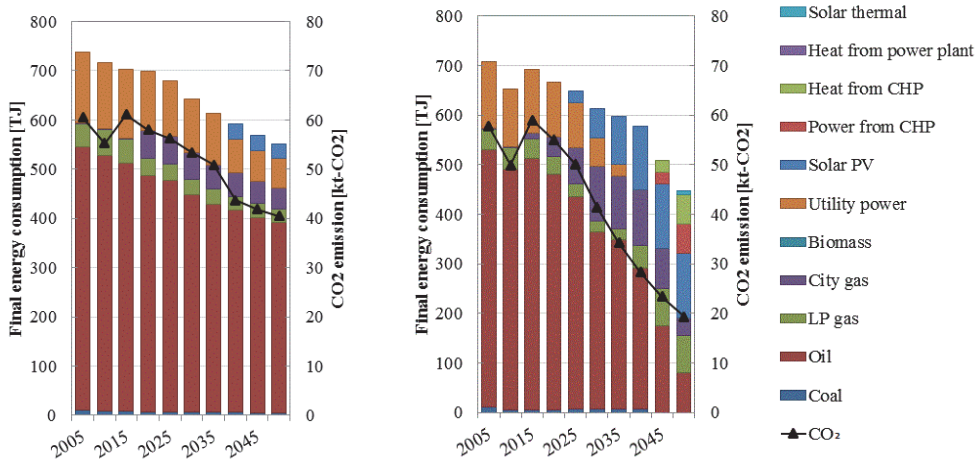
3.2 Development of scenarios of recovery towards 2050 by using integrated assessment models

For the local governments in the regions affected by the tsunami disaster, recovery is also a chance to establish new energy systems that are more efficient and self-sufficient, create new local businesses, and reduce GHG emissions. Another important issue is to stop local population decreases, a trend evident prior to the Fukushima disaster. To support the development of plans aimed at achieving these targets, we developed a quantitative methodology that considered population, employment, industry, energy demand and supply, and energy technologies in a consistent manner. By applying the methodology to the town of Shinchi in Fukushima Prefecture, we have developed scenarios for how the town will be by 2050. Under the business-as-usual scenario, the population will decline to almost half the current level. This declining trend could be reversed under a scenario of strategic location of industries on the basis of industrial symbiosis to utilize energy efficiently; more local energy industries (including smart network operators); co-generation facilities; and renewable-energy producers (Fig. 14). To determine the optimal energy systems to suit local characteristics, we developed a bottom-up technology-selection energy system model for the town. In the baseline case, CO_2 emissions would stay at around 50 kt-CO_2/year in 2050. This could be reduced by 80% by installing regional energy systems such as solar photovoltaics and combined heat and power plants under a low-carbon scenario (Fig. 15).



(a) Population (b) GDP

Fig. 14 Projected population and gross domestic product (GDP) of the town of Shinchi under four scenarios: BaU (business as usual) LNG (liquefied natural gas facilities), CID (conventional industrial development) EID (eco-industrial development)



(a) Baseline scenario (b) Low-carbon scenario

Fig. 15 Final energy consumption and CO_2 emissions, by scenario, in the town of Shinchi. OV, photovoltaics; CHP, combined heat and power plant

3.3 Overview of the development of a regional Information and Communications Technology (ICT) System

The town of Shinchi in Fukushima Prefecture was designated a “Future City” by Japan’s Cabinet Office in 2011. A program was subsequently implemented with the aim of creating a “Smart Hybrid Town” based on the environmental, economic, and social values associated with Future Cities. We collaborated closely with the government of Shinchi to develop the “Shinchi Life Assist Tablet System,” which includes two facilitating functions, namely “regional energy-assist” and “life-assist.”

We programmed tablet computers to graphically depict energy consumption information for residential houses and public facilities, and we established a regional ICT system to share information regarding town development for the reconstruction process after the tsunami disaster. This system also included information-sharing on social and community activities such as health, welfare, and transport. In addition, we constructed a central management server system termed a “Smart Hybrid Center,” and created interactive regional ICT infrastructure that was combined with the use of the Shinchi Life Assist Tablet. Regional stakeholders associated with reconstruction of the municipality (e.g.

residents, town officers, NPOs [Nonprofit Organizations], and local companies) were thus able to share information about multiple services related to eco-friendly action, welfare activities, economic activity, and transport information through the introduction of this system. We analyzed regional data compiled at the Smart Hybrid Center, and we made a substantial contribution to town development activities as part of the municipal reconstruction. Our main objectives were to (1) promote eco-friendly action through the use of regional information; (2) streamline the use of regional on-demand transportation; (3) support the reconstruction efforts of victims of the earthquake; and (4) share information interactively among regional stakeholders.

