ISSN 2187-9486

NIES Annual Report 2016

AE - 22 - 2016

National Institute for Environmental Studies
http://www.nies.go.jp/

ISSN 2187-9486

NIES Annual Report

2016

AE - 22 - 2016

National Institute for Environmental Studies
http://www.nies.go.jp/

Foreword

This annual report is the official record of activities at the National Institute for Environmental Studies (NIES) in Fiscal Year (FY) 2015 (April 2015 to March 2016). FY 2015 marked the final year of the Third NIES five-year plan (FY 2011–2015). In this, NIES Annual Report 2015, we will take the opportunity to make a final report on the research undertaken at NIES based on this five-year plan.

Under the strategy outlined in the Third NIES five-year plan, research was 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, was carried out by NIES in its capacity as a leading institute in the region.

The second aspect of our research strategy was 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 involved the maintenance of medium- to long-term initiatives in step with the sustainment and furtherance of environmental research. This included 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 included 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 included 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 was 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 was established at NIES and we cooperated in the setting up of the planned "Centre for Environmental Creation" of Fukushima Prefecture. Our Project Office has been replaced by our Fukushima Branch, which is now located inside the building of the Centre for Environmental Creation. Through this step we intend to increase our presence and on-the-ground activities in the area.

April 2016 marks the beginning of our Fourth NIES five-year plan (FY2016–2020). 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
June 2016

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.

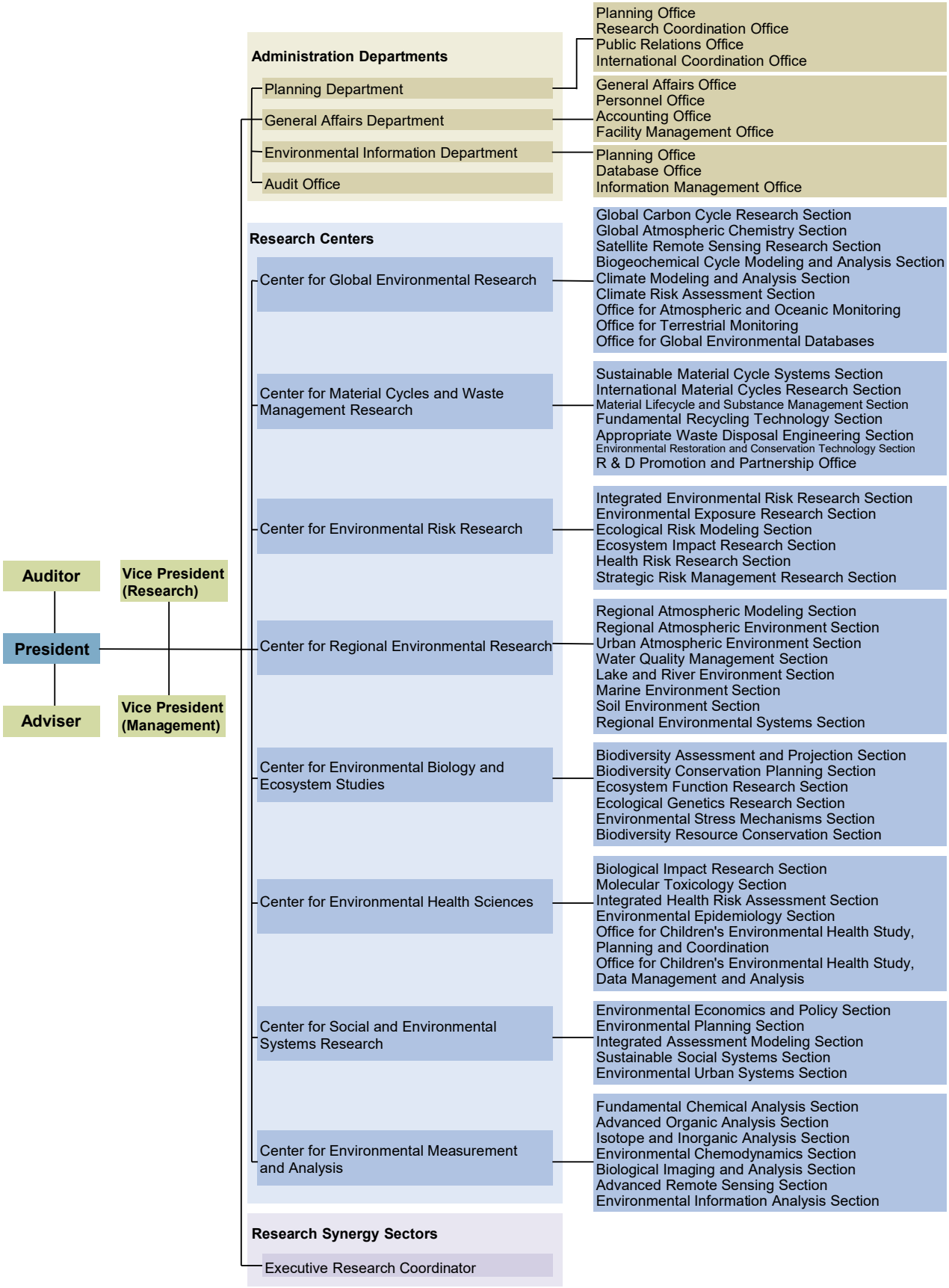
During the two decades following the establishment of NIES, rapid technological progress, structural changes in industry, and lifestyle changes, created additional issues for environmental science to confront. Moreover, global environmental problems such as climate change; depletion of the stratospheric 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, 2016, the NIES permanent staff number 272, and there are 498 non-permanent researchers (Table 1; Figs. 2 to 5). The total budget for FY2015 was 16,018 million yen (Table 2).

Table 1 Numbers of permanent staff

Administration Departments	55
Research Centers	212
Executive	5
Total	272

(As of April 1, 2016)

Table 2 Budget for the third five-year plan

(Unit: million yen)

	Category	2011–2015 Budget (5 years)	Fiscal Year 2015 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	:	55	
Research Centers	:	212	(6)
Executives	:	5	
Total		272	(6)

Notes:
1. Data is as of April 1, 2016.

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

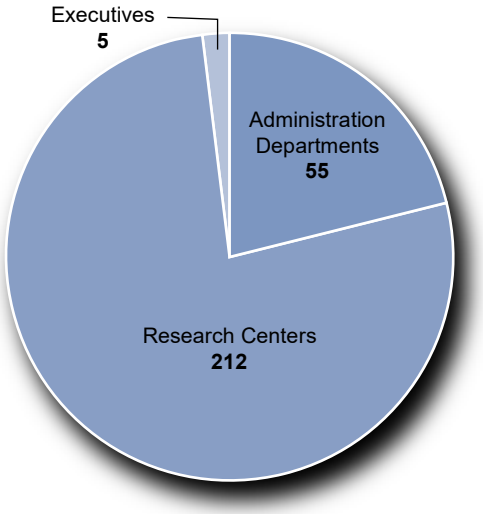


Fig. 2 Permanent staff breakdown

Basic Sciences (Physics, Chemistry, Biology)	:	79	39.11%
Engineering	:	67	33.17%
Agricultural Sciences	:	32	15.84%
Medical Sciences	:	11	5.45%
Pharmaceutical Sciences	:	5	2.48%
Fisheries Sciences	:	1	0.50%
Economics	:	2	0.99%
Sciences	:	3	1.49%
Law	:	1	0.50%
Veterinary Medicine	:	1	0.50%
Total		202	

Notes: Data is as of April 1,2016.

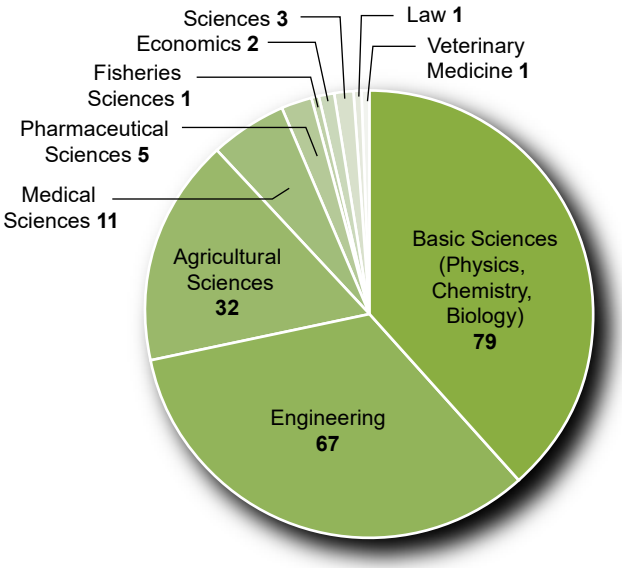


Fig. 3 Fields of expertise（Researchers holding doctorates（95.5%））

Senior Fellow	:	1	
Fellow	:	16	
Research Associate	:	86	(20)
Junior Research Associate	:	9	(1)
Research Assistant	:	26	(10)
Specialist	:	188	(5)
Assistant Staff	:	247	(1)
Senior Staff	:	9	
Total		582	(37)

Notes:
1. Data is as of April 1,2016.

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

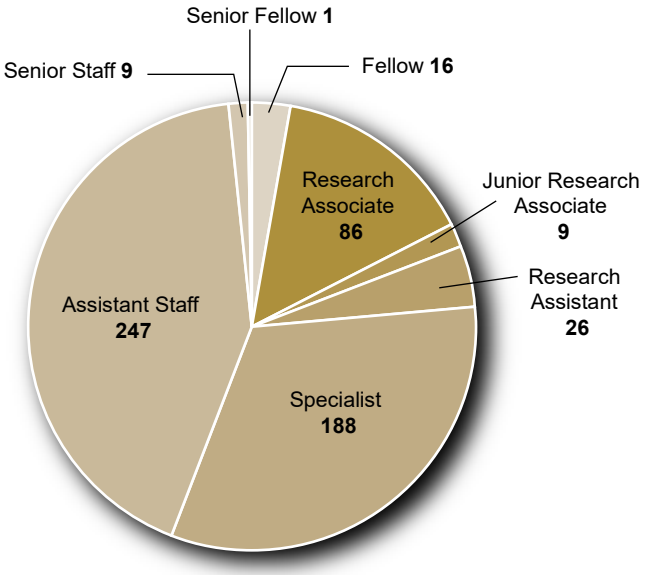


Fig. 4 Contract Staff Breakdown

Visiting Researchers	235	(7)
Research Students	47	(17)
Collaborative Researchers	78	(15)
Total	360	(39)

Notes:

1. Data is the total number accepted in FY2015.

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

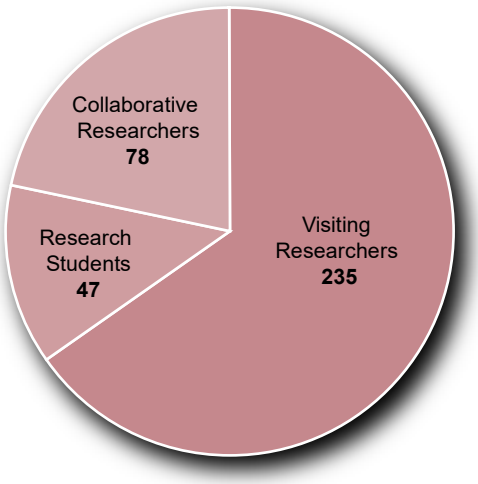
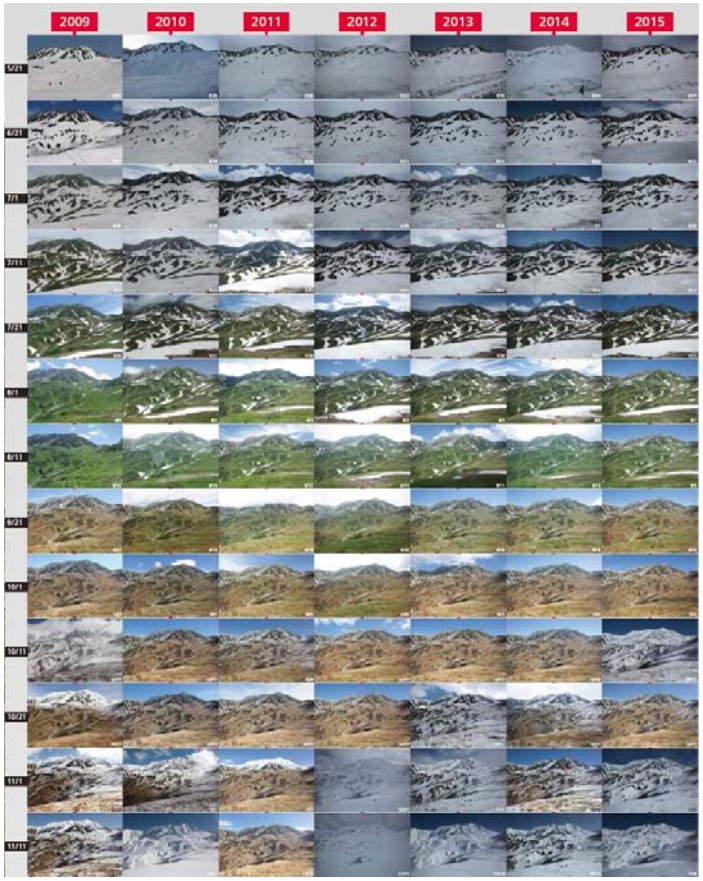


Fig.5 Visiting and Collaborative Researchers and Research Students

Center for Global Environmental Research



Monitoring of ecosystems in the Japanese Alpine zone by digital repeat photography for 7 years from a mountain hut at Tateyama, Murodo. By comparing photographs taken at the same time each year, we can determine the timings of snowfall and snowmelt and the spatial differences in their speed, as well as the phenology of the alpine flora from leaf flush to autumn coloring.

Long-term continuous camera-based monitoring provides information on the response of alpine flora to the climate and helps us understand variations in the distribution of alpine flora.

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 unclear. 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 2015.

Collaborative Research Group on Data-Model Fusion Planning

From 2009 to 2011, a joint JAMSTEC (the Japan Agency for Marine-Earth Science and Technology) and NIES research team compared terrestrial CO_2 exchange by using a data-driven top-down approach (GOSAT [Greenhouse gases Observing SATellite] CO_2 inversion) and a bottom-up approach (eddy flux upscaling based on a support vector regression model). The monthly surface CO_2 flux of GOSAT level 4A data (GOSAT L4A ver. 02.02) was used for the comparison, and the emissions from fossil fuel and biomass burning were subtracted from the total flux of GOSAT L4A to achieve direct comparability with the bottom-up biosphere flux. The seasonal patterns and amplitudes of the CO_2 exchanges obtained by using the two approaches agreed well in boreal and temperate regions of the Northern Hemisphere. However, a systematic difference was obtained in tropical regions: a larger tropical sink of CO_2 was estimated by the bottom-up approach. High uncertainty still remains in tropical regions because of limited spatial coverage by the observational data. Observations for both atmospheric CO_2 concentrations and surface CO_2 fluxes need to be strengthened by using a variety of earth observation platforms such as satellites, aircraft, ships, and ground stations, particularly in South and Southeast Asia. Improved estimates of emissions from land-use change, forest (peat) fires, and other sources are also

essential for better estimations of terrestrial CO_2 sink and source distributions.

Visualizing the interconnections among climate risks

One of our objectives is to clarify climate risks globally by including not only negative, but also positive, impacts. Therefore, experts in various fields participating in our project have reviewed the latest research and compiled a comprehensive list of climate risks. We have also prepared a comprehensive list and drawn a complex map of the causal relationships among climate risks. Existing reports such as IPCC AR5 (the Intergovernmental Panel on Climate Change's Fifth Assessment Report) have, until now, described climate risks in separate categories, but cross-sectoral causal relationships have not been systematically summarized. We expect that our comprehensive list and network diagram will contribute to global understanding of the complete picture of climate problems.

By investigating the causal relationships among climate risks, we have been able to gain a clearer overall picture of climate-related risks. We have found that changes in the climate system cause changes in the natural environment, socio-economic systems, and ecosystems. Figure 1 shows the causal relationships among risks in connection with food. Change in the climate system causes a decline in crop production and changes in the natural capital. These changes alter the social system, destabilizing the food supply and reducing food security. These changes also affect human activities in the form of an increase in malnutrition and intensification of human migration. However, depending on the place, these changes may also have positive impacts, such as an increase in crop productivity. In the near future we plan to add to our diagram more quantitative information on the size and probabilities of the damage and benefits, as well as information on the effects of countermeasures.

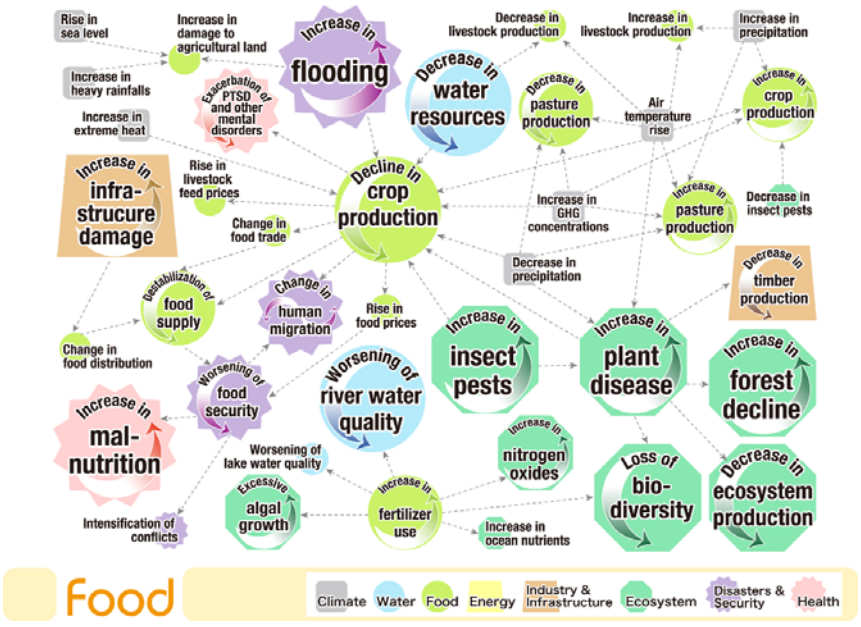


Fig. 1 Food-related risks among climate-change relationships. Relationships between risks are marked with arrows. Only relationships where food is involved in either the cause or the effect are illustrated. Risks are shown in three different sizes. Risks related to more than eight other risks among the causal relationships reviewed in our study are shown as large circles, those related to more than four other risks are marked as moderate-sized circles, and those related to fewer than three other risks are shown as small circles. The color code in the figure is based on the sectors of climate risk. Adapted from the work of Yokohata et al. (submitted).

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

In this project, our aim 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, our 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) a study of international institutions and negotiation processes for the development of an LCS. The following are the main results obtained in 2015 in each sub-theme.

In sub-theme 1, we have continued to develop LCS scenarios and roadmaps at both the country-level scale (e.g. for Thailand and Indonesia) and the city-level scale (e.g. for Ho Chi Minh City) by using the Asia-Pacific Integrated Model (AIM). AIM modeling has helped to quantify Intended Nationally Determined Contributions (INDCs) for these countries, as well as climate change action plans. In the case of Ho Chi Minh City, GHG emissions will increase from 30 to 52 $MtCO_2$-eq between 2013 and 2020. By introducing a climate change action plan in this city, GHG emissions in 2020 will decrease by 17.1% compared with those under a business-as-usual scenario. Through the Low Carbon Research Network and Low Carbon Asia Research Network, we have developed a network involving researchers and policymakers in Asian countries such as China, India, Korea, Thailand, Malaysia, Indonesia, Vietnam, and Cambodia to implement climate policies. The results were introduced at a side event at UNFCCC's COP (Conference of the Parties) 21 in Paris.