3.4 Development and verification testing of an interactive regional information system between residents and town officers

To promote energy-conservation activities among the residents of Shinchi, we conducted some experiments in the form of campaigns. The campaign duration was two weeks, and the average household electricity consumption over one week before the campaign was set as the baseline. During the campaign period, daily electricity consumption was compared with the baseline, and the daily power-saving rate was calculated for each result. After the campaign, the average power-saving rate and ranking of each household were calculated. Special gift certificates that could be used at local shops were provided by the Shinchi local government, and these were awarded to the top four households. We conducted campaigns in September, November, and March. The maximum average power saving was 7% of the September rate.

In parallel, we conducted several questionnaire surveys and interviews. For these investigations, we surveyed respondents regarding their views on an eco-friendly lifestyle. Consequently, we intend to analyze behavioral changes by combining the results of the experiments and surveys and identifying the factors that determine eco-friendly actions in each household. We will also attempt to combine the regional energy-assist and life-assist functions and to develop a method for creating a low-carbon community.

3.5 Community planning support by stakeholder communication

In December 2014 we held a workshop titled “Let’s talk about Shinchi in 2050!” The participants were 88 students in the second grade at Shoei Junior High School in Shinchi. We organized this workshop as a follow-up to a previous workshop (held in January 2014) and to forge a convergence of opinion among students about Shinchi’s future town planning. The purposes of the workshop were 1) for students to learn more about their hometown from maps and photos and 2) to establish a more concrete vision of 2050 Shinchi among the younger generation.

The students displayed an enthusiastic and cooperative attitude despite the short workshop time. They had a lively exchange of views about future visions of their town in small groups and each group made a presentation. We distributed the results of the workshop to their parents and to town officers in February 2015. The results of the workshop will be used as basic information to develop a comprehensive plan for Shinchi. The various stakeholders (e.g. town officers, residents, and researchers) will need to work together to overcome the problems associated with reconstruction.

4. Environmental Emergency Management Research Program "Studies on establishment of the environmental management system prepared for future disasters"

Our Environmental Emergency Management Research Program aims to establish practical management systems and technologies for handling disaster debris in and after disasters, and to develop the strategy for the environmental and health risk management in times of emergency in order to create more resilient social environmental systems and foster the associated community.

4.1 Quantitative and qualitative disaster debris management systems

In this study, by using per-unit data on the generation of disaster debris (including damage to housing), we estimated the discharge of disaster debris as the product of the number of damaged buildings times the per-unit generation.

As part of disaster debris management operations, disaster debris discharge must be estimated for each category of debris. The amount of each specific type of disaster debris was calculated as a percentage of the total amount of disaster debris. Disaster debris was classified into five categories: burnable, unburnable, concrete, wooden, and metal. In accordance with observations made following the 2011 Tohoku disaster, we determined the proportion of disaster debris discharge in each category.

4.2 Establishment of disaster waste management technologies and systems

1) Evaluation of an intermediate treatment technology for disaster waste
We conducted experiments to isolate the factors affecting performance in the manual sorting of mixed construction and demolition (C&D) waste, the features of which are similar to those of disaster waste. In the manual sorting of mixed C&D waste on a conveyor belt of belt width 1 m × length 10.62 m × height 0.55 m and belt speed 16.8 m/min, six types of waste item were sorted at 77 to 99 kg/person at a loading of 25 m^3/h in 30 min of work.