In sub-theme 2, we developed AIM-based integrated assessment models and used them to compare emission profiles in the case of INDC implementation in major countries and in the case of long-term global GHG emission projections assuming the achievement of a 2 °C global temperature change limit. For these purposes we used the AIM/CGE and AIM/Enduse models at both the global scale and the national scale in Japan. Figure 2 shows the trends in global GHG emission projections with the achievement of 2 °C target pathways and INDC targets in 2030. As a result of mitigation efforts consistent with INDC commitments, global GHG emissions will decline by 2 $GtCO_2$ in 2030 compared with the emission level in 2020, assuming fulfillment of the Copenhagen pledges. Implementation of INDCs is therefore meaningful in our efforts to achieve a low-carbon society. However, global emissions would have to be reduced dramatically after 2030 to achieve a 2.6-W/m^2 radiative forcing target in the long term. (This value is equivalent to the 2 °C target.) By 2100, total primary energy supply needs to be around 60% of that under the reference scenario; moreover, 75% of the total primary energy supply will need to be renewable. The analysis for Japan provides a similar conclusion: shifting to low- or no-carbon-content

energy would be an important strategy to achieve long-term targets.

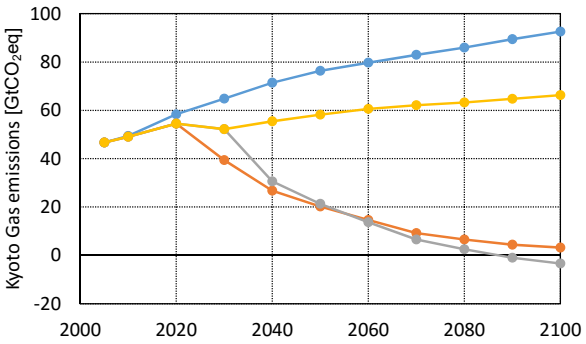


Fig. 2 Trends in global GHG emission projections.

Note: "Kyoto Gas Emissions" refer to the emissions of six GHGs, namely Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), and Sulphur hexafluoride (SF_6)

●	Ref	No climate policy.
●	2.6W_opt	Mitigation efforts consistent with Copenhagen pledges until 2020 and then the efforts increase to achieve the long-term 2 °C target.
●	2.6W_INDC	Copenhagen pledges until 2020, thereafter INDCs until 2030, and then implementation of mitigation policies to achieve the 2 °C target. (Cumulative GHG emissions during the 21st century will be the same as those in 2.6W_opt.)
●	INDC_cont	Copenhagen pledges until 2020, thereafter INDCs until 2030, followed by the same carbon price for INDC.

In sub-theme 3, we summarized a three-year project on a possible international framework for climate change for the post-2020 period. We came up with two options that we hoped would be found agreeable at COP21, which was held in Paris in December 2015. The actual Paris Agreement was quite similar to one of these two options: that is, the Paris Agreement is not called a "protocol" but is a legal instrument with legal force. It is a simple agreement, and emission reduction targets for the post-2020 period will be registered outside the agreement's main text. The emission targets themselves are not legally binding, but countries must implement the policies necessary to achieve the targets. References to the long-term temperature targets of 2 °C and 1.5 °C are great achievements, but the total amount of current emission reduction targets is not enough to reach these goals, and more needs to be done in the near future. The same can be said for the reporting process for the post-2020 period. As part of sub-theme 3, we closely followed the negotiation process during COP21 and highlighted areas for further research.

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). Routine samplings are conducted from aircraft over three sites in Siberia to measure the vertical distributions of GHGs.

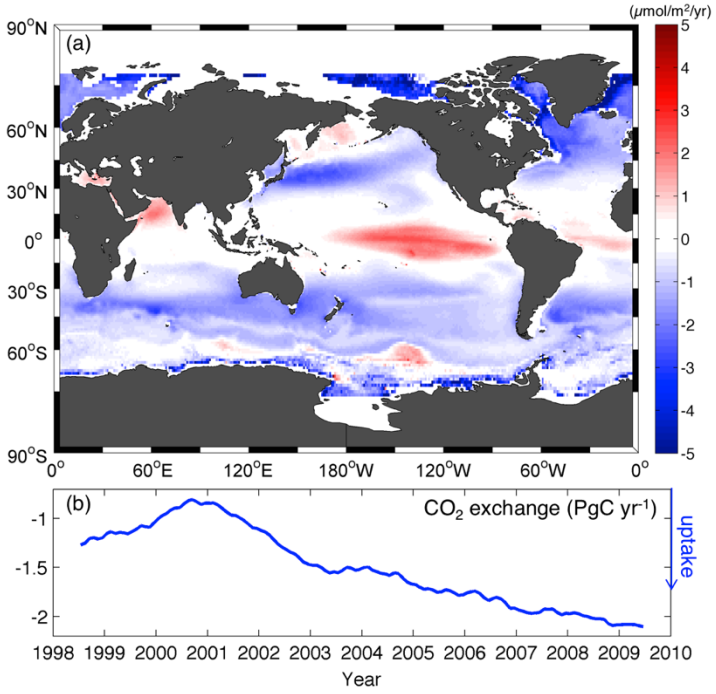


Fig. 3 (a) Long-term mean global sea–air CO_2 flux distribution; (b) deseasonalized temporal variation in global oceanic CO_2 exchange from 1998 to 2011. Negative values indicate oceanic CO_2 uptake from the atmosphere.

Commercial ships operating between Japan and Australia, New Zealand, and North America are used to observe the partial pressure of CO_2 (pCO_2) in surface waters and evaluate comprehensive sea–air CO_2 flux distributions. For this purpose, observed data are submitted to the international pCO_2 database project called SOCAT (Surface Ocean CO_2 ATlas) and since 2011 SOCAT has been releasing the data to the public.

Using the SOCAT database, we estimated global monthly pCO_2 distributions by using an artificial neural network technique. We then evaluated the sea–air CO_2 flux. Figure 3a shows the long-term distributions of mean sea–air CO_2 flux from 1998 to 2009 and Figure 3b shows the temporal evolution of global oceanic CO_2 exchange. In Figure 3a, CO_2 sinks are apparent in the North Pacific and North Atlantic, as well as south of 30°S. In contrast, there is a strong CO_2 source area in the eastern-central equatorial Pacific. The temporal pattern of oceanic CO_2 exchange shows a recent increase in CO_2 uptake; this is caused mainly by an increasing difference between atmospheric and oceanic CO_2 concentrations.

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 and chemical transport models by using satellite and ground-based data for ozone. We applied our models to a severe ozone depletion event in the Arctic in 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, as described in last year's NIES annual report. This year, we investigated the meteorological field globally and at Rio Gallegos, Argentina (51.6°S, 61.2°W) in November for the 33 years from 1979 to 2011. Figure 4 indicates that there was an unusually large negative anomaly of 50 hPa geopotential height over Rio Gallegos in 2009. The figure also shows that the large negative anomalies in November are associated with outflows of ozone-depleted airmass from the Antarctic region. Outflow toward Rio Gallegos was found only in 1980 and 2009. This implies that future low-ozone events over Rio Gallegos could occur in the austral late spring as long as the ozone hole occurs, although the frequency in the past has been low (twice in the 33 years studied).

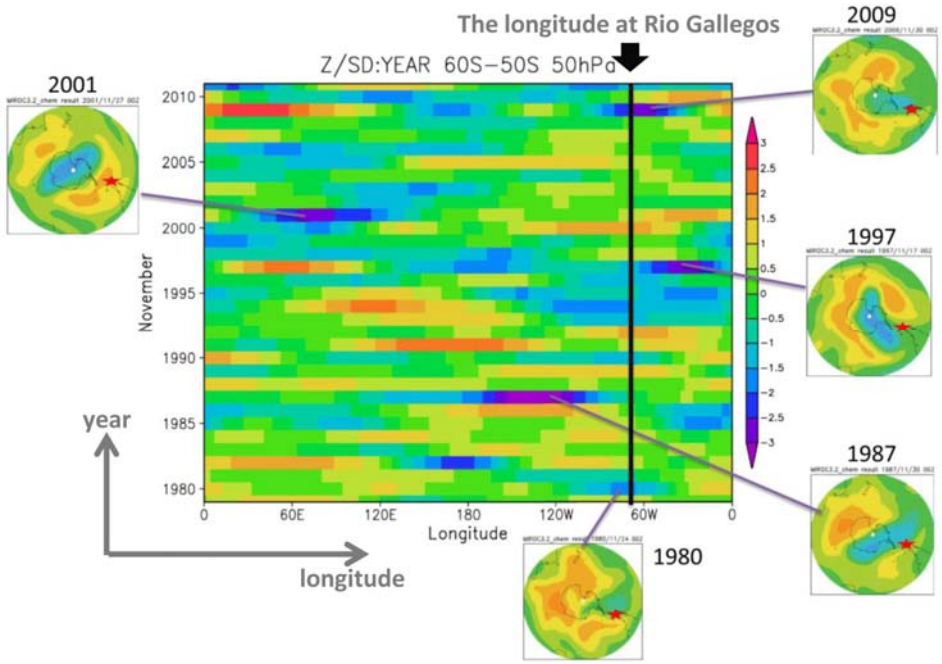


Fig. 4 Geopotential height anomaly at 50 hPa and 50°–60°S compared with the average for 1979–2011 November at each global longitude. The anomaly is indicated as a ratio to the standard deviation at each longitude. Polar maps of total ozone distribution in the Southern Hemisphere are also shown for several years; Rio Gallegos is indicated by the red star, and total ozone amounts are indicated by color (high, orange; low, blue).

NIES GOSAT project

GOSAT (nicknamed "IBUKI") is the world's first satellite designed specifically to monitor GHGs from space. Since its launch on 23 January 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).

Whole-atmospheric monthly mean CO_2 concentrations (observations made vertically through the whole atmosphere) calculated by using GOSAT data reached 398.8 ppm in May 2015. Concentrations showed a pattern of seasonal oscillation with a yearly rise over the period of analysis (Fig. 5). We also confirmed that the trend line of the whole-atmosphere CO_2 mean, derived by removing averaged seasonal fluctuations from the monthly CO_2 time series, reached 398.2 ppm in July 2015. The trend line is expected to exceed 400 ppm for the first time in 2016 if this rise continues. Our findings demonstrate the importance of GHG monitoring from space.

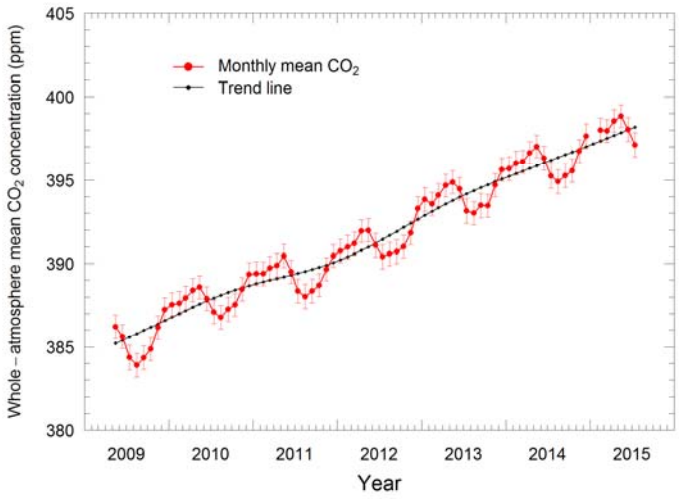


Fig. 5
Whole-atmosphere monthly mean CO_2 (red dots) and their trend line (black diamonds) between May 2009 and July 2015. Error bars on the red dots indicate uncertainty (one standard deviation) associated with the whole-atmosphere monthly mean.

We analyzed CH_4 concentrations in megacities and their surroundings for the 3.5 years from June 2009 to December 2012 by using observational data acquired by GOSAT. The analysis showed that CH_4 concentrations tended to be high over anthropogenic emission areas, where populations are highly dense, intense agriculture is conducted, and oil and natural gas are produced and processed. Also, the observed CH_4 concentrations were positively correlated with the concentrations estimated by using an anthropogenic emission inventory named EDGAR v4.2 FT2010. The results indicate that GOSAT observations can enable us to detect enhanced CH_4 concentrations resulting from anthropogenic emissions.

NIES GOSAT-2 Project

GOSAT-2, a successor of GOSAT, is a joint effort of the Ministry of the Environment, the Japan Aerospace Exploration Agency, and NIES. It will be launched in FY 2017. NIES is responsible mainly for the Level 2 to 4 processing, validation, and distribution of GOSAT-2 data.

In FY 2015, preliminary designs for the GOSAT-2 Data Processing System (G2DPS)—a computer system for operational GOSAT-2 data processing—were finished and the critical designs were started. To accommodate personnel and computers for G2DPS, two new buildings were constructed on the NIES Tsukuba Campus. To accelerate algorithm development for GOSAT-2, a dedicated supercomputer, namely the GOSAT-2 Research Computation Facility procured by the Ministry of the Environment, was installed at NIES Tsukuba Campus.

To mitigate the effects of the lack of geographic homogeneity of the Total Carbon Column Observing Network (TCCON) sites, which are indispensable for GOSAT-2 data validation, preparation of a new TCCON site installation in Southeast Asia is ongoing. Burgos, in the Philippines, was recommended as the new site after field investigations of several sites and discussions at TCCON and GOSAT-2 Science Team meetings.

In FY 2015, nine GOSAT-2 Science Team meetings, each with about 45 participants, and five GOSAT-2 Science Team Calibration Working Group meetings, each with about 20 participants, were held.

Exhibitions and other outreach activities for GOSAT and GOSAT-2 were conducted at several international conferences, including the Group on Earth Observations 12th Plenary Session (Mexico) and the UNFCCC COP21 (Paris, France).

Center for Material Cycles and Waste Management Research

Research Laboratory of Material Cycles and Waste Management Research

Thermal treatment plant

Landfill simulation plant

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)

Land transformation area caused by nickel mining

In today's globalized economy, each country has indirect and hidden flows supporting its economic activities, and natural-resource consumption through supply chains has environmental impacts far removed from the place of consumption. The area of land transformed by mining varies greatly depending on the type of mineral deposit and the mining methods used. Existing factors used to determine the land area transformed per unit of ore mined (i.e. land transformation factors) consider only differences in mining methods. In this study, we determined and accounted for the key parameters affecting the area of land transformed by nickel mining with the objective of developing a method for efficiently estimating land transformation factors.

The land transformation factor (m^2/t) was defined as the land area transformed to produce 1 t of crude nickel ore, nickel metal (grade: >99%), or ferronickel (grade: 20%). Formulae for calculating land transformation factors that considered parameters such as the specific gravity of the ores and the depth of mining were developed by first classifying mines into three types: laterite ore surface mines, sulfide ore surface mines, and sulfide ore underground mines. An uncertainty analysis to obtain a land transformation factor for each type of mine was conducted, and the key parameters affecting the results were identified. Finally, the land transformation factors for 38 mines were calculated by using the proposed method.

Application of the proposed method demonstrated that, by considering key parameters, it was possible to efficiently estimate land transformation factors by mine type (Fig. 1). Future estimates of land transformation factors by country will require the acquisition of data for the key parameters of ore grade and stripping ratio. Although this method was developed for nickel, it provides a good basis for discussing application of the method to other metals.

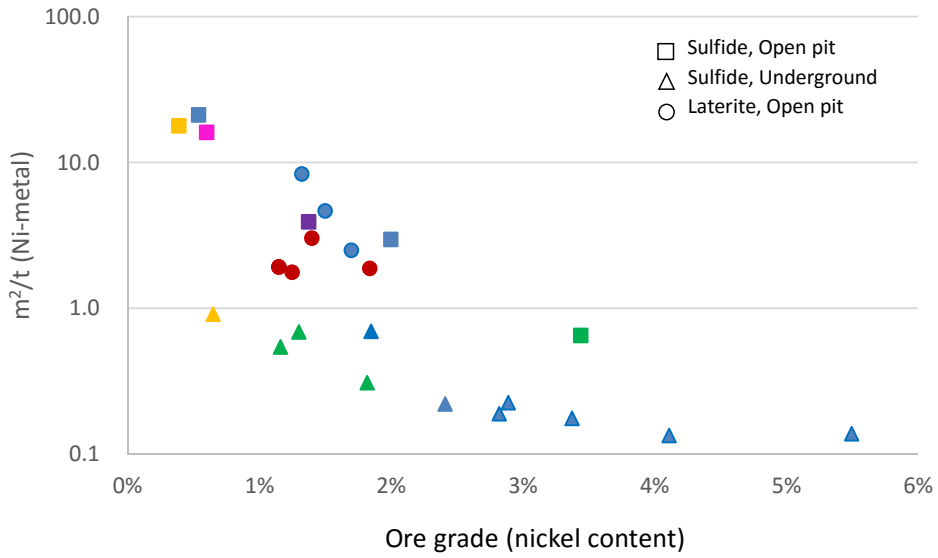


Fig. 1 Relationship between land transformation factors (by mine type) and ore grade. Colors represent countries or regions where mines were located. Blue: Australia; green: Canada; purple: Russia; pink: Spain; black: Indonesia; red: Brazil, Cuba; yellow: Botswana, Zimbabwe

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

Since January 2012, our research group has been investigating e-waste-processing activities in Bui Dau, a village in the My Hao district of Hung Yen Province in northern Vietnam, to elucidate the current levels of contaminants associated with various types of e-waste processing and to monitor 3-year temporal trends—not only of chemicals that may be initially present in e-waste, such as brominated and chlorinated flame retardants (FRs), phosphorus-containing FRs, and heavy metals, but also of hazardous chemicals that may be generated during e-waste processing, such as dioxin-like compounds. Our results clearly indicated that FRs (including BDE-209 as a candidate persistent organic pollutant [POP]), FRs as potential alternatives to POP-FRs, dioxin-like compounds, and heavy metals such as Pb and Cu accumulated in samples collected around e-waste-processing areas such as open-burning sites and e-waste-processing workshops. Dioxin-like compounds were likely transported from their sources to surrounding areas over the course of several years. Some of their concentrations were higher than the maximum acceptable values promulgated by various authorities, and accumulation of FRs such as BDE-209, dechlorane plus, and triphenyl phosphate in fish and chicken for human consumption was revealed. These results indicate that exposure assessment for these compounds should be conducted in subsequent assessments of the risks to worker and resident health. Our findings also indicate that open burning and open storage of e-waste should be prohibited, and that wastewater

treatment measures should be implemented at each e-waste-processing workshop to mitigate pollution by e-waste-derived hazardous compounds.

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

To apply a population balance model (PBM) to the estimation of future waste electrical and electronic equipment (WEEE) generation, we developed regression models to quantify in-use EEE in developing countries by means of linear multiple regression analysis of in-use products per capita, using several socioeconomic indicators as explanatory variables. We also developed a product lifespan distribution model that incorporates the age profiles and lifespans of imported secondhand products. For this purpose, we investigated the product ages of imported secondhand home appliances at a secondhand market in the Philippines. On the basis of these models and the PBM, we conducted case studies to estimate future WEEE generation in developing Asian countries by using future scenarios for socioeconomic indicators and product lifespans.

With the ultimate aim of promoting an international sound material-cycle society, we collected information about WEEE recycling capacity in Asian countries and the current transboundary movement of WEEE-related secondary resources in Asia. By using studies of battery and electronic scrap and of fluorocarbons from air-conditioners and refrigerators in selected countries in Asia, we examined future recycling scenarios, including transboundary movement.

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 emissions from solid-waste disposal sites was revised to match the behaviors of emissions from sanitary landfills and semi-aerobic landfills in Thailand. A pilot-scale experiment in a wetland constructed at a landfill in Thailand revealed the effective removal of organic compounds and nitrogen from leachate, indicating the strong role of microbial reactions in this system. We investigated the feasibility of using the constructed wetland for landfill leachate management. We have also been using a heat balance approach to the operational development of mechanical-biological treatment (MBT) of solid waste in cooperation with a municipality in Tropical Asia. Minimization of residue will help to reduce the environmental impact of the overall systems of municipal solid waste management.

Development of on-site wastewater treatment technologies for developing nations

Hydrodynamic analysis of siphon-driven mixing in an anaerobic digestion reactor indicated that liquid viscosity within a range of 10 to 100 mPa s^{-1} (at 35 ºC) significantly improved mixing. In semi-continuous experiments, the reactor could

treat most organic wastes with viscosities of less than 40 mPa s^{-1}. We used these results to design a full-scale household reactor that allowed enough mixing to treat sticky wastes such as oily food waste, and we then performed a semi-continuous experiment, treating the food waste produced daily by a restaurant. The new reactor showed good performance—comparable to those in our previous laboratory experiments. In addition, to promote the transfer of *johkasou* technology to foreign countries, we have been establishing a performance-testing method for decentralized domestic wastewater treatment facilities in Asian countries. In parallel, we have examined the applicability of *johkasou* in Indonesia from the perspective of power supply. Using a full-scale *johkasou*, we examined the effects of the Indonesian power outage situation. With the maximum daily cut-off time power outage time of 95 min, no significant deterioration in effluent water quality was observed.

Development of tools for planning waste-management systems

An organic waste source-separation and collection program has been operated in model areas in Hanoi, Vietnam, since 2007. We proposed three key parameters (participation rate, separation rate, and discharge rate) for behavior related to the source separation of household organic waste. We then monitored the progress of the program on the basis of the physical composition of household waste sampled from 558 households in the model program areas of Hanoi. We proposed six potential future household behavior patterns to help local officials identify a final or midterm goal for the program (Fig. 2). We also suggested that the city government take further actions to increase the number of people participating in separating organic waste; improve the accuracy of separation; and prevent non-separators from discharging mixed waste improperly.

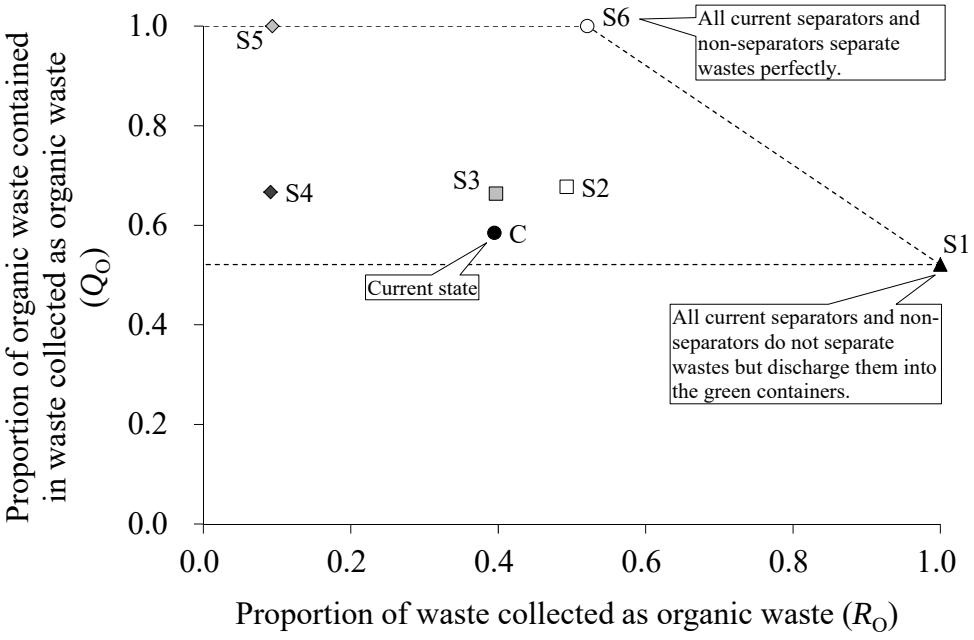


Fig. 2 Current status of source separation of organic waste (C), and possible future scenarios for source separation (S1 to S6) based on various assumptions of household behaviors

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 recycling 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. This year—the last year of the project—we continued to investigate and analyze several cases of local material cycles. We also analyzed the environmental and economic effectiveness of integrating municipal waste incinerators, and we compiled a guidance report that summarized our insights into the key actions to be taken to develop regional recycling systems.

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

We visited a municipality where a municipal waste incinerator had been integrated with another unit in a neighboring municipality and investigated the practical issues associated with the process of integrating waste-treatment facilities. We then assessed the environmental and economic effectiveness of facility integration in the region by using several different scenarios of integration and collaboration between different municipalities.

As a study of implementation, we revisited seven cases of the establishment of local recycling systems, which we had investigated previously, to confirm the results of a historical analysis using four strategic aspects: rational, practical, negotiatory, and institutional. We also obtained information about the events that had occurred recently (since the last visit) and the actions that had been taken toward the establishment of better, regionally appropriate, material-cycle systems.

Designing a framework for constructing regionally appropriate material-cycle systems

To distribute the outcomes and insights of this research project to regional stakeholders, we published a guidance report in consultation with experts on biomass utilization. It explains the important points of regional biomass recycling and fundamental terms and aspects of recycling strategy. It also depicts three fictional stories of biomass recycling that were created from real stories obtained in our case studies. The report lists 18 key actions that need to be taken to realize regional recycling systems (Fig. 3).

Fig. 3 Eighteen key actions for establishing a regional recycling system

1	Planning	7	Visit to good practice cases	13	Lecture/advise by experts
2	Persuasion of key persons	8	Trial project	14	Survey
3	Invitation to group	9	Explanation to the public	15	Avoidance of competition
4	Collaboration	10	Press release	16	Branding
5	Organizational set up	11	Informal information provision	17	Guaranty
6	Information gathering	12	Informal meeting	18	Assessment

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 interviewed staff at local municipalities that have waste-incineration plants with power-generation equipment that is used as a basis for energy supply or disaster countermeasures. From these interviews, we created a concept for the design of such base systems in harmony with local characteristics, and we then calculated the cost of constructing them. In addition, we suggested a realizable scenario in which these base systems could be introduced as part of plans for renewal of the waste-treatment facilities designed by local municipalities.

We improved the stoker-type simulator we have been developing since last year, and we then calculated the behavior of heavy metals during waste incineration. By comparing our calculated results with experimental data on waste behavior in an actual waste-incineration plant with a stoker-type furnace, we were able to tune the simulator to represent the experimental data. Furthermore, we developed another simulator applicable to waste-incineration plants with kiln-type furnaces. We compared our calculated results with experimental data on the behavior of heavy metals, and we suggested some points of improvement for the simulator.

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

We continued our development of a new leachate collection system (in the form of a layered drainage system) for seashore landfills. We had already determined that the layered drainage system could provide early stabilization of leachate discharged from seashore landfills This fiscal year, we conducted a

laboratory-scale tank test and a numerical analysis to elucidate the influences of seawater infiltration via consolidation of the sediment clay on the quality of the discharge leachate. Seawater infiltrating from the sediment clay worsened the leachate quality, but this influence was expected to vanish within about 10 years because of a gradual decrease in the amount of infiltrating seawater owing to convergence of the settlement.

We also evaluated the behavior of heavy metals leaching from a municipal solid-waste incinerator fly ash treated with a chelating agent. Flushing the fly ash with water in the form of continuous drops or a single addition per week affected the behavior of the metals in different ways, even when the total amount of water added was the same. Intermittent dry and wet conditions may enhance the release of metals.

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

We investigated the effects of exhaust-gas circulation on greenhouse gas emission in a *johkasou* domestic wastewater-treatment facility. According to the gas monitoring data, rates of methane and nitrous oxide emission were lower than under normal operating conditions. This finding suggested that methane and nitrous oxide gases were dissolved in water in the aeration tank and oxidized. In addition, we investigated recycling technologies for treating excessive amounts of biomass residue produced by environmental restoration and liquid-waste treatment. Use of a hybrid system combining electrolysis and anaerobic digestion enabled us to stabilize and accelerate the methane conversion of waste vegetation that was difficult to degrade biologically. Moreover, CO_2 produced during the digestion could be electro-biologically converted into methane. We also investigated the biological conversion into hydrogen of algal biomass used for nutrient remediation. We found that the hydrogen yield varied widely (by about 100%) according to the algal species; an appropriate species therefore needs to be selected from the perspective of energy recovery.

2.4 Development and evaluation of treatment technologies for legacy wastes and hard-to-recycle materials

In a study of appropriate ways to manage asbestos-containing wastes, we examined the use of Raman microspectroscopy to identify and quantify airborne asbestos fibers. We also investigated conditions of negative pressure and airflow in a curing space in a workplace that removes sprayed asbestos.

To find appropriate treatment technologies for wastes containing POPs, we conducted combustion experiments on the use of decabrominated diphenyl ether (decaBDE) as a brominated FR. We found that decaBDE was completely decomposed by combustion; the amounts of brominated dioxins and mixed

halogenated dioxins formed were very small.

We proposed a plan to promote the use of landfill sites as solar power plants by means of landfill cover-soil enhancement, and we used lysimeter experiments to examine the effectiveness of cover-soil enhancement. We also trained local government officers to ensure that the disaster-waste treatment plans in place at combustible-waste depots include fire-prevention.

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

We developed a set of pH-testing procedures consisting of continuous flow conditions and batch conditions for the utilization of steel slag in marine applications. These tests are called the "type test" and "delivery test," respectively. Characterization leaching tests such as up-flow percolation tests were applied to municipal solid waste incinerator ash to evaluate the leaching behavior of heavy metals and the long-term stability of the ash. With the aim of standardizing the percolation tests, we conducted a second ring test that joined together 17 organizations. The effect of standing period and flow rate were evaluated. The results were reported at the ISO/TC 190 annual meeting.

3. Promotion of seed and fundamental research

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

To establish a systematic approach to conducting time-series material flow analysis (MFA) of metals within a global system boundary, we have developed MFA software. Use of the software ensures MFA within a global system boundary encompassing 231 countries and regions and considering all possible trade commodities that might contain the metals in question. By using this software, we have performed MFA of critical metals and base metals for the period 1995 to 2010. In our policy study, we continued to analyze the responses to an international survey of extended producer responsibility (EPR). This year we focused on between-country differences in stakeholders' perceptions of EPR. We found that the Japanese tend to place more importance on improving product design and providing product information, whereas they place less importance on promoting new business models and innovation and on improving overall systems. We documented our results and published a report.

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

We used our bioassay system to evaluate the hazards posed by a mixture of a new biofuel and a fossil fuel oil and by the exhaust gas from combustion of this mixture; we also suggested points that could be improved in this evaluation. We

measured the vapor pressures, water solubility, and octanol:water partition coefficients of some selected brominated benzenes used as alternatives to POP-like flame retardants. The results indicated that these compounds may in fact be POP like.

In a study of a dual-fuel production system for converting grease-trap waste to biofuel oil (BFO) and biogas, we developed a predictive method for homogeneously blending BFO and a low-sulfur fossil fuel oil. We also developed a monitoring technology to detect the concentration of inhibitors of biogas production from de-oiled grease-trap waste. The performance of these technologies was evaluated. Furthermore, we tried to develop a new biofuel production method by using fast pyrolysis, and we analyzed the thermal decomposition behavior of woody biomass.

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 metals. For the former database, we collected and compiled data on waste-management facilities, including recycling plants, incinerators, and landfills. For the latter, we improved the accuracy of estimated flow data by adding constraints on the apparent consumption in each country to the flow calculation. We collected and compiled data on the amounts of elements in municipal waste residues after incineration; this was in addition to last year's investigation of 55 elements in e-waste.

4. Promotion of collaborative R&D projects

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

We have continued our efforts to reinforce the capacity of researchers and government experts to institutionalize existing research outputs in the form of regulations, policies, guidelines, and standards in the Asian region and internationally. An initiative newly launched in FY 2015 was participation in the Japanese delegation to the ISO (International Standards Organization) technical committees TC297 and TC300, which are involved in waste management technologies. We are aware of our role as a group of leading researchers in the field of waste management technologies and of the growing importance of international standards for international goods and service exchange. As a result, we intend to continue to collaborate with our commercial and government partners and to lead discussions on setting appropriate rules for waste management–related standards.

Another initiative taken this year was a continued effort to establish an Asian standard for treatment-performance testing methods for decentralized wastewater

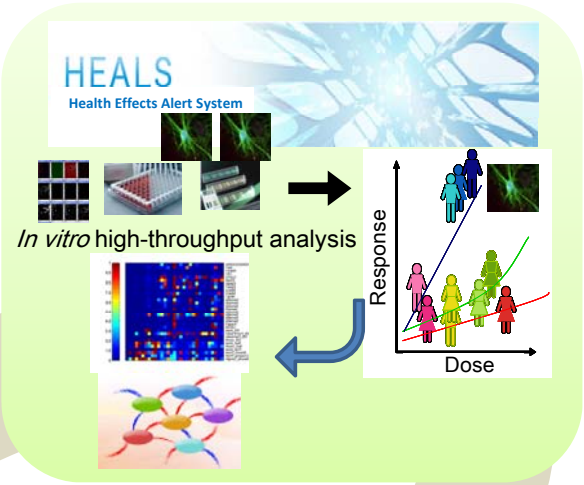
treatment facilities. Our pilot project continues to gather stakeholders in Indonesia to draft testing methods and form a domestic technical committee towards standardization in Indonesia. Our efforts have expanded to explore the possibility of regional harmonization of testing standards by creating a network of experts in the field of decentralized wastewater treatment in other ASEAN countries.

Finally, to summarize 2 years of study of flood-waste management in mid-scale Asian cities, supported by the Asia-Pacific network for Global Change Research, we have developed a Vulnerability Assessment Tool for flood-waste management by Asian municipalities and Flood Waste Management Guidelines for Bangkok based on microdata and interviews conducted in districts of Bangkok. Our hope is that these tools will help policymakers and international donors in developing Asian countries to mitigate the negative impacts of floods on waste management. A summary of our overseas research, including our collaborative research, is presented in Figure 4.

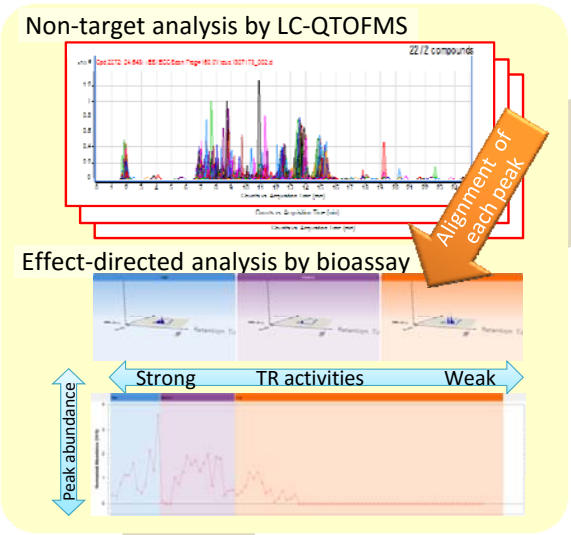
Fig. 4 Overview of our international R&D collaboration and the major outputs of FY 2015. On the basis of our research outputs, we collaborate with various stakeholders. We conduct socially influential activities such as institutional design and development of policy-making assistance tools; capacity building; and researcher exchange.

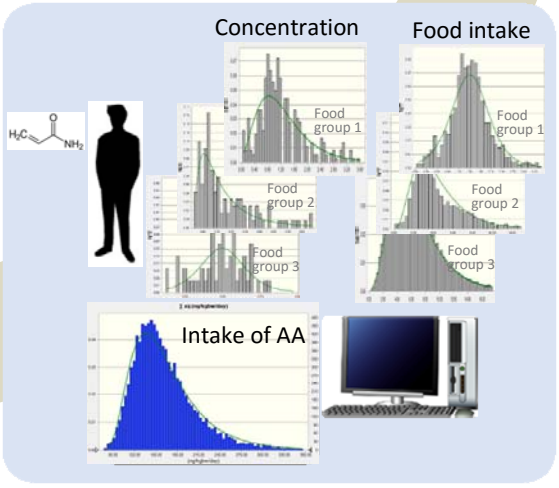
Center for Environmental Risk Research

Prediction of chemical effects by a Bayesian network analysis



Exhaustive analysis of environmental samples





Estimation of dietary intake of chemicals in Japanese using probabilistic modeling

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 and other anthropogenic factors (e.g. nutrient loading) on ecosystems. This fiscal year we have made progress in two areas of ecological research,

namely the development of software for the Aquatic Tri-trophic Ecological Risk Assessment Model (A-TERAM) for the ecological risk assessment of chemical substances, and a field survey of the interrelationship between hypoxia and survival of the early life stages of benthic animals in Tokyo Bay to determine the environmental effects of low dissolved oxygen levels.

i. **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. In FY 2015, we completed the development of user friendly software, A-TERAM version 1 (Fig. 1), which was designed for conducting deterministic and stochastic simulations and evaluating ecological risk in terms of the relative reduction in the population growth rates of top species (i.e. the ecological risk quotient, ERQ). The software also calculates the toxicant concentration that induces a specific ERQ as com-EC_x (x-percent community-level effect concentration) when the ERQ is x.

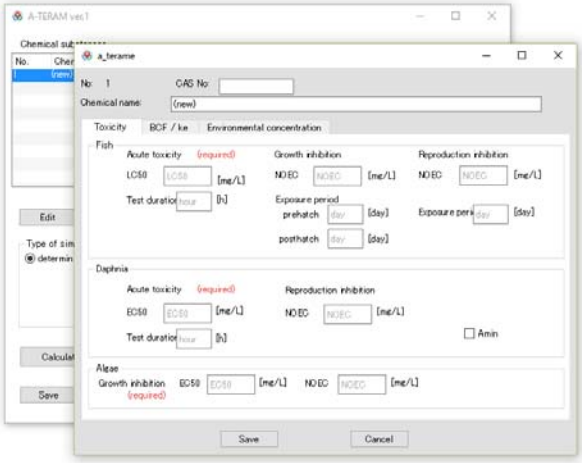


Fig. 1
The input screen of A-TERAM ver. 1

Input data available for A-TERAM ver. 1 include the 50% lethal concentration (LC_{50}) for fish mortality; 50% effect concentrations (EC_{50}s) for *Daphnia* immobility and algal growth inhibition; and no observed effect concentrations (NOECs) for fish growth and reproductive inhibition, *Daphnia* reproductive inhibition and algal growth inhibition. They also include bioconcentration factors (BCFs) in fish and the environmental concentrations. Among these ecotoxicity data, fish LC_{50}, *Daphnia* EC_{50}, and algal NOEC or EC_{50} are essential input data for evaluating ERQ and com-EC_x. We completed a user's manual and technical guide in Japanese and are now preparing an English version. The software and the document will be published on NIES's homepage early in FY 2016.

ii. **Effects of hypoxia on survival of early life stages of megabenthic animals in Tokyo Bay**

We investigated the effects of severe hypoxia (dissolved oxygen <1 mL L^{-1})

on the recruitment of mantis shrimp (*Oratosquilla oratoria*) in Tokyo Bay. A 10-year field survey was conducted to examine the quantitative relationships between the annual mean densities of larvae and juveniles and between the spatial distribution of juveniles and severe hypoxia. There was no significant correlation between the annual mean densities of larvae and juveniles, suggesting that mortality during the larval or juvenile stage varies among years and might thus regulate the abundance of young-of-the-year juveniles (Fig. 2a).