2) Studies of the proper management of asbestos in disaster waste treatment
We distributed a questionnaire survey to local governments affected by the Great

East Japan Earthquake. The survey examined the management of asbestos-containing wastes (ACWs) and the risks these wastes pose in the treatment of disaster wastes. The amounts of friable and non-friable ACWs treated in each of the local government areas, were 4 to 2,372 tonnes and 3 to 23,964 tonnes, respectively. The health risk posed by dispersed asbestos was well recognized by the local governments before the earthquake, and after the disaster they had ordered demolition and waste disposal workers to prevent asbestos from spreading and to wear dust respirators. Problems in planning a disaster waste disposal plan were listed as (i) awareness of the use status of friable asbestos in buildings; (ii) establishment of a procedure for settling disaster waste disposal sites; and (iii) comprehension of the essentials of asbestos risk management.

3) Development of recycling technologies and a strategy for handling disaster waste and by-products

Over a one-year period, we accumulated monitoring data on an embankment constructed by using tsunami deposits. We showed that the physical properties of the deposits and the environmental impact of the contaminants released from the deposits were at acceptable levels. On the basis of these data and last year's investigation, we published guidelines to promote the beneficial utilization of soils recovered from tsunami deposits, with the Japanese Geotechnical Society.

4) Establishment of a disaster reduction–oriented decentralized johkasou system

We calculated the stress on *johkasou* domestic wastewater treatment plants during earthquakes in order to develop and standardize earthquake-resilient construction and installation techniques for *johkasou*. We also corrected the capacity and electric power consumption of earthquake refuges so as to design an energy- and water-independent *johkasou* system for these shelters. In many cases the design capacity of these refuges involves less than 500 persons. Water demand and the design wastewater discharge can be estimated by using this capacity. Demand for electric power in refuges is mainly for lighting, TVs, PCs, and printers; however, energy demand for mobile phones, hot water dispensers, and refrigerators is sometimes additionally listed. The average emergency electric power generating capacity in refuges is 0.031 kW/person. We also developed a mathematical model for human waste and sludge transportation to sludge treatment facilities in a certain prefecture. This model showed that enhancing the capacity in some key treatment facilities would be required in various emergency scenarios and two-step transportation would be effective and practical.

4.3 Disaster waste management methods

We have conducted several studies on the development of management methods and institutions for smooth and appropriate disaster waste management. First, we tested our theory on the emergency support functions needed for disaster waste management through case studies in localities with different public administration capacities. We also clarified the basic framework required to develop

vulnerability indicators within the context of Japanese waste management systems. Finally, we studied the attitude of the public toward management of the environmental risks associated with disaster waste management. The results suggested that there was public demand for such management.

4.4 Networking of disaster and environmental emergency research

We established and promoted a website as an information platform for disaster waste management. The website is expected to serve several purposes in facilitating preparedness for future disasters. For example, it could support the development of disaster waste management plans by local governments. In particular, disaster waste management in the cities of Hiroshima and Tanba following the 2014 heavy rain disaster and debris flows were reported on this website.

We held a workshop to identify and outline the necessary capacities of local government personnel for waste management in disasters and other emergencies. Personnel with experience in disaster waste management during the Great East Japan Earthquake participated in the workshop. As a result of the discussions at the workshop, we were able to systematically organize the required capacity elements. On the basis of our research findings, we designed and proposed a comprehensive training program. We further developed and conducted a training workshop as the central component of the proposed program. The impact of the training methodology was evaluated and subsequently improved.

All of these practical research activities also provide a chance for researchers and practitioners to network; these connections will be useful in dealing with future disasters.

Environmental Information Department

The NIES Environmental Information Department provides the public with various kinds of environmental information through websites.

The Environmental Information Department provides information technology (IT) support for research and related activities at NIES; supports public relations activities (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-9/A(ECO); 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-9/A(ECO) 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 2014, 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 member of staff at the Institute.

1.3 Library service

As of March 2015, the NIES library (Fig. 2) held 53,806 books, 306 journals (including electronic resources), 122,268 microfiches, 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 materials, researchers at NIES can use abstracts and full-text articles through scientific and technical information databases such as Web of Science (including Medline, Essential Science Indicators, and Journal Citation Reports) and CiNii.

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

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 renewed and improved in step with the restructuring of NIES as an Independent Administrative Institution. The website was again renewed in July 2013. It also provides information on NIES initiatives related to the Great East Japan Earthquake.