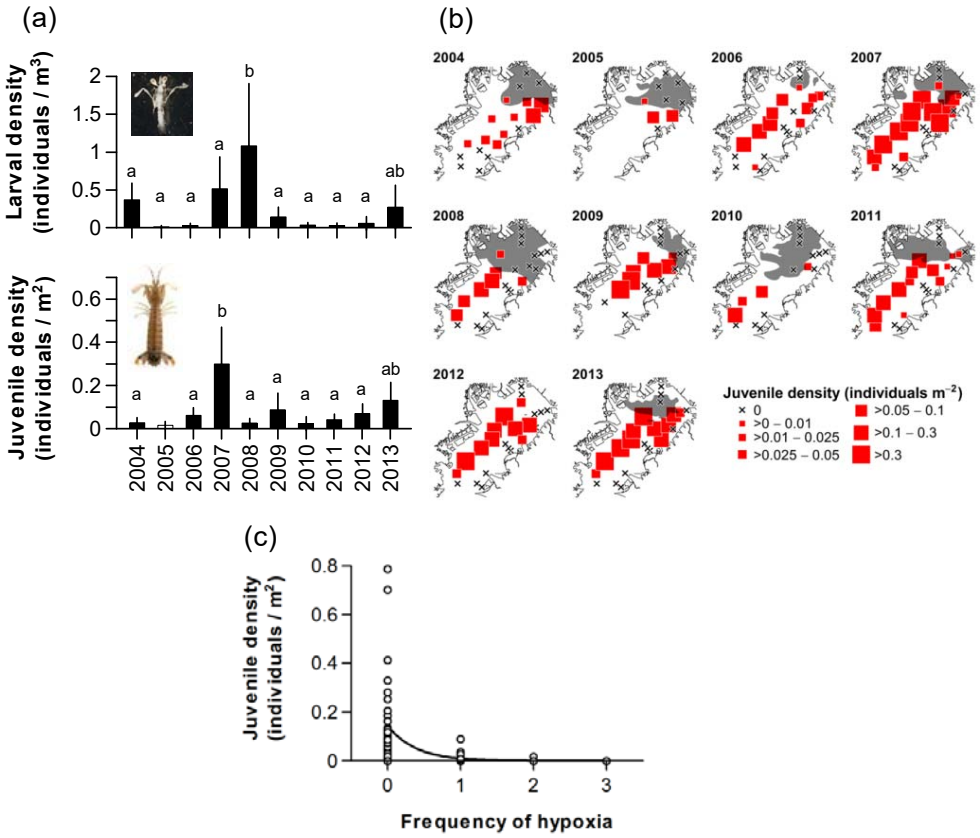


Fig. 2 (a) Changes in annual mean population densities of larval and juvenile mantis shrimp. Different letters indicate a significant difference by the Tukey-Kramer test at $P < 0.05$. (b) Spatial distribution of settled juveniles in Tokyo Bay. Areas where there had been severe hypoxia (dissolved oxygen 1 mL L^{-1}; gray) since the estimated settlement date of juveniles are also shown. (c) Scatter plot of juvenile density against frequency of severe hypoxia (dissolved oxygen 1 mL L^{-1}) at sites in northern Tokyo Bay. The juvenile density predicted by a generalized linear model assuming a negative binomial distribution is also shown (solid line).

Juvenile density was low in the severely hypoxic area, implying that hypoxia could affect the survival and spatial distribution of juveniles (Fig. 2b). In addition, juvenile density showed a marked decline when hypoxia occurred after the estimated date of settlement (Fig. 2c).

Our results imply that even a single hypoxic event after juvenile settlement can lead to a marked decline in juvenile density. To date, however, there is no information regarding fatal dissolved oxygen concentrations and the duration of exposure to hypoxic conditions that causes mortality of mantis shrimp juveniles; these factors should be examined to assess the validity of the adverse effects of severe hypoxia on mantis shrimp juveniles in Tokyo Bay.

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

In our first nanotoxicology 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, uses mammalian cells and laboratory animals and focuses on the mechanisms of *in vitro* and *in vivo* toxicity of silver nanoparticle carbon nanotubes and of chemically modified dendrimers. We are also performing ecotoxicological evaluations of titanium dioxide nanoparticles by using the embryos and sac fry of zebra fish (*Danio rerio*). We have improved our *in vitro* nanoparticle exposure system for toxicity screening of various types of airborne 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 effects of the shape, dispersibility, and surface charge of nanomaterials on living systems.

Deposition of nanoparticles on the cell surface is the initial step in eliciting toxic effects. We investigated the deposition efficiency of particulate substances empirically and computationally by using an air–liquid interface (ALI) cell exposure system. Deposition efficiency was found to be minimal (below 1%) at 200 to 300 nm in diameter, showing that inertia and diffusion are important determinants. We also found that deposition efficiency can be predicted for arbitrary particle properties, air flow conditions, and ALI cell-exposure chamber geometry on the basis of the Stokes number, the Froude and Peclet numbers, and the distance between the nozzle head and the cell surface.

We investigated the pulmonary and vascular effects of multi-walled carbon nanotubes (MWCNTs) in a murine atherosclerosis model. Male apolipoprotein E-deficient (apoE-/-) mice were given 2 or 10 μg MWCNTs intratracheally once a week for 4 weeks. In the bronchoalveolar lavage fluid, LDH (lactate dehydrogenase) activity; the concentrations of total protein, the chemokine KC, and M-CSF (macrophage colony-stimulating factor); and total cell number were increased after exposure to MWCNTs at either dose. Although the serum concentrations of total and LDL cholesterol were unchanged, the concentration of TNF-α (tumor necrosis factor alpha) increased in the thoracic aorta and atherosclerotic lesions were exacerbated in mice given 10 μg MWCNTs.

Once nanoparticles are deposited on the cell surface, they are internalized by endocytosis, macropinocytosis, or phagocytosis. The Macrophage Receptor with COllagenous structure (MARCO) protein is a plasma membrane receptor that plays a critical role in cellular uptake of environmental particles such as carbon dusts and silica. In Chinese hamster ovary cells stably transfected with green fluorescent protein–conjugated MARCO, we found that MARCO was internalized either by ruffling of the plasma membrane followed by macropinocytosis or by endocytosis followed by fusion with autophagosomes.

The macropinocytic process generated large vesicles when the plasma membrane subsided. The endocytosis/autophagosome process generated small fluorescent puncta, which were visible when lysosomal function was suppressed in the presence of glutamine (Fig. 3). Our current hypothesis for particle internalization is that MARCO, which is an adhesive molecule expressed on the phagocytic cell surface, binds to the environmental particles as an initial step. Internalization of particles then occurs through either invagination or ruffling of the plasma membrane.

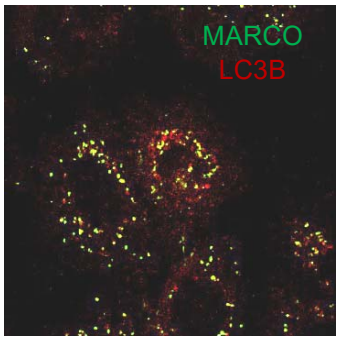


Fig. 3
Co-localization of MAcrophage Receptor with COllagenous structure (MARCO, green fluorescence) with an autophagosome marker, Light Chain 3B (LC3B, red fluorescence) in Chinese hamster ovary cells. The cells were treated with chloroquine. (Adapted from. *PLOS ONE* 10(11): e0142062, 2015)

Neurodevelopmental toxicity of silver nanoparticles (diameter 10–30 nm) was elicited by their oral administration to rat pups at a dose of 30 μg/animal when the nanoparticles were dispersed with carrier proteins. However, agglomerated nanoparticles did not cause marked effects, suggesting that hyperactivity to silver nanoparticles occurs only when the particles are dispersed. We previously showed that silver nanoparticles inhibited neuronal cell migration *in vitro*, resulting in the disruption of neuronal networks. The neurodevelopmental disorder observed in the rat pups that received silver nanoparticles orally might reflect a deficit in motor behavior neural networks.

Amine-terminated polyamidoamine dendrimer (PD), an unmodified plain type of PD, has obvious cytotoxicity because of its easy adhesion to the cell surface, resulting in its easy cellular uptake. We performed single photon emission computed tomography imaging of a mouse by using radiolabeled PDs, but we were unable to detect any signal in the intracranial region. Moreover, we examined the permeability of the blood brain barrier to PDs by using an *in vitro* test kit. Our results indicated that the permeability of the barrier was low and was suppressed by an inhibitor of caveolae-mediated endocytosis, not by an inhibitor of macropinocytosis. Physicochemical analysis of PD revealed that cationic PDs are likely to aggregate rapidly (as soon as they are suspended in general body fluid) and that this acute aggregation seems to be driven by a non-Derjaguin-Landau-Verwey-Overbeek attractive force that originates in the surrounding divalent ions. These results suggest that the possibility of transport of intravenously-administered cationic PDs into the intracranial nervous tissue is quite low, likely because the particles aggregate rapidly and cannot pass through blood brain barriers.

TiO_2 nanoparticles have been used widely in construction materials and cosmetics and are presumably released into the environment, where they could affect aquatic ecosystems. We recently 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 the TiO_2 was correlated with the degree of toxicity. We analyzed the viability data and found that the lowest observed effective concentration of the TiO_2 nanoparticles was 100 mg/mL. The data were analyzed by using different metrics of TiO_2 nanoparticles.

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; our own PeCHREM/G-CIEMS (Pesticide Chemicals High Resolution Estimation Method/Grid-Catchment Integrated Environmental Modeling System) model is 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 (perfluorooctane sulfonate) 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) to predict the fate of persistent organic pollutants and mercury. 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 this topic in relation to chemical spatiotemporal variation, the 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 2016, as part of sub-theme 1-1, we used the PeCHREM/G-CIEMS model for preliminary calculations of time trends in the rankings of hazard quotients for 49 paddy pesticides in river water from 1990 to 2010. In sub-theme 1-2 we measured and qualitatively modeled the transfer of flame retardants from

products to attached dusts. We also estimated the relative contributions of various pathways to the emission of these compounds from products during use. As part of sub-theme 1-3, we continued developing FATE for mercury (FATE-Hg), as described in the next paragraph. In theme 2 we surveyed the possible differences between scientific and societal understanding of the basic concept of risk.

As part of sub-theme 1-3 we developed an improved atmosphere-ocean-sediment-biosphere Hg model and implemented this in FATE-Hg (Fig. 4, left panel). This new sub-model describes Hg transformation, including the production of toxic methylated Hg in seawater and sediment, its deposition, and its biotransport from lower- to higher-order marine organisms. In addition, we used data from literature surveys to investigate parameters used in this sub-model, including rate constants for transformation, a bioconcentration factor (BCF) for marine particle organic matter, and the trophic magnification slope (TMS). We found that BCF depends on the surface Chl a concentration (i.e. productivity): BCFs in oligotrophic open oceans showed larger values (by about 1 to 2 orders of magnitude) than those in eutrophic coastal oceans (Fig. 4, right upper panel). In contrast, TMS was insensitive in terms of ocean section, habitat (i.e. freshwater–seawater difference), and environmental variables such as temperature (Fig. 4, right lower panel). We are continuing to improve model processes and parameters and to perform comprehensive validation.

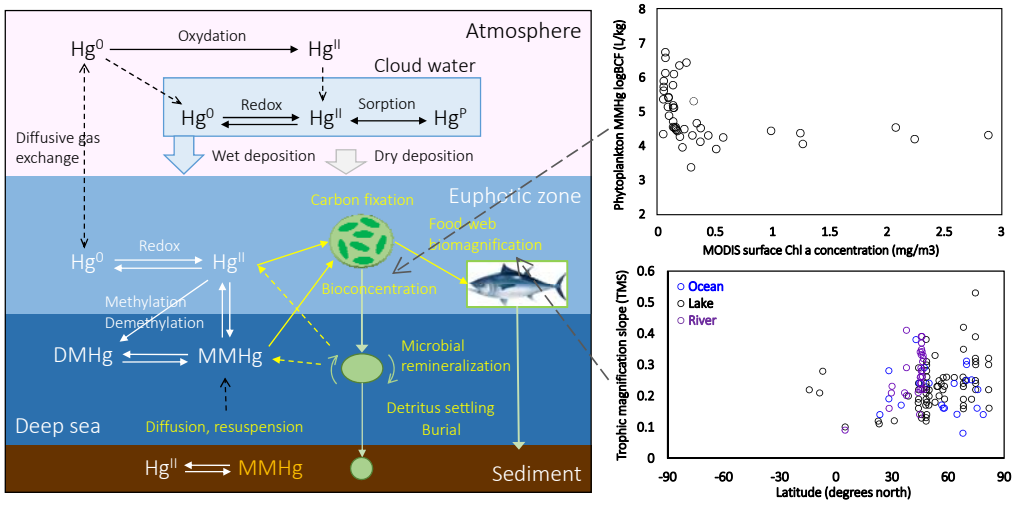


Fig. 4
Mercury atmosphere-ocean-sediment-biosphere processes modeled in FATE-Hg (left panel). Relationships between the $\log_{10}$-transformed monomethyl mercury (MMHg) bioconcentration factor (BCF) for marine phytoplankton and surface chlorophyll a (Chl a) concentration, from satellite observations (right upper panel). MMHg trophic magnification slopes (TMSs) for freshwater and marine food-webs and latitude (right lower panel). BCF and TMS data were obtained from the peer-reviewed literature.

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 2015, we simulated the time courses of potential emissions of a phthalate plasticizer, DEHP, from products during product use, by using a tool that we had developed in previous years. We estimated emissions by assuming the time course of production volume, the distribution of product lifetime, and either a constant or an increasing emission factor with time (Fig. 5). The results suggested that emission factor values and their temporal changes need to be carefully considered in the case of long-life products.

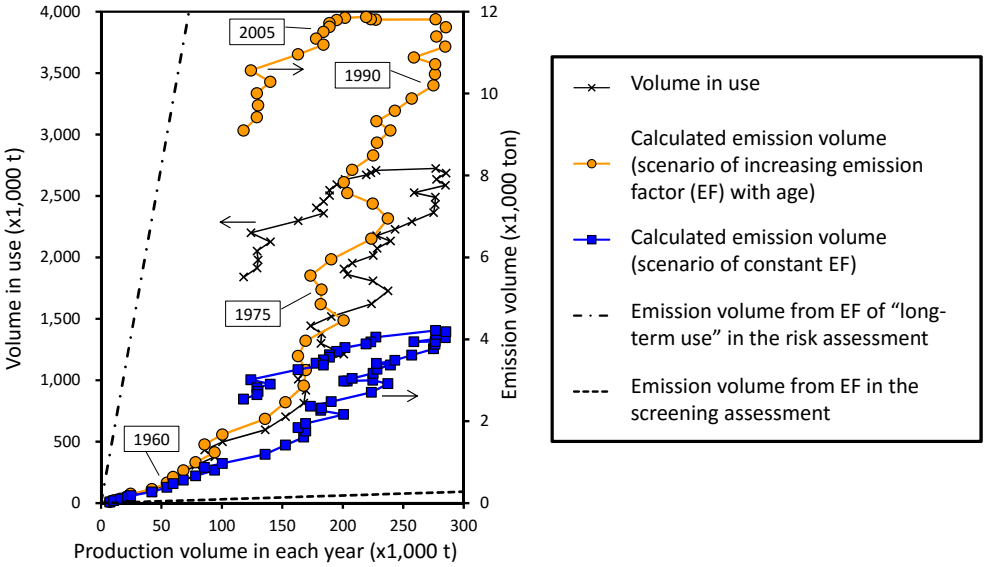


Fig. 5
Relationship between production volume of DEHP and its volume in use or its emission volume in Japan, as calculated for various scenarios and assessments under the Chemical Substances Control Law.

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

Sound chemical management is important for protecting the environment. In many countries, including Japan, data from standard eco-toxicity tests are used for regulatory purposes. For regulatory purposes, quantitative structure–activity relationships (QSARs) for eco-toxicity predictions can be used to assess the hazards and risks posed by chemicals. We have proposed a three-step strategy that uses the structural and physicochemical properties of chemicals to predict their 72-h growth inhibition toxicities against the alga *Pseudokirchneriella subcapitata* (Fig. 6). Step 1: Using a criterion based on log *D* (the log of the distribution coefficient) and structural alerts, we produced an interspecies QSAR between algal and acute daphnid toxicities for the initial screening of chemicals. Step 2: We categorized chemicals according to the Verhaar scheme for aquatic toxicity, and we determined the QSARs for the toxicities of Class 1 and Class 2 chemicals

by linear regression. Step 3: We used structural profiles to predict toxicity (either quantitatively or qualitatively) and to assign the chemicals to five categories. Although the proposed three-step strategy cannot be used to estimate the algal toxicities of all chemicals, it is useful for chemicals within its domain. The strategy is also applicable as a component of Integrated Approaches to Testing and Assessment.

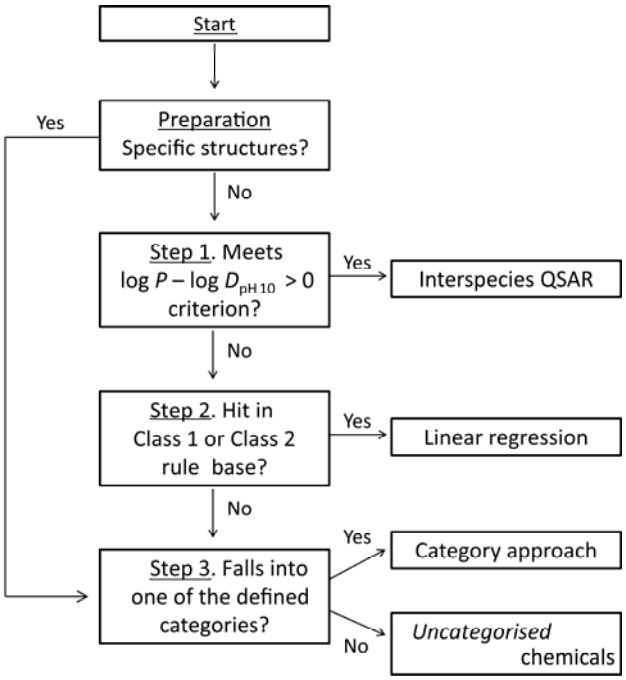


Fig. 6
Three-step strategy for prediction of algal growth inhibition toxicity (Adapted from SAR QSAR Environ. Res., 27(5): 343–362, 2016)

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 risk of combined exposure, 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 data gathered from bioassays.

i. **Anatomization of the mutagenic or carcinogenic potency of environmental chemicals**

By using *in vitro* testing systems such as bacterial mutation testing and *in vivo* bioassay systems such as transgenic rodent testing, we analyzed how polycyclic aromatic hydrocarbons and other chemicals identified in particulate matter in the ambient air exert their total mutagenicity or carcinogenicity. We used two types of approaches for the risk assessment of combined exposure to multiple chemicals: a component-based approach and a whole mixture approach, as described in NIES Annual Report 2015. A whole mixture approach is generally used for mixtures that are not well characterized, especially if toxicological data

are obtained for the mixture itself. To assess the carcinogenic potency of chemical substances in the ambient air—and especially in particulate matter—we used *gpt* delta mice, which are transgenic mice used to detect mutations in organs, to evaluate the *in vivo* mutagenicity of tar extracted from particulate matter. Tar was extracted from particulate matter collected in Tokyo and then intratracheally dosed into the lungs of mice. In the lungs, the mutation frequency (MF) increased with increasing dose of tar; the mutagenic potency of samples collected in 2010 was estimated to be approximately 1.7×10^{-5} MF/mg. Rates of G:C to T:A transversion—a molecular signature of oxidative stress-induced mutation—at mutation hotspots appeared to increase with increasing tar dose.

ii. **Analysis of the endocrine-disrupting activities of chemical substances**
By using a yeast two-hybrid bioassay system, we have been screening various chemicals detected mainly in aquatic environments for ligand-dependent transcriptional activity. About 600 chemicals have been screened for their activity in binding to the hER (human estrogen receptor), medER (medaka, *Oryzias latipes*, estrogen receptor), AhR (arylhydrocarbon receptor), RAR (retinoic acid receptor), and CAR (constitutive androstane receptor); 30% of the screened chemicals showed agonist activity toward the AhR and 46% showed agonist activity toward the CAR. Data from the screening will be published in our database.

3. Development of infrastructure for environmental research

To establish infrastructure for assessing and managing the risks posed by chemical substances, we performed the major tasks 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 in Japan and abroad to develop new test methods by using the latest research trends and social scenarios associated with environmental risk. In FY 2015, we investigated six industrial effluent samples by using whole-effluent toxicity testing. We also worked on developing new testing methods for endocrine disruptors: SPSFs (Standard Project Submission Forms) for two test protocols—a juvenile

medaka anti-androgen screening assay and a juvenile hormone activity screening assay using *Daphnia magna*—were submitted to the OECD (Organization for Economic Co-operation and Development) as new test guideline/guidance documents.

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 eighth practical training seminars (in November) to teach elementary knowledge and techniques for eco-toxicity testing on daphnids via lectures, practical training, and tours of our laboratory. Approximately 30 participants from various organizations (companies, research institutes, and universities) who have an interest in introducing eco-toxicity testing enjoyed the seminars. Participants 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 (culturing 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/ (in Japanese)). These are publicly accessible, as are a related database and website (EnvMethod: http://www.nies.go.jp/emdb/ (in Japanese)). 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 (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.

Center for Regional Environmental Research

Mt. Happo Observatory is used to monitor surface ozone and aerosols, including long-term trends and the impacts of long-range transport.

Stream water sampling on Mt. Tsukuba, Ibaraki Prefecture, to determine the influence of chronically high nitrate runoff from the forested catchment

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

The center consists of 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 2015, 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 “Investigation of PM2.5 pollution mechanisms,” “Development and demonstration of appropriate wastewater treatment technologies,” “A Comparative Study of the Development and Evaluation of Amendment Technologies for Sediments in Coastal Seas,” and “Atmospheric Behavior and Toxicity Study of Particulate Matter from Unregulated Burning.”

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.

Below, we briefly describe some of the important results of the Center’s research in FY 2015.

1. Research Programs
East Asian Environment Research Program

Japan is closely connected to the rest of Asia both geographically and economically, and rapid development is expected in Asia into the future. As part of this region, Japan needs to facilitate the conservation of the East Asian environment to promote environmental security and create a sustainable society

throughout Asia. In this context, 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 help solve 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 at local to hemispheric scales, with particular emphasis on transboundary transport of air pollutants and its impacts on human health and ecosystems in East Asia.

The *Ozone Monitoring Team* has analyzed the impacts of emissions from boreal forest fires in Siberia on the air quality standard over Japan. Long-term observations of $PM_{2.5}$ (fine particulate matter) at ground-based stations in Japan during 2001–2012 were revisited to examine the possible impacts of Siberian wildfires on Japan's air quality. Exceedances of Japan's air quality standard for daily mean concentration (35 μg m^{-3}) were observed several times on Rishiri Island in northern Japan in spring 2003 and 2008, when intense wildfires occurred in Siberia. Satellite observations showed that aerosols and CO originating from biomass burning were transported from Siberia toward Japan (Fig. 1). A regional chemical transport model demonstrated that the $PM_{2.5}$ enhancements during high $PM_{2.5}$ days (>35 μg m^{-3}) were attributable to the Siberian wildfires, suggesting that Siberian biomass burning had a critical impact on exceedances of the air quality standard. In 2003 on Rishiri Island, where the influence of Siberian wildfires was the greatest in Japan, the monthly (May) mean $PM_{2.5}$ concentration was about twice the long-term average and the annual mean $PM_{2.5}$ concentration was about 20% higher than the long-term average. Other than in 2003 and 2008, there were no days on which high $PM_{2.5}$ values due to Siberian wildfires were recorded. Despite this lack of effect on the $PM_{2.5}$ air quality standard in years without large fires, the exceedance of air quality standards when intense fires do occur is of critical concern. The influence of Siberian biomass burning on $PM_{2.5}$ mass concentrations should be carefully monitored because fire activity in boreal forests is predicted to increase under future climate warming.

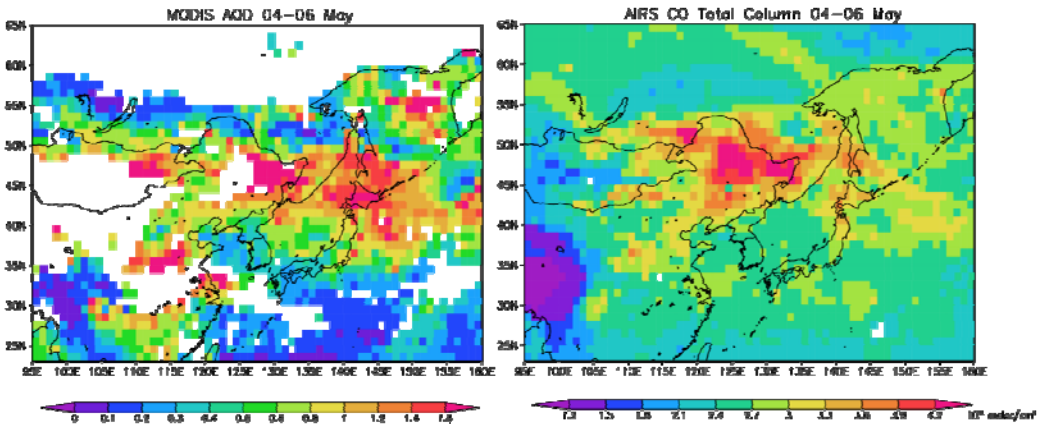


Fig. 1 Distributions of aerosol optical depth (left) and carbon monoxide (right) during intense fires in Siberia, as observed by satellites from space

The *Aerosol Measurement Team* has set up an Aerodyne quadrupole-type aerosol mass spectrometer (Q-AMS) in Fukuoka for long-term monitoring. Fukuoka is one of the biggest cities in western Japan. To determine the influence of transboundary air pollution on the air quality in Fukuoka, we also set up an Aerodyne aerosol chemical speciation monitor at a rural site (Fukue Island) in Nagasaki, Japan. Organic aerosol data were analyzed by using the positive matrix factorization (PMF) method. We classified the chemical compositions of the aerosols in accordance with the mass concentrations of particulate matter. Sulfate was found to be one of the major species in the case of all $PM_{2.5}$ mass concentrations on Fukue Island. Sulfate is one of the typical species observed during transboundary air pollution. The PMF analysis revealed that low-volatile oxygenated organic aerosol (LV-OOA) was also a dominant species in OA. LV-OOA is produced by photochemical oxidation during long-range transport. Fukue Island is therefore likely affected by transboundary air pollution in winter and spring, and sulfate and LV-OOA are indicators of this transboundary pollution. In Fukuoka, sulfate and LV-OOA accounted for large percentages of OAs with high $PM_{2.5}$ mass concentrations (>35 μg m^{-3}), whereas the percentages of organics and nitrate were relatively high under low $PM_{2.5}$ (<10 μg m^{-3}) conditions. Thus, high $PM_{2.5}$ mass concentrations are partly attributable to long-range, transboundary transport, whereas local air pollution influences $PM_{2.5}$ concentrations to a certain extent. We therefore need to reduce both local and transboundary air pollution to improve the air quality in Fukuoka.

High $PM_{2.5}$ events are often observed in winter and spring, but a high-sulfate event was observed in July 2012. Several factors—volcanic activity, photochemical reactions, and transboundary air pollution—are likely behind the occurrence of high-sulfate events in summer. We confirmed that transboundary air pollution occurs not only in winter and spring but also in summer, and that it was an important driver of the summer high-sulfate event that we observed.

The *Modeling Team* has examined the spatial and temporal behavior of simulated O_3 concentrations by comparing modeling data with observations obtained by cargo ship observations, EANET (Acid Deposition Monitoring Network in East

Asia), and the AEROS (Atmospheric Environmental Regional Observation System) monitoring network. Increasing trends in O_3 levels over Japan during 2000–2009 and a subsequent stagnation in this increase were simulated well by the model, although it generally overpredicted O_3 concentrations (in summer particularly). Comparison of the simulated diurnal variations in surface O_3 with the observations revealed that the model could not adequately simulate a gradual decrease in O_3 from evening to early morning, which could largely account for the model's overprediction of O_3. Representation of aerosol nitrate (NO_3) has been improved by increasing the dry deposition velocities of HNO_3 and NH_3, and that of organic aerosol has also been improved by introducing a Volatility Basis Set (VBS) model. With this model, we estimated the contributions of different source regions and categories of $PM_{2.5}$ to the concentrations of $PM_{2.5}$ over Japan. The relative importance of each region or category differed substantially among different locations and seasons and among different chemical components of $PM_{2.5}$. In general, the contribution of transboundary air pollution to total $PM_{2.5}$ was higher in western and northern Japan (especially in Kyushu and Hokkaido, at around 80%), whereas the contributions of domestic sources were higher in eastern Japan (especially in the Kanto region, at 40% to 60%). Improvement of $PM_{2.5}$ representation in the model introduced a considerable difference in the estimation of source contributions, largely through changes in the importance of NH_3 sources, biogenic sources, and stationary evaporative sources. We estimated the effect of applying Japan's emission controls on air pollution across Asian countries; we found that doing so could significantly improve $PM_{2.5}$ pollution but would have a limited impact on O_3 pollution. The deposition of nitrogen calculated in the abovementioned model simulation was input into the marine ecosystem model in Project 2 below.

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 land and ocean numerical models; a catchment water and material circulation model for evaluation of the pollutant loads (total nitrogen [TN] and phosphorus [TP]) transported to the ECS from China's Yangtze River Basin (YRB); and an ocean assessment model for evaluating the response of the ECS environment to changes in the pollutant loads discharged from the YRB. Last year, we finished validating these models by using field monitoring data from the YRB and ECS. We then simulated the variations in freshwater and nutrient discharges from the YRB and the variations in physical and biogeochemical properties in the ECS from 2000–2010.

In FY 2015, we forecast the near-future marine environment in the ECS by using our land–ocean models under various scenarios of pollutant loadings from the

YRB, as well as the atmospheric nitrogen deposition predicted in Project 1.

To provide datasets of future pollutant loading, we predicted TN and TP emissions in the YRB on the basis of a provincial-scale economic growth forecast for China from 2002 to 2030. This forecast was produced by NIES's Center for Social and Environmental Systems Research. The forecast included the industrial gross output of each sector, as evaluated by the Asia–Pacific Integrated Model/Computable General Equilibrium (AIM/CGE) model. The following three emission scenarios for 2030 were developed by using a variety of emission coefficients (i.e. pollutant load per unit of gross output). The basic scenario was business as usual (BaU), in which wastewater treatment capabilities in 2030 were regarded as the same as at present. Emission coefficients were estimated from Chinese statistical data disclosed in the 2000s. As other possible future changes, we set two reduction scenarios, namely Chinese regulation observance (CHINA) and dissemination of wastewater treatment as seen in Japan now (JPN). In the CHINA scenario, we assumed that the industrial gross output was the same as that under BaU but that the Chinese wastewater regulation directed by China's Ministry of Environmental Protection (MEP) was perfectly observed as of 2030. In the JPN scenario we assumed that, by 2030, all industrial sectors in China would have achieved the emission coefficients currently applied in Japan. By comparing pollution loads under the different scenarios, we examined the effectiveness of wastewater reduction measures on future environmental conservation in the ECS.

AIM/CGE forecast that the Chinese industrial gross output in 2030 would increase by approximately 400% of that in the early first decade of the 2000s. Under the BaU scenario, TN and TP loads from the industrial sectors would increase by 2.4 and 2.5 times during the same period, respectively. These increases in pollution loads would be fairly well suppressed under the CHINA and JPN scenarios. Under the JPN scenario, particularly, the increases in TN and TP loads would be only 1.2 and 1.3 times, respectively, and the resulting levels would be within the effluent standards (i.e. target values) set by MEP.

The water and material discharge simulations under the above-described future emission scenarios predicted that pollutant discharge from the YRB to the ECS would increase by approximately 1.9 times under the BaU scenario and 1.1 times under the JPN scenario.

The ocean simulations under the above-predicted pollutant discharge from the YRB were as follows (Fig. 2): Under the BaU scenario, the area of high ratio of dissolved inorganic nitrogen to phosphorus (DIN/DIP) on the continental shelf of the ECS would expand greatly compared with that at present, initiating an increase in primary production, with further predominance of dinoflagellates over diatoms. Under the reduction scenario (JPN), the increases in nitrogen concentration and primary production in the ECS would be milder than those

under BaU, but the effect of water quality improvement (e.g., a reduction in dinoflagellate standing stocks) would be limited.

Our quantitative analysis of nitrogen input to the ECS revealed that the present rate of atmospheric nitrogen deposition was of a magnitude similar to that of the present nitrogen discharge from the YRB. We found a notable reduction in the areas of excess nitrogen and dinoflagellate appearance in the ECS in 2030, but only in the simulation in which there was simultaneous application of both the JPN (for wastewater pollution) and the Air Pollution (AP) countermeasure scenarios (prepared in Project 1) (Fig. 2). Our collaborative work in Projects 1 and 2 concluded that concurrent measures against both wastewater and air pollution should be promoted to conserve the ECS environment.

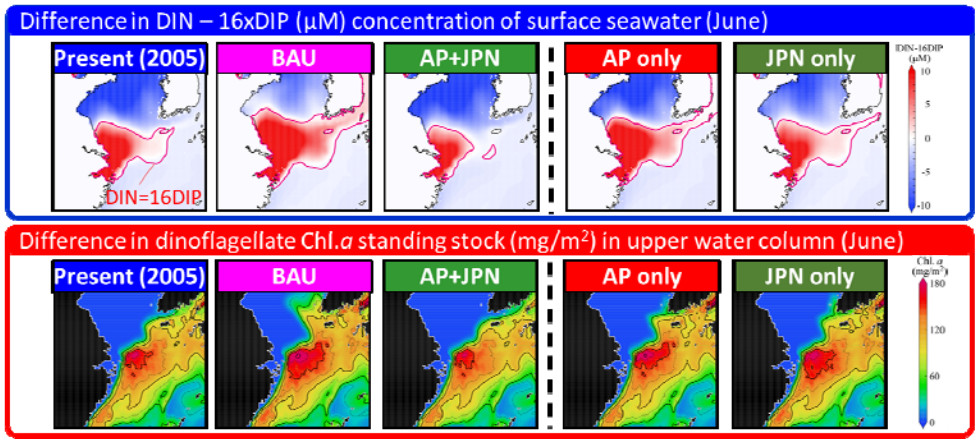


Fig. 2 Estimated near-future (2030) environments of the East China Sea under various socioeconomic scenarios

Basin Ecosystem Functions Research Program

To minimize the loss of biodiversity in important ecosystems, it has been proposed that we should utilize the power of ecosystem functions by exploiting their effects on ecosystem soundness. However, there have been few reports on quantitative methods for the evaluation of ecosystem functions in natural environments. In important ecosystems in the natural environment, the lineages and relationships between ecosystem functions and environmental factors have not been elucidated, which is why there has been no substantial progress in determining how best to protect, restore, and resurrect ecosystem functions.

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 quantitatively assessing 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

Change in the nitrogen budget of a forested catchment over 25 years

At the Mt. Tsukuba experimental forest, where the nitrogen budget had last been studied in 1985–1987, we conducted monthly observations of inorganic nitrogen levels in bulk precipitation, the soil solution, artesian groundwater, and stream water during 2010s. The annual average concentration in bulk precipitation during this study was 70% of that 25 years ago, whereas the concentration in stream waters was 120% of the previous value. Annual average concentrations in the soil solution below the rhizosphere (below 50 cm depth) and in artesian groundwater were twice those observed 25 years ago. A large stock of inorganic nitrogen has accumulated below the rhizosphere and in the artesian groundwater and has likely caused chronically high nitrate runoff from the forested catchment for 25 years.

Possibility of calcium shortage for trees as a side effect of chronically high nitrate runoff from the forested catchment

Nitrate (NO_3^-) is the major form of inorganic nitrogen in stream waters. In our previous study of Japanese stream waters, elevated concentrations of NO_3^- and SO_4^{2-} in stream waters were often associated with high levels of Ca^{2+} (instead of Al^{3+}), which serves as a major counterion for the NO_3^- and SO_4^{2-}. However, if continuously high runoff of Ca^{2+} cannot be compensated for by supply through bedrock weathering, Ca^{2+} stocks in the soil will decrease and a shortage of Ca^{2+} (an element essential to plants) and mobilization of Al^{3+} (an element toxic to plants and fishes) may result in forest decline. Mt. Tsukuba experimental forest has experienced high concentrations of NO_3^- in its stream waters for at least 25 years. The bedrock in part of the forest is granite, and the capacity of granite to supply Ca^{2+} and other base cations is relatively low. Therefore, we anticipated that a relative Ca^{2+} shortage could be present at the study site because of chronically high nitrate runoff and insufficiently rapid bedrock weathering.

To evaluate the possibility of Ca^{2+} shortage in the catchment, we used the strontium isotope ratio ($^{87}Sr/^{86}Sr$) as a tracer for Ca^{2+}. Previous studies have revealed that Sr^{2+} acts as an analog for Ca^{2+} in the majority of forest ecosystem processes. Under the assumption that if the amount of granite weathering–derived Sr^{2+} is insufficient, then $^{87}Sr/^{86}Sr$ in stream waters should indicate a large contribution of atmospheric deposition–derived Sr^{2+}, we measured the $^{87}Sr/^{86}Sr$ of bulk precipitation, soil, and stream waters. Although we unexpectedly found that volcanic ash–derived Sr^{2+} existed as a third end-member, we were able to

determine that the contribution of atmospheric deposition–derived Sr2 in stream waters was relatively low (<20%) (Fig. 3). Therefore, sufficient Ca2+ as well as Sr2+ seems to be supplied through the weathering of granite and volcanic ash, and it is unlikely that a Ca2+ shortage will cause forest decline in the Mt. Tsukuba experimental forest.

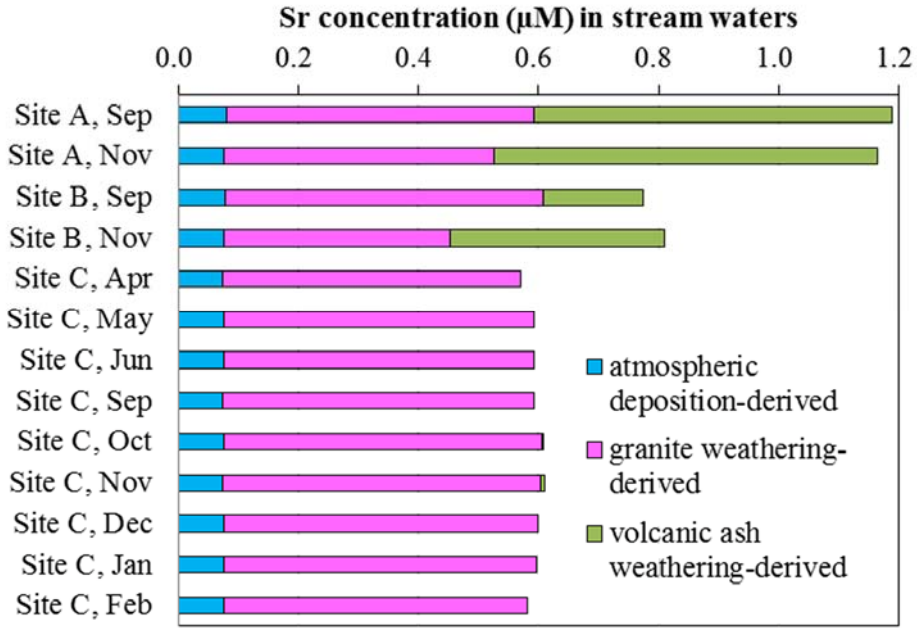


Fig. 3 Contributions of atmospheric deposition–derived Sr, granite weathering–derived Sr, and volcanic ash–derived Sr in stream waters.