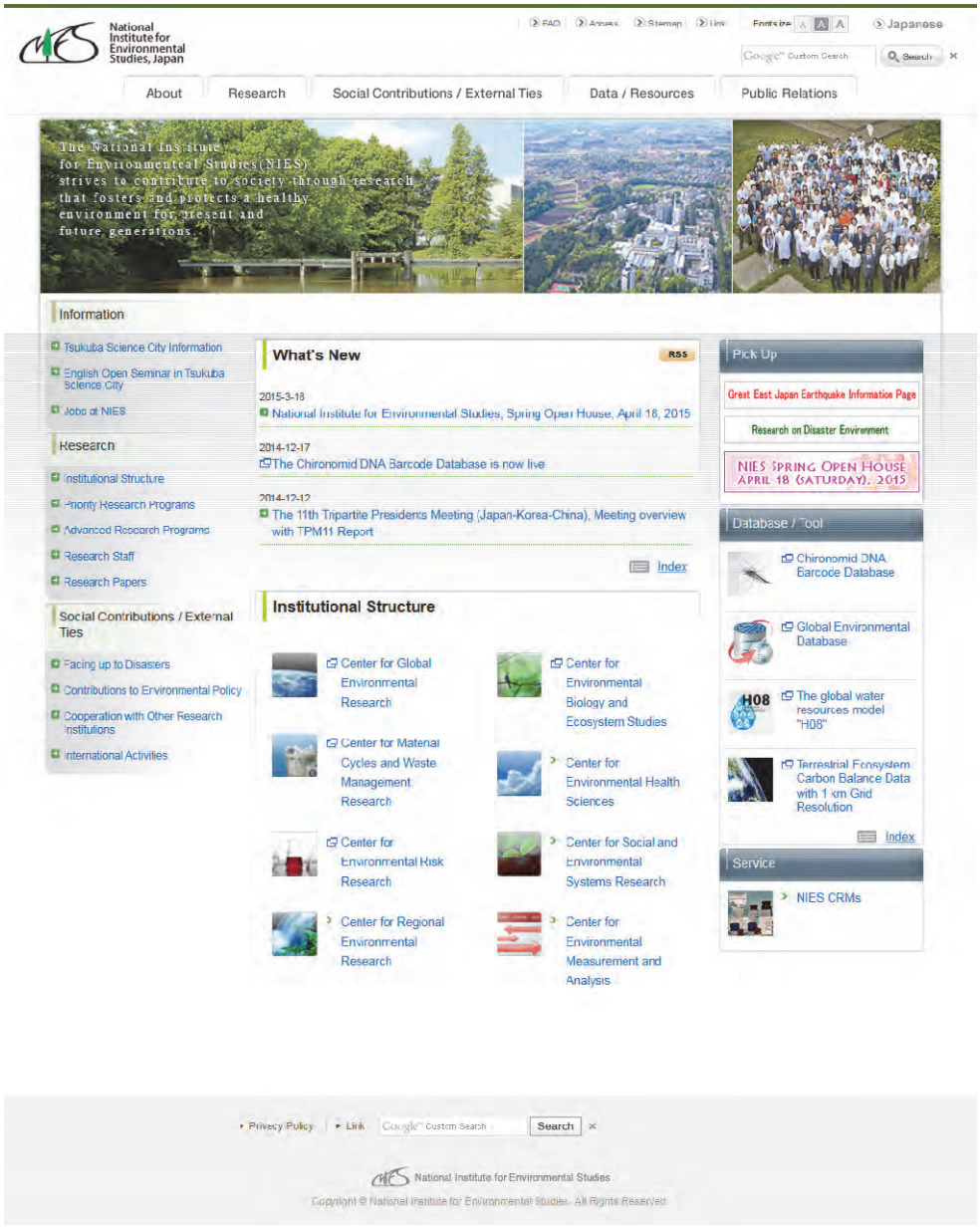


Fig. 3 The NIES website

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.

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, processes and manages environmental information databases, and provides environmental information via GIS (Geographic Information Systems).

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 related 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 environmental issues, etc. 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.

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 the MOE. These processed data can be accessed through the database on the NIES website. Duplication and lending services are also available.

Provision of environmental information via GIS
The department, with the cooperation of the MOE, has been using GIS to develop an environmental data provision system. This system helps users to easily understand the status of the environment by displaying data on environmental quality and other information on maps. 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 2014 the department performed the following task, as commissioned by the MOE:

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

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