Quantitative evaluation of links between ecosystem functions and environmental factors in a lake ecosystem

To assess the validity of the FRRF (Fast Repetition Rate Fluorometry) technique, we compared primary production rates estimated by using FRRF and ^{13}C techniques. The comparison indicated a high correlation ($r^2 = 0.93$ to 1.00, $n = 33$) between the values analyzed by using the two methods; however, the slopes of the regression lines were found to be <1.0. The FRRF values were therefore underestimated compared with those obtained by using ^{13}C. One of the likely reasons for the underestimate was the effect of the predominant algal species: FRRF was adjusted to estimate the primary production of diatoms, but the predominant phytoplankton species in Lake Kasumigaura were mainly blue-green algae, especially in summer.

We measured primary production rates by using FRRF before and after an algal bloom in 2012 in Lake Kasumigaura. The results showed that primary production was higher at the center of the lake than in Takahamairi Bay or Tsuchiurairi Bay, despite the high chlorophyll-a concentrations in these bays. Primary production rates in Nam Ngum Lake (located in the Lao People's Democratic Republic and a representative lake in the Project2 of this program) were also quantified by using the FRRF technique. The results suggested that primary production in the lake,

which is oligotrophic and warm throughout the year, was about four times higher than that in Lake Kasumigaura (a eutrophic lake). Thus we found that nutrient conditions or the presence or absence of water blooms is not always linked to the rates of primary production by algae.

Additionally, we installed a multiparameter data sonde with an automatic elevation system at a pier on Lake Kasumigaura, and we used the system to continuously quantify cyanobacteria, chlorophyll-a, pH, water temperature, turbidity, dissolved oxygen, conductivity, and redox potential. A marked increase in levels of cyanobacteria was identified in the bottom and surface. These results suggest that primary production affects the environment of the bottom layer, especially in shallow lakes such as Lake Kasumigaura.

Quantitative evaluation of links between ecological functions on a tidal flat and the explosive dominance of invasive species

We have been investigating the effects of green tides on the ecological functions of Yatsu tidal flat, in Chiba Prefecture. These tides are caused by extreme propagation of the invasive algal species *Ulva ohnoi*. This fiscal year, research into the cause of the extreme propagation of *U. ohnoi* on the tidal flat was performed from the perspective of physiological ecology.

A comparative study of the relative rates of increase in weight of *U. ohnoi* and the domestic species *Ulva pertusa* was performed with a series of water temperature changes. *Ulva ohnoi* grew at only 0% to 3% a day at 5 to 10 °C, but at 20 to 30 °C it showed maximum growth (12% to 15% a day). In contrast, the maximum growth rate of *U. pertusa* (6% to 8% a day) was observed at 10 to 25 °C, suggesting that *U. ohnoi* was more suited to growth in higher water temperature regions, where its growth rate was double that of *U. pertusa*.

We then elucidated the characteristics of nutrient absorption in the two species during 2 weeks' cultivation under natural light in a greenhouse. The rate of absorption of inorganic nitrogen by *U. ohnoi* (0.9 mgN gDW^{-1} day^{-1}) was 12 times that by *U. pertusa*. This suggests that the higher growth rate of *U. ohnoi* is supported by a higher capacity for nutrient absorption.

To compare differences in growth-rate recovery after exposure to emergent conditions for various periods, we measured the relative rates of increase in weight of the two species at 20 to 25 °C over 1 week after exposure to 2 to 4 h of emergent conditions. The growth rate of emergence-treated *U. pertusa* recovered to between 28% and 50% of that of untreated plants, whereas the recovery rate in emergence-treated *U. ohnoi* was between 47% and 60%, suggesting that *U. ohnoi* was more tolerant to emergence stress.

Together, these findings indicate that the invasive species *U. ohnoi* has the

following adaptive abilities: tolerance to high water temperatures in shallow-water areas; high growth rates supported by high levels of nutrients in the water; and rapid recovery from emergent conditions. These characteristics enable *U. ohnoi* to be explosively dominant over the domestic species *U. pertusa* on the Yatsu tidal flat.

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

Over the last 5 years, we have developed techniques and procedures to assess strategically the effects of dam development in the Mekong River basin. Our primary focus was to provide a multifaceted perspective regarding the balance between losses of fishery production due to damming and gains in production through aquaculture in newly created reservoirs. To achieve this, we have monitored a variety of limnological parameters in multiple reservoirs and natural lakes in the basin, including nutrients, primary productivity, concentrations of harmful algae such as *Microcystis*, fish production, and the carbon sources and trophic levels of major food web components. We have also investigated the migration behavior of commercially important fish species and assessed the potential impacts of damming on their reproduction. Computer modeling was used to assess the effects of damming on fish species diversity, biomass, and the eco-hydrological properties of the Mekong River as an entity. Brief summaries of these research activities and their major findings are given below.

Phosphorus cycling

We investigated sediment nutrient patterns and processes in reservoirs and lakes in the Mekong River basin, including phosphorus sedimentation and cycling and the associated reaction states. We found that sediment total phosphorus (TP) increased from the littoral to the pelagic areas of water bodies. However, the organic phosphorus to TP ratio was higher in littoral areas than in pelagic areas, suggesting that organic matter is supplied constantly from the watershed to littoral areas. This transition from organic to inorganic phosphorus in the sediment toward deeper pelagic environments was commonly observed in the reservoirs. However, this was not the case in a natural lake, namely the Tonle Sap ("Great Lake"), where the inorganic phosphorus level was high in the littoral area because of its direct supply from riparian villages.

Harmful algae and cyanobacteria

We used a real-time PCR (polymerase chain reaction) method to detect the harmful alga *Microcystis aeruginosa* in some of the water bodies in the Mekong River basin. We investigated the relationships between TP and *M. aeruginosa* concentrations and between TP and cyanobacterial 16S rDNA concentrations. Log-transformed concentrations of *M. aeruginosa* and of cyanobacteria generally

(including *M. aeruginosa*) exhibited linear relationships with log-transformed TP. The slope of the regression line for the cyanobacteria in general was approximately 1, indicating that the abundance of this group of algae increased in direct proportion to increasing TP concentration. In contrast, the regression slope for *M. aeruginosa* in particular was >1.5, indicating that the abundance of this alga increased exponentially with increasing TP concentration. This implies that there is a potential risk of harmful algal blooms that may prevail in both existing and planned dam reservoirs, given the economic growth expected in the Mekong countries and the resulting likely increase in nutrient levels in these water bodies.

Primary production and fish yield

We found a positive correlation between TP and primary productivity measured *in situ* by using the ^{13}C stable isotope method in water bodies of the Mekong basin, with the exception of Tonle Sap. Because Tonle Sap is rich in nutrients but is also turbid because of a high concentration of suspended solids, the lake's primary productivity is severely limited by solar radiation but not by nutrient availability. Consequently, the depth-integrated primary production was no higher in Tonle Sap than in the other water bodies, where the phosphorus concentration was the limiting factor. We also found a positive correlation between primary productivity and annual fish yield per unit area among the water bodies, again with the single outlier of Tonle Sap. Although the primary productivity of this lake was relatively low, its fish yield was much higher than expected given the above correlation. This suggests that allochthonous inputs of organic matter from the floodplain or from the lake's tributaries, or both, play an important role in sustaining fish production in this lake, whereas the other water bodies are likely supported primarily by autochthonous production by phytoplankton and periphyton.

Food web structure

To verify this difference in contributions (autochthonous versus allochthonous) between the reservoirs and natural lakes, we used stable carbon and nitrogen isotope ratios to compare food web structures. The stable isotope analysis revealed that phytoplankton and periphyton were the two most dominant carbon sources for fish in the reservoirs, whereas terrestrial plants served as an additional carbon source for fish in natural lakes such as Tonle Sap. The analysis also showed that the reliance of fish on terrestrial carbon was manifested only during the wet season; this agreed well with the flood pulse concept of Junk et al. (1989). Flood pulse is typical of natural lakes, whereas it is much less pronounced in reservoirs because their water levels are controlled artificially, such that extreme floods are eliminated and the annual discharge patterns smoothed. Because of limited availability of carbon sources for the food web, reservoir ecosystems and their ecological services (e.g. fishery production) are presumably less sustainable than natural lakes and their services.

Fish migration

The most obvious consequence of damming is the blockage of fish migration. This is especially true for the Mekong River, because more than half the fish species of this river have migratory life cycles. We used an otolith microchemistry technique to investigate the migration of Siamese mud carp (*Henicorhynchus siamensis* and *Henicorhynchus lobatus*), two of the most economically important fish species in the Mekong River. Examination of the otolith strontium and barium profiles revealed extensive synchronized migrations, with similar natal origins among individuals captured within the same location. The profiles also revealed that the 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. Meanwhile, *H. lobatus* collected both up- and downstream from a proposed major hydroelectric dam (the Don Sahong Dam) exhibited no significant differences in otolith "core" elemental signatures, which represent the elemental signatures of the water in the fish's spawning ground. This suggests that the same population of the species, dispersing from a single natal origin, migrated either up- or downstream through the proposed dam site before being captured by fisherpeople. Together with other evidence, this finding raises concerns over mainstream Mekong hydropower projects that will most likely block major fish migrations in this river.

Modeling the impact of damming

To predict the distribution of fish species diversity and the impact of dam construction on 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 decreased significantly under the damming scenario—not only near the dam site but also in areas farther upstream of 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 increased near the dam; however, this effect varied depending on the feeding type of the fish. Concurrently, we applied the NICE (National Integrated Catchment-based Eco-hydrology) model to the entire Mekong River basin to predict the impact of dam construction. 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.

Starting from the origins of nutrients and their dynamics, this project was successful in clarifying and quantifying biological processes and productivities in a number of both constructed and natural water bodies in the Mekong River basin.

Although a certain level of fisheries production can be expected in constructed reservoirs, its sustainability is much less secure than that in natural lakes, where carbon sources for higher trophic levels are more numerous, fish species richness is higher, and the food web structure is more complex. Modeling is valuable for providing alternative plans for hydroelectric dam development in the Mekong River basin. By informing us of the possible hydrologic changes and their implications for fish diversity, modeling allows us to propose alternative locations for dam constructions that might have less impact on fish diversity and biomass and on the ecological services they provide.

Center for Environmental Biology and Ecosystem Studies







A wetland with a large number of unique, endangered, and rare species, including (clockwise from top left) *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. During the third NIES five-year plan, four 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 status of biodiversity on a broad scale and analyze scenarios for future predictions; and elucidate the effects of anthropogenic disturbances on biodiversity and find ways of managing these effects. The following are examples of our progress in 2015.

1. 1 Development of a simple and cost-effective method of DNA-based classification of wild organisms

In biological research, identification of organism is indispensable. Recently,

DNA-based identification—so-called DNA barcoding—has become widely used. This method focuses on the differences in nucleotide sequence in a particular fragment of genome among organisms. Although recent advances in molecular biology have enabled us to use massive amounts of DNA data, there still are some difficulties. DNA barcoding is labor intensive and requires expensive reagents and equipment. To make it a standard method for species identification, there is a need to simplify the methods used and reduce the cost.

In this research project, we developed a few smart methods to detect differences in DNA sequences without determining those DNA sequences. One of these methods is polymerase chain reaction (PCR)–restriction fragment length polymorphism (RFLP), which detects differences caused in the restriction fragment lengths of PCR products by the creation or abolition of a specific sequence recognized by a restriction enzyme that splits the DNA into fragments. This creation and abolition may occur as a result of base change, insertion, or deletion. The assay uses amplified DNA fragments that are digested with a restriction enzyme to display the RFLP. Another method we developed is high-resolution melting (HRM) analysis, which is based on the detection of small differences in PCR melting (dissociation) curves derived from small differences in DNA sequences. We used this method to identify four Chironomidae species commonly found in Lake Kasumigaura, and we showed that it could be used to discriminate all four species (Fig. 1).

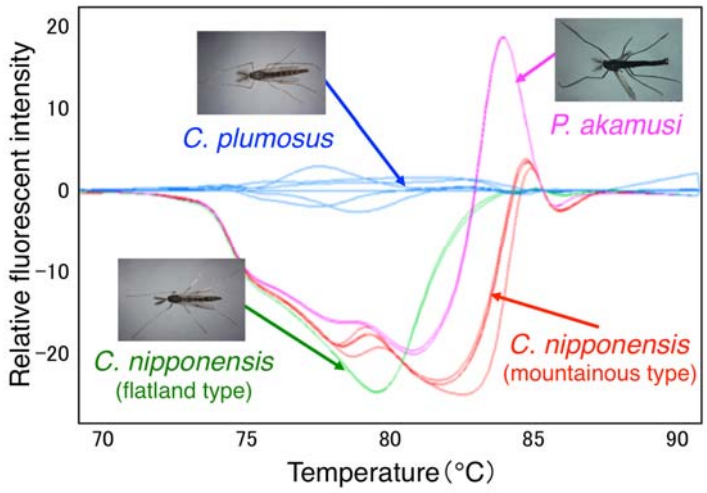


Fig. 1 Classification of Chironomidae species by using the HRM method. Chironomidae species commonly found in Lake Kasumigaura were classified by differences in their *COI* sequences by using HRM analysis.

The advantages of these two methods include lower cost and labor input than with DNA sequencing (Table 1).

Table 1 Comparison of DNA-based methods of identification of the wild organisms investigated in our study

	Cost	Throughput	Time for analysis	Initial investment
DNA sequencing	1,000 yen/ sample	48 samples/ analysis	2 days	High
PCR–RFLP	200 yen/sample	96 samples/ analysis	4 hr to 1 day	moderate
HRM analysis	100 yen/sample	96 samples/ analysis	2.5 hr	High

1.2 Selection of conservation areas in the face of severe uncertainty regarding population dynamics

To reduce the risks of extinction of vascular plants when we have only a limited budget, we need to choose effective conservation areas. However, the available information on the population size of plants and its rate of change is largely uncertain. Furthermore, we do not have enough knowledge about how effectively we can combat declining population size in conservation areas. We developed a robust decision-making model against these uncertainties by using info-gap decision theory to derive the optimum conservation areas in Chiba Prefecture, Japan, with the ultimate aim of improving rates of increase in population size. Info-gap decision theory derives the most robust management action against uncertainty to meet a predetermined acceptable outcome.

More than 500 citizen botanists have twice archived quantitative information on population size and the rate of change in population size for 1618 Japanese plant taxa (1994–1995 and 2003–2004). We used the data obtained by this monitoring as best estimates of population size and rate of change in population size. As best estimates of the effectiveness of the conservation areas, we also used the probabilities of avoiding declines in population size within the conservation areas calculated by using the monitoring data. However, we do not know how uncertain these best estimates are. Information-gap decision theory allows us to select a conservation area that delivers a predetermined acceptable outcome under the greatest level of uncertainty; it does not allow us to specify the extent of uncertainty in population size, the rate of change in population size, and the effectiveness of a conservation area.

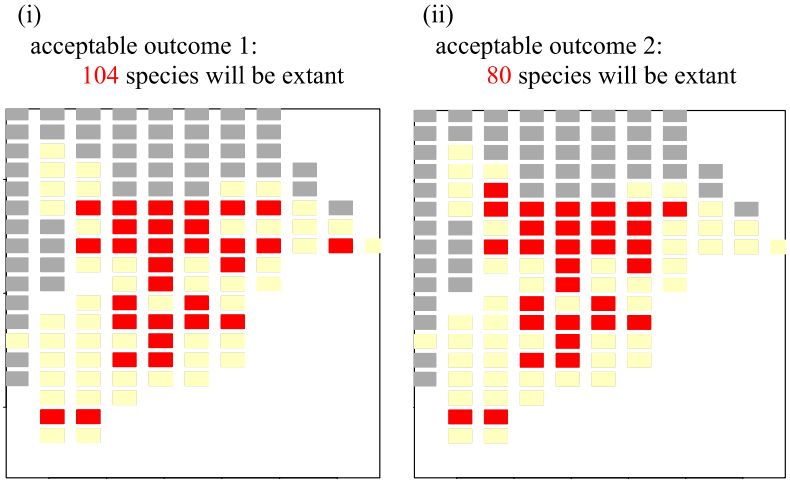


Fig. 2 Selected conservation areas in Chiba Prefecture (shown in red). Yellow boxes indicate areas not selected for conservation and gray ones, land outside of the prefecture. In this case, acceptable outcomes are that the number of extant species in 50 years is 104 in (i) and 80 in (ii).

Our analysis recommended different regions as protected areas when we incorporated uncertainty of population size, rate of change in population size, and effectiveness of the conservation area. This result highlights the importance of dealing with uncertainty properly to select effective conservation areas. We also found that the selected conservation areas depended on a predetermined acceptable outcome—in this case the number of extant species in 50 years (Fig.

2). The data available for estimating population dynamics are generally very limited. Selecting conservation areas by using info-gap decision theory is a promising way of dealing with severe uncertainty.

1.3 Chemical control of the European bumblebee, *Bombus terrestris*

We have been performing intensive studies aimed at controlling and eradicating alien species that have serious ecological and environmental impacts in Japan. For each target species we assess the effectiveness of the eradication methods and design efficient eradication strategies.

One of the targets is the European bumblebee, *Bombus terrestris*, which was introduced in 1991 as a pollinator of agricultural crops (especially tomatos in greenhouses). Over 70,000 artificially bred colonies of the species are used annually for pollination in Japan, contributing greatly to tomato production. However, this alien bumblebee has negative effects on Japan's biodiversity. It became naturalized soon after its introduction and has caused ecological damage to native species.

We have developed a chemical treatment procedure that uses an insect growth regulator (IGR) insecticide. The framework of the chemical control is illustrated in Figure 3. First, we spray the IGR insecticide on the foraging workers of *B. terrestris*. The adult workers are not killed by the insecticide, because it inhibits only the molting of larvae. The sprayed workers go back to their nest, and the larvae in the nest are exposed to the IGR via pollen and nectar brought back by the sprayed workers. The exposed larvae cannot proceed to the next stage, and they die. Therefore, new queen and male bees do not emerge from the colony.

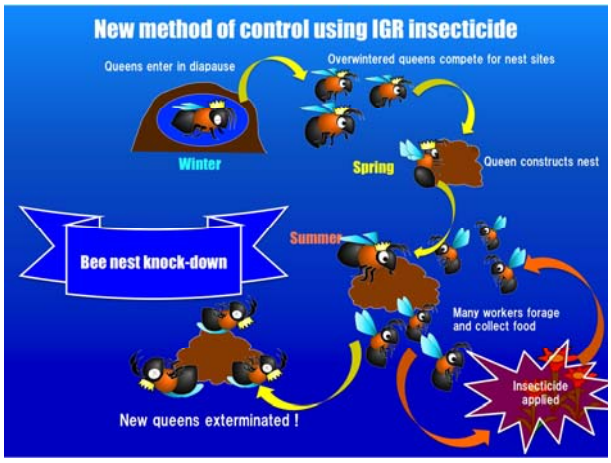


Fig. 3 Concept of the chemical control of the European bumblebee

We screened IGR insecticides for the control of colony reproduction in laboratory tests, and we found that etoxazole was the most effective. We then tested the effectiveness and risk of this insecticide in a greenhouse experiment. We settled artificial colonies of *B. terrestris* and the native bumblebee *Bombus ignitus* in the same flower garden in a greenhouse. We then captured 10 foraging workers of *B.*

terrestris and sprayed them with 100 ppm etoxazole. After their release, we counted the numbers of foraging workers, new queens, and males of each bumblebee species every day for 4 weeks. During this period, the *B. ignitus* colony produced not only workers but also new queens and males. However, the *B. terrestris* colony produced no new queens and no males. We concluded that etoxazole was effective in controlling colony reproduction in *B. terrestris*. We are now testing this chemical control method in the field on the island of Hokkaido.

2. Fundamental Research

2.1 Roles of fragmented communally reserved forests managed by indigenous people in biodiversity conservation in a human-modified landscape in Borneo

Tropical rain forests are highly biodiverse and provide ecosystem services, although anthropogenic disturbance and land-use changes have caused the intensive loss of such forests and their biodiversity. There is a strong demand for strategies for the conservation and sustainable use of biodiversity in tropical areas—especially strategies that integrate the knowledge and practices of indigenous communities, as stated by the Convention of Biological Diversity.

Here, we focused on one of the traditional forest management systems in Borneo—namely communally reserved forests (CRFs)—as a conservation target integrated with indigenous practices. CRFs are customarily reserved and managed by local communities for the communities' cultural and practical use; villagers use them to obtain various kinds of natural resources, such as wood -for the construction of houses, boats, and other hardware such as hinges and canes. Generally, CRFs are meant to be left undisturbed as major sources of timber. However, much of the traditional land, including that within CRFs, has recently been transformed into market-oriented land for use for commercial logging and plantations of oil palm and acacia. Subsequently, CRFs have become more fragmented and more isolated from other primary forests, and the species diversity within them is likely to decrease because of edge and isolation effects. To evaluate the conservation values of CRFs, we investigated whether they had regional species diversity in terms of species richness and endangered species.

The study was conducted in the middle part of the Jelalong River basin, Sarawak, Malaysia. We established 16 plots (50 × 50 m each; 0.25 ha) in the eight CRFs of five villages in this area. In each plot, all tree stems with a diameter at breast height >10 cm were tagged and then identified to the species level by examining vegetation samples. We found 2556 trees that comprised 63 families, 183 genera, and 559 species in total. To evaluate the species diversity in each CRF, rarefaction curves (i.e., curves showing the expected species richness in random subsamples of a given sample size from the focal community in a fixed area) were created for the number of trees in each plot and compared with those in primary forest.

Comparison of the curves among CRFs and primary forest indicated that all CRFs had the same level of species diversity as primary forest (Fig. 4). We also found that the CRFs contained a total of 50 species that were on the IUCN Red List or that were protected plants in Sarawak, or both. This indicated that CRFs in this small area (4 ha in total) could cover 20% of the IUCN Red List of Threatened species [the categories of critically endangered (CR), endangered (EN), and vulnerable (VU)] from among the dicots (Magnoliopsida) occurring in Sarawak. Although the CRFs in Jelalong are fragmented, we found that they harbored species of high diversity—equivalent to that in primary forests—and endangered species.

In conclusion, our results suggested that traditional land-use practices in indigenous communities, as exemplified by CRFs, would be useful for the conservation of biodiversity, including endangered species, at least in under current conditions. CRFs would be plausible options as biodiversity conservation targets in terms of biodiversity conservation strategies if their management were integrated with the practices of indigenous communities.

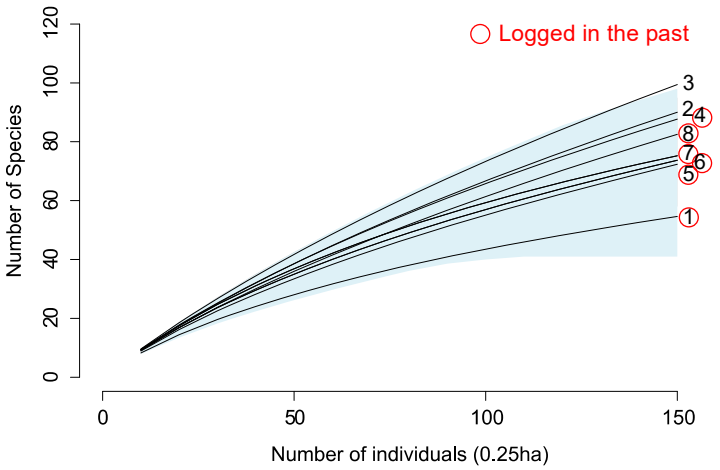


Fig. 4
Sampling-standardized species richness within a 0.25-ha plot. Averaged rarefaction curves of eight CRFs (identified by numbers) are shown. Circled numbers indicate CRFs logged in the past. The light blue area indicates the 95% CI of the primary forest.

2.2 Dietary composition of herbivorous waterbirds in lotus fields

In Japan, farmers grow lotus to use its root as a food. Lotus fields, which are flooded in winter, are thought to be important foraging habitat for wintering waterbirds. However, feeding damage by animals has been found on lotus roots. Farmers believe that waterbirds cause this damage and set bird nets to prevent the birds from entering the lotus fields; many birds are killed from entanglement in the nets. However, because of observational difficulties it is unclear what the birds actually eat in lotus fields. Such uncertainty about the waterbirds' diet is causing conflict between farmers and bird conservation groups regarding the degree of damage caused to the lotus by waterbirds. To conserve the foraging habitat of wintering waterbirds and resolve this issue of agricultural damage, we need to gain a detailed understanding of the dietary composition of each bird species foraging in lotus fields. Recent improvements in DNA barcoding techniques using next-generation sequencing have enabled us to estimate dietary

compositions in detail from the DNA of fecal samples. We therefore targeted the herbivorous waterbirds foraging in the lotus fields around Lake Kasumigaura and conducted a dietary analysis based on DNA barcoding.

To develop a reference database for the DNA barcoding, we collected 108 vascular plants from around the lotus fields and near the shore of Lake Kasumigaura. We then sequenced the chloroplast trnL P6 loop region from the extracted DNA. We successfully obtained sequences from 107 species, 73% of which were unique to each species.

From November 2015 to January 2016, we then collected 180 fecal samples from around the lotus fields at three study sites. By using the DNA extracted from these samples, we sequenced a portion of the mitochondrial 12S region to determine the bird species of origin of the samples in reference to a public DNA database. To identify the food plants in the samples, we conducted high-throughput sequencing of the chloroplast *trn*L P6 loop region by using the Ion PGM next-generation sequencing system (Thermo Fisher Scientific). For the plant sequences we obtained, we identified plant taxa by referring to the database we had developed.

Six species of herbivorous waterbirds were detected from 128 fecal samples. From these samples, we obtained the sequences of 32 plant taxa. The bird species and their diet varied among sites and months (Fig. 5). Except at Site 1, multiple bird species were detected. Their diversity was greatest at Site 2. Sequences of lotus, *Nelumbo nucifera*, were detected at especially high rates in the feces of all of the bird species detected at Site 3. However, the percentage detections of lotus were not high at the other sites, even in the diets of the same bird species in which they were high at Site 3. Several factors, including landscape and food resource availability and its seasonality, may affect food selection by waterbirds in lotus fields.

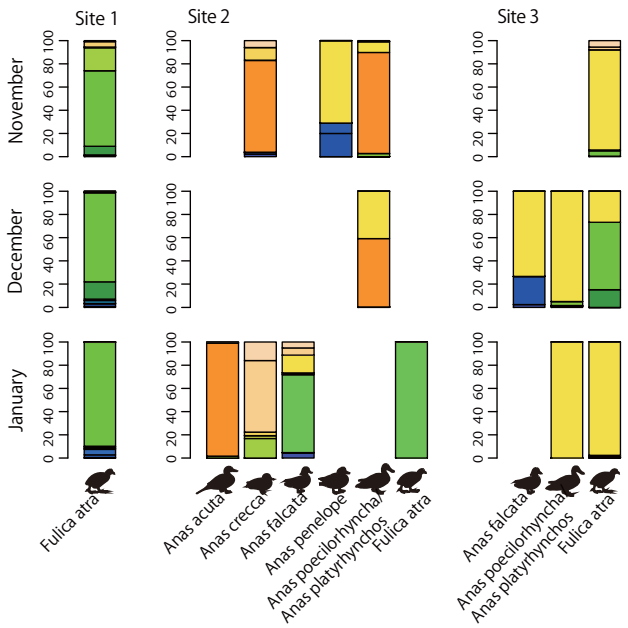


Fig. 5 Rates of detected plant sequences in fecal DNA of herbivorous waterbirds at three study sites from November 2015 to January 2016. Each color represents a plant taxon. Sequences of lotus are shown in yellow.

3. Platform for biodiversity databases

3.1 Tropical Coastal Ecosystems Portal (TroCEP)

The National Institute for Environmental Studies (NIES), Japan, and ISME (the International Society for Mangrove Ecosystems) have been compiling a variety of information on coastal ecosystems in the tropics and subtropics. Some of this information is now being made available through a newly launched portal site, the Tropical Coastal Ecosystems Portal (TroCEP) (Fig. 6).

Coastal ecosystems of the tropics and sub-tropics, represented by mangroves, coral reefs, and sea grasses, are rich in biodiversity and highly productive. They play important roles in providing livelihoods for coastal communities and mitigating the impacts of natural disasters. However, these ecosystems have been drastically altered by land-use changes due to human activities. Accumulation of basic information on these tropical coastal ecosystems is crucial if we are to understand their current status and conserve them. Research on tropical coastal ecosystems has developed separately in each ecotype (mangroves, sea grasses, and coral reefs). However, from now on, we need to study these ecosystems as integrated coastal ecosystems because they are linked together.

TroCEP aims to improve our understanding of tropical coastal ecosystems by compiling and providing past-to-current information on them. As a first step, the portal will provide information on mangroves, including detailed global distribution maps and flora lists. The main contents of the TroCEP website are (i) an outline of the TroCEP Project; (ii) an explanation of mangrove ecosystems; (iii) mangrove distribution maps by country or territory; (iv) lists of mangrove flora sorted by country or territory; (v) lists of mangrove flora sorted by species; and (vi) data source lists. The portal will be extended to other ecosystems such as coral reefs and seagrasses in the near future.

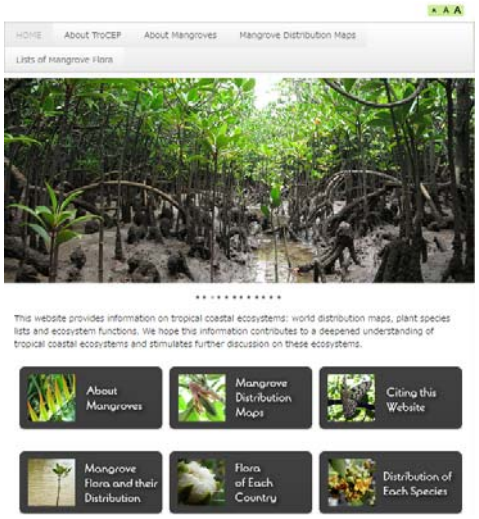


Fig. 6 Home page of the Tropical Coastal Ecosystems Portal.

For more information see the Tropical Coastal Ecosystems Portal at http://www.nies.go.jp/TroCEP/index.html (language: English).

3.2 Biodiversity Web Mapping System (BioWM)

To conserve biodiversity, our decision-making needs to be based on scientific knowledge generated from accumulated data. CEBES promotes the publication of research data by releasing databases and datasets on our websites as well as on international data portals such as the Global Biodiversity Information Facility (GBIF), where users can explore and download biodiversity data.

The Biodiversity Web Mapping System (BioWM) created by CEBES (Fig. 7A) aims to promote data publication on GBIF, utilization of GBIF data, and "open data"* in biodiversity science through the visualization of biodiversity data. BioWM contains mapping systems for GBIF occurrence data (Fig. 7B), research data provided by CEBES (Fig. 7C), and data provided by local users (Fig. 7D). In a search tool called "Search and map species", you can also match scientific names against the GBIF Backbone Taxonomy.

We thank all JBIF (Japan Node of Global Biodiversity Information Facility) members for their support and feedback throughout the development of the BioWM.

* Open data is defined as "data that can be freely used, re-used and redistributed by anyone - subject only, at most, to the requirement to attribute and sharealike" according to "OPEN DATA HANDBOOK" by Open Knowledge International.

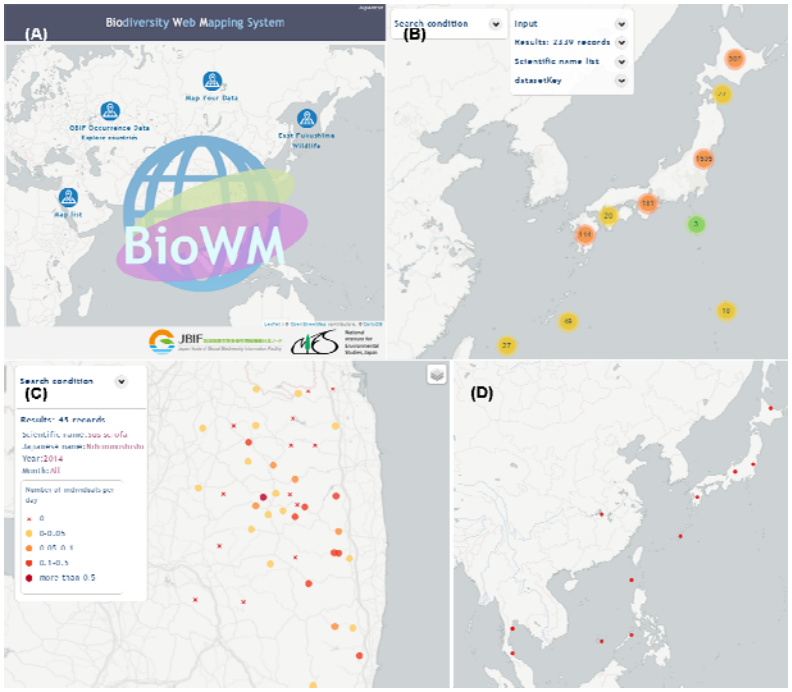
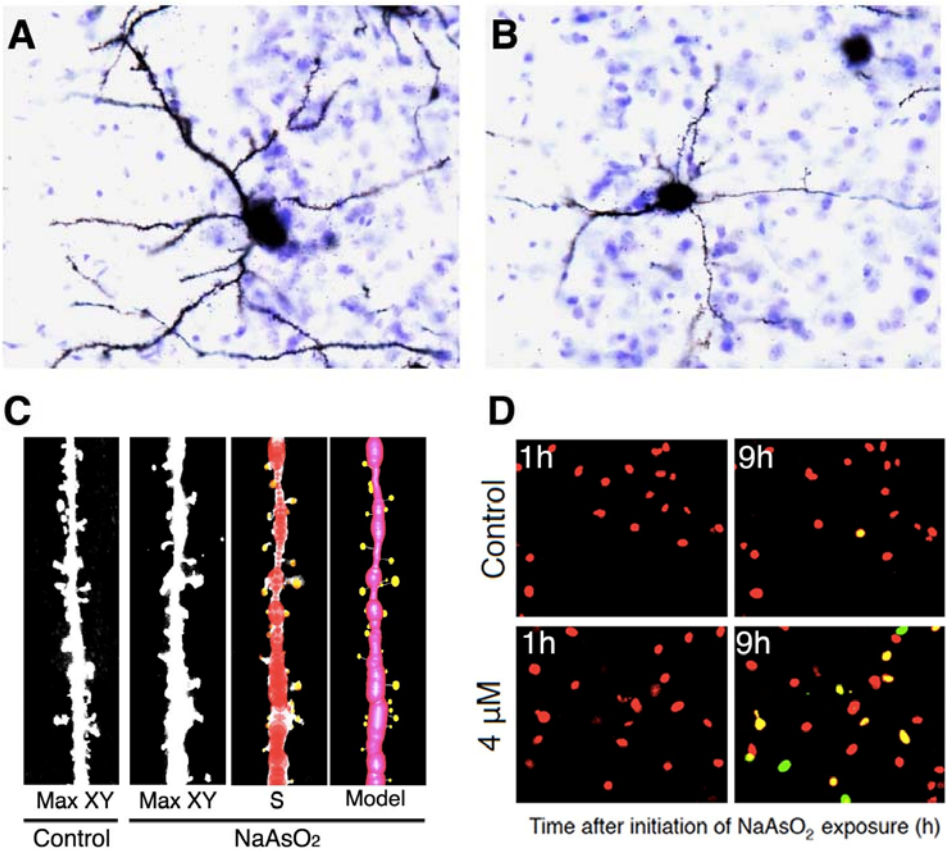


Fig. 7
(A) Home page of BioWM (http://www.nies.go.jp/biowm/index.php?lang=en).
(B) Example of the distribution of GBIF occurrence data provided by CEBES, retrieved on 13 April 2016 from GBIF (http://doi.org/10.15468/dl.ouaqse)
(C) Number of *Sus scrofa* individuals recorded on camera per day in a survey in east Fukushima in 2014.
(D) Example of mapping local data.
All map images were created with BioWM by NIES and JBIF under a Creative Commons Attribution 4.0 International License (Map tiles by CartoDB, under CC BY 3.0. Map data by OpenStreetMap, under ODbL.).

Center for Environmental Health Sciences



Effect of arsenic on brain development. Compared with controls, mice prenatally exposed to sodium arsenite displayed a significant decrease in neurite length in the prelimbic cortex (A: Control, B: Arsenic-exposed group). (C) Representative photomicrographs of dendritic spines with maximum-intensity projections onto the XY plane from Z-series images (Max XY) for the control group (Control) and arsenic-exposed group ($NaAsO_2$). Photomicrographs analyzed by using Spiso-3D software (S) and three-dimensional models (Model) are also shown for analysis of dendritic spines in the prelimbic cortex of the arsenic-exposed group. (D) Time-lapse images of astrocytes expressing fluorescent ubiquitination–based cell-cycle indicator (Fucci) after the initiation of arsenic exposure. Images of mAG and mKO_2 signals were merged after the original colors were converted to pseudocolors (mAG: green; mKO_2: red). Fucci-expressing astrocytes were exposed to $NaAsO_2$ at doses of 0 (Control) or 4 μM arsenic. Images were obtained 1 and 9 h after the initiation of arsenic exposure.

The health impacts of environmental factors such as environmental pollutants have yet to be adequately clarified. To prevent or reduce 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, in cooperation with 15 Regional Centers located nationwide, we are conducting the Japan Environment and Children's Study (JECS) in our role as the Programme Office. JECS plans to recruit 100,000 pregnant women and analyze the relationships between the environmental factors that children are exposed to *in utero* and during early childhood and their health outcomes and development. The Programme Office is taking a leading role in the JECS, including accumulating data collected by Regional Centers; maintaining the database and data management system; maintaining a repository of biological and environmental specimens; and performing exposure measurements, including chemical analyses, on specimens. The Programme Office prepares standard operating procedures, performs administrative tasks, provides administrative and technical support for Regional Centers, and is responsible for risk management and public communication.

We aim to comprehensively investigate, assess, and elucidate the impacts of environmental factors, beginning with environmental pollutants, on children and future generations 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. Simultaneously we will develop a method for measuring 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 improve the epidemiological health impact assessment methods

and biostatistical techniques used to evaluate children's growth and development. 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 the immune system, central nervous system, and metabolism by using animal disease models and cell lines, with children and future generations 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 2015 were as follows.

The **Biological Impact Research Section** is involved in experimental studies on the effects of environmental pollutants on the immune system, central nervous system, and metabolism. It is also developing an *in vitro* assay for assessing these toxicological effects.

Our previous studies have shown that intratracheal exposure to bisphenol A (BPA) disrupts the immune system and central nervous system in a murine model of allergic asthma. Combined treatment with ovalbumin (OVA) and a low or moderate dose of BPA especially aggravated airway inflammation and Th2 immune responses. In contrast, high-dose BPA reduced allergic inflammation. We gained further insights into the mechanisms of the effects of BPA exposure on the immune system and central nervous system in a murine model of allergic asthma. We also evaluated the changes in hormone levels in the sera and the bone marrow microenvironment of these mice. Low-dose BPA exposure significantly decreased serum levels of the anti-inflammatory hormone corticosterone in the presence of OVA. Previously, we also found that treatment with BPA plus OVA dose-dependently increased the mRNA levels of estrogen receptor-β in the lung. Thus, BPA exposure regulates allergic responses via endocrine disruption. On the other hand, low and moderate doses of BPA altered total cell numbers and the expression of CCR2, a receptor for monocyte infiltration of inflammatory sites, in bone marrow cells. Furthermore, moderate-dose BPA significantly increased the level of stromal cell–derived factor 1 in bone marrow fluid. These changes in the bone marrow microenvironment in response to BPA exposure might contribute to the inflammatory response.

We also investigated the effects of various doses of BPA on the ability of OVA-immunized allergic asthmatic mice to recognize novel objects. OVA alone did not affect object discrimination ability. However, although the results were not statistically significant, novel object recognition ability was impaired in a dose-dependent manner in OVA-immunized mice exposed to low, moderate, or high doses of BPA. These findings suggest that exposure to BPA affects memory function in allergic asthmatic mice.

We investigated the effects of oral exposure to the brominated flame retardant (BFR) decabromodiphenyl ether (DecaBDE) in C57BL/6J mice fed a high-fat diet (HFD) or a normal diet (ND). Our previous studies had shown that high-dose DecaBDE increases fasting blood glucose levels, especially in HFD-fed mice. We therefore aimed to gain further insights into the mechanisms of the effects of DecaBDE exposure on glucose metabolism. In HFD-fed mice, DecaBDE exposure reduced the mRNA levels of peroxisome proliferator–activated receptor gamma in the liver; glucose transporter 4 in the skeletal muscle (Fig. 1A); and leptin receptor in the hypothalamus. These results suggest that DecaBDE exposure enhances diet-induced hyperglycemia via the dysfunction of glucose metabolism.

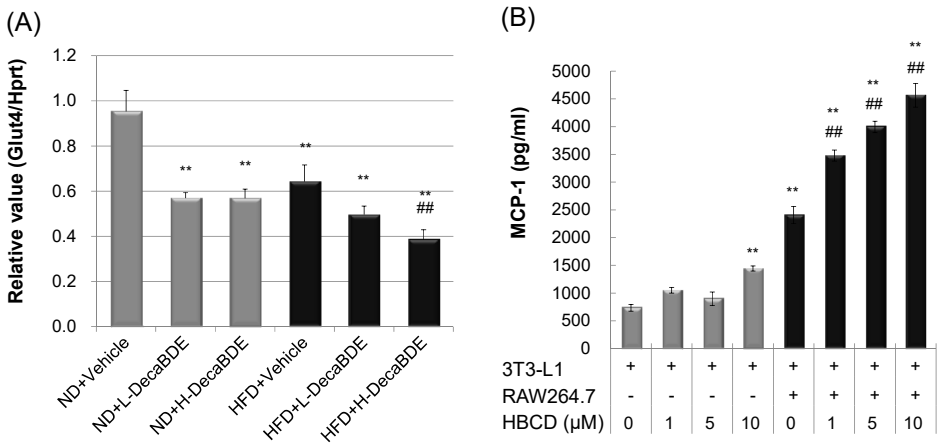


Fig. 1
(A) mRNA levels of glucose transporter 4 (Glut4) in the skeletal muscle of HFD-fed mice following exposure to decaBDE. Relative intensity was normalized against that of an endogenous control gene (hypoxanthine phosphoribosyltransferase 1; Hprt1). Data are presented as means ± SE (n = 5; $^{**}P < 0.01$ vs. ND+vehicle group, $^{\#\#}P < 0.01$ vs. HFD+vehicle group).

(B) Production of monocyte chemotactic protein-1 (MCP-1) in a coculture of 3T3-L1-derived adipocytes (Day 10) and RAW264.7 macrophages in the presence of HBCD for 24 h. Data are presented as means ± SE of triplicate cultures ($^{**}P < 0.01$ vs. RAW264.7 (-), HBCD 0 μM (Control); $^{\#\#}P < 0.01$ vs. RAW264.7 (+), Control).

We investigated the effects of hexabromocyclododecane (HBCD) on the interaction of adipocytes and macrophages *in vitro*. HBCD significantly increased the production of the inflammatory cytokines tumor necrosis factor-alpha (TNF-α) and monocyte chemotactic protein-1 (MCP-1) in a coculture of 3T3-L1-derived adipocytes and RAW264.7 macrophages (Fig. 1B) whereas it only slightly affected MCP-1 production in single cultures of adipocytes and macrophages. We also found that exposure to BFRs such as HBCD, decabromodiphenyl ether, and tetrabromobisphenol A promoted TNF-α production by RAW264.7 macrophages in the presence of the saturated fatty acid

palmitate. These results suggest that exposure to BFRs aggravates macrophage–mediated inflammation in the adipose tissue in obesity.

We established a novel olfactory-based spatial learning test for neonatal mice and examined the effects of gestational and lactational exposure (from gestation day 13 to postnatal day [PND] 10) to nano-sized diesel exhaust–origin secondary organic aerosol (DE-SOA) on learning performance in preweaning mice. On PND11, we subjected preweaning mice to the olfactory-based spatial learning test and found that mice exposed to DE or DE-SOA took longer than control mice to reach the test target (Fig. 2). Expression levels of neurological markers such as the N-methyl-D aspartate receptor subunits NR1 and NR2B, and of immunological markers such as TNF-α, cyclooxygenase (COX)-2, and ionized calcium-binding adapter molecule-1, were significantly greater in the hippocampi of DE-SOA-exposed preweaning mice than in control mice. Our results indicate that DE-SOA exposure *in utero* and in the neonatal period may affect olfactory-based spatial learning behavior in preweaning mice by modulating the expression of memory function–related pathway genes and inflammatory markers in the hippocampus.

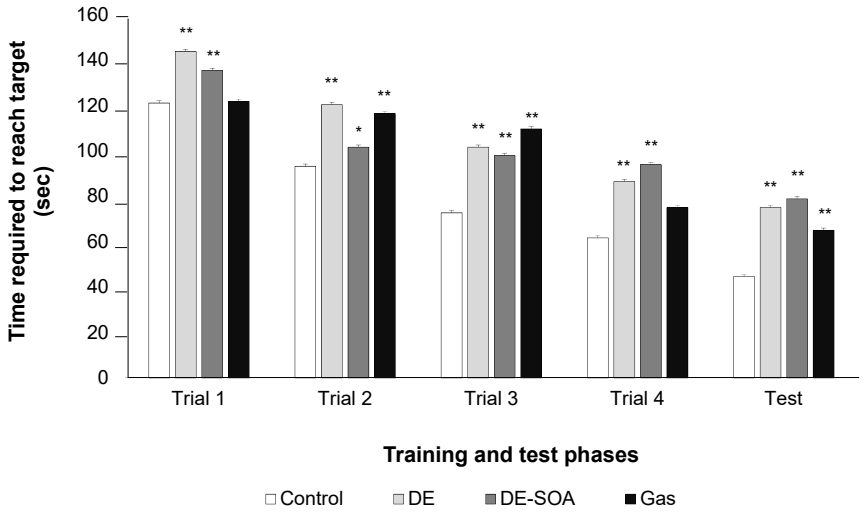


Fig. 2
Effects of DE (diesel exhaust), DE-SOA (diesel exhaust–origin secondary organic aerosol), or gas without particles on olfactory-based spatial learning ability in preweaning mice. Data are presented as means ± SE (n = 8 to 10; *P < 0.05, **P < 0.01 vs. control).

We also investigated whether exposure of immature male mice to DE-SOA affects allergic airway inflammation. DE-SOA exposure reduced allergic airway inflammation, including eosinophil infiltration and IL-5 levels, in the lung. DE-SOA exposure also tended to reduce the activation of antigen-presenting cells and T cells in lung local mediastinal lymph nodes. Next, we examined the effects of DE-SOA exposure of young adult mice on lipopolysaccharide (LPS)-induced acute lung injury. DE-SOA exposure had little effect on LPS-induced neutrophilic inflammation. DE-SOA exposure significantly reduced the activation of antigen-presenting cells and tended to reduce total cell numbers in lung local mediastinal lymph nodes. Taken together, these findings suggest that DE-SOA exposure of immature and young adult mice in these models has little effect on

respiratory diseases such as allergic airway inflammation and LPS-induced acute lung injury.

Induced pluripotent stem (iPS) cells are able to develop into any type of somatic cells, suggesting that they could be useful as alternatives to animal testing. To develop iPS cells into new tools for the toxicological assessment of air pollutants, we tried to generate macrophages from iPS cells. Macrophage-like cells were obtained from mouse iPS cells by using an embryoid body formation method. When iPS cell–derived macrophages were exposed to LPS, we found strong induction of the expression of several inflammatory genes, including those encoding KC, IL-1beta, IL-6, COX-2, and inducible NO synthase (iNOS), in a dose-dependent manner; these findings were similar to those obtained in the macrophage cell line MH-S. We also examined the effects of $PM_{2.5}$ (fine particulate matter with a mean aerodynamic diameter of 2.5 μm) collected in China on the inflammatory reactions of iPS cell–derived macrophages. Exposure to $PM_{2.5}$ induced expression of the genes encoding inflammatory cytokines in iPS cell–derived macrophages, and these effects were stronger than those in bone marrow–derived macrophages and MH-S. In addition, induction of *Cyp1a1* gene expression was found in iPS cell–derived and bone marrow–derived macrophages, but not in MH-S. Cyp1a1 is a marker of activation of the aryl hydrocarbon receptor, and its expression is induced mainly by exposure to polycyclic aromatic hydrocarbons, which are well known as major air pollutants composed of airborne particles derived from the burning of fossil fuel. Our results suggest that iPS cell–derived macrophages have a phenotype similar to those of the primary cells generally used in toxicological tests; their use may therefore be an important alternative to animal testing for evaluating the toxicities of air pollutants.

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 effects of inorganic arsenic on cancer development and the central nervous system.

We previously found that gestational arsenite exposure of F0 female mice increases the incidence of hepatic tumors in the F2 male offspring in adulthood. This year, we performed genome-wide DNA methylation analyses of normal liver and hepatic tumor tissues of control and arsenite-treated F2 males to explore the involvement of epigenetic mechanisms in tumor augmentation in the F2. RRBS (reduced representation bisulfite sequencing) libraries were prepared from genomic DNA samples from the abovementioned tissues and sequenced with a next-generation sequencer. The data were analyzed by using the methylKit and eDMR packages for the R statistical computing environment. Differentially methylated cytosines (DMCs) and differentially methylated regions (DMRs) between the control group and the arsenite-treated group were then selected. We also investigated the association between the DMRs around transcription start sites and gene expression. Our study detected several DMRs that may

epigenetically regulate gene expression. In future we intend to study the involvement of these genes in tumor augmentation in the F2.

We performed experiments to assess whether developmental exposure to environmental chemicals such as arsenic and neonicotinoid pesticides impairs brain development. We found that mice prenatally exposed to sodium arsenite displayed impaired adaptation to repetitive reversal tasks and a significant decrease in neurite length, but not dendrite spine density, in all layers of the prelimbic cortex, which is critically involved in cognition. (See the Figure on the front page of this section.) In a primary culture of astrocytes, we also found that adding sodium arsenite led to cell death by impairing cell cycles. We found that developmental exposure (from gestation to lactation) to a neonicotinoid led to not only abnormal sexual and aggressive behaviors but also abnormal emotional behavior.

Naturally occurring inorganic arsenic has been causing serious health problems, such as cancer, in many Asian countries and other areas globally. We aimed to establish epigenetic markers to detect the adverse biological effects of arsenic by analyzing the DNA methylation levels of affected genes. Following our work of last year, we used pyrosequencing to analyze the DNA methylation levels of long interspersed nucleotide element 1 (LINE-1) in blood DNA. We measured the LINE-1 methylation levels of a total of 236 human subjects: 175 from arsenic-endemic, and 61 from non-endemic, areas of rural Bangladesh. We found that LINE-1 methylation levels were significantly lower in arsenic-endemic individuals than in non-endemic individuals. We also revealed that arsenic exposure levels showed a dose-dependent inverse relationship with LINE-1 methylation and that sex was a significant confounder in arsenic-related LINE-1 methylation. Thus chronic arsenic exposure was inversely associated with LINE-1 methylation, and females were more susceptible than males to arsenic-related LINE-1 methylation.

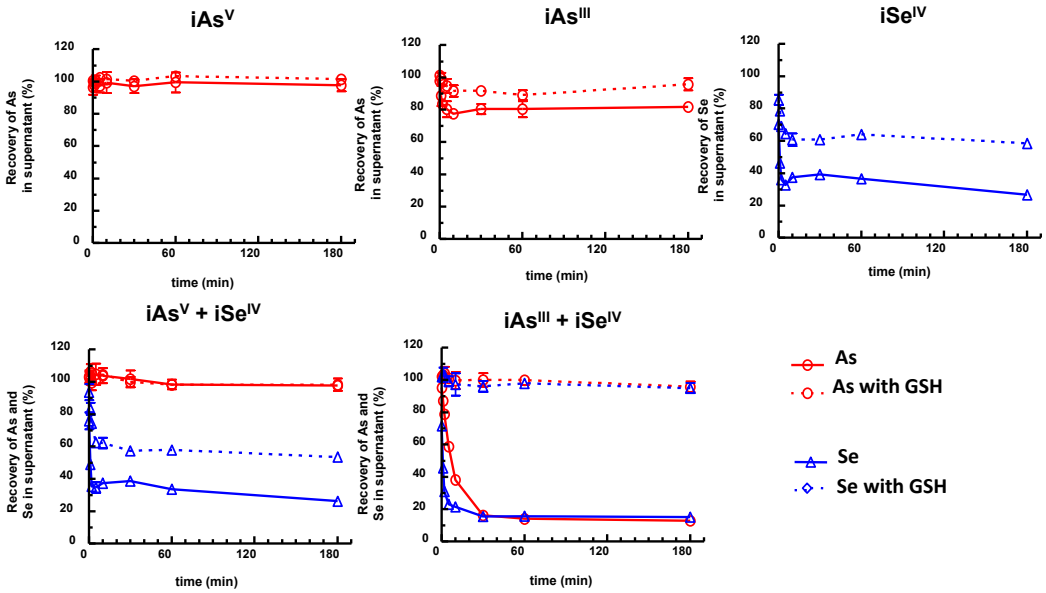


Fig. 3
Effects of glutathione on the uptake of arsenic and selenium by rat red blood cells.

We investigated the uptake of arsenic and selenium in rat red blood cells (RBCs) after co-exposure of the cells to selenite (iSe^{IV}) and either arsenite (iAs^{III}) or arsenate (iAs^{V}). Only the combination of arsenite and selenite increased the uptake of these elements compared with exposure to arsenite or selenite alone, and this uptake was inhibited by exogenous glutathione. Selenide (a reduction product of selenite) was produced by glutathione in the RBCs and may be involved in this enhanced uptake by forming an As–Se complex (Fig. 3).

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.

Exposure to ambient air pollutants such as particulate matter ($PM_{2.5}$) is associated with a number of adverse health outcomes ranging from increased symptoms of allergic airway disease to increased mortality. Children are considered to be particularly susceptible to air pollution—more so than adults—because their lungs are still growing and their immune and pulmonary systems are developing, making them vulnerable to infection with respiratory pathogens. However, although a number of studies have been conducted in the field of air pollution epidemiology, the adverse health effects of low-level exposure to air pollutants and the seasonal effects of air pollution (Fig. 4) on respiratory symptoms remain unclear. We examined the association between outdoor air pollution and meteorological parameters and the numbers of primary care visits (PCVs) at night in response to asthma attacks. We found an association between ozone levels and number of PCVs, suggesting that certain meteorological conditions are associated with an increase in PCVs.

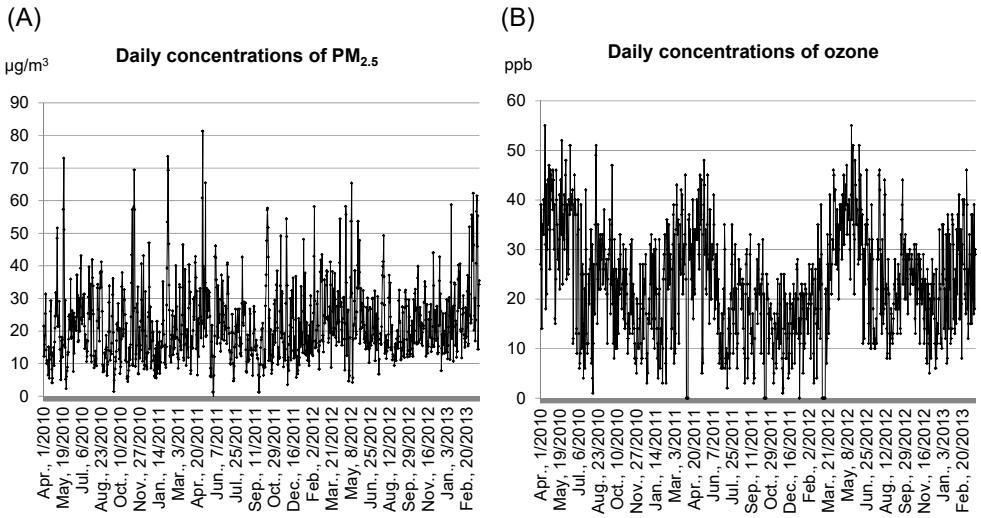
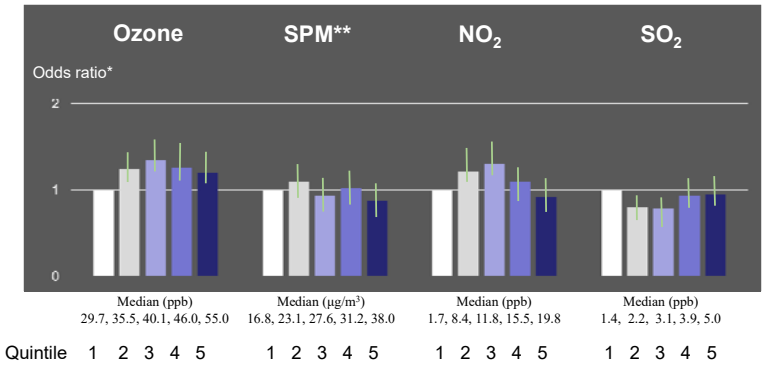


Fig. 4 Daily concentrations of $PM_{2.5}$ (A) and ozone (B) from April 2010 to March 2013 in Himeji, in southern Japan

There has been little study on the effects of traffic-related air pollution on the incidence and persistence of asthma in preschool children. We used a population-based study to evaluate the association between exposure to traffic-related air pollution and the incidence/persistence of asthma during the first 3 years of life. Although no statistically significant association was observed in terms of the incidence of asthma, the persistence of asthmatic symptoms in preschool children was significantly associated with the degree of exposure to traffic-related air pollution. This supports the importance of such exposure as a risk factor in childhood airway disease.

There is evidence of an association between ambient air pollution and adverse birth outcomes, such as preterm birth and low birth weight; however, the pathways linking air pollution to adverse birth outcomes are not fully understood. We consider that understanding these pathways may at least partly reveal the mechanisms behind some of the obstetric complications associated with prematurity and intrauterine growth restriction. First, we focused on hypertensive disorders in pregnancy, including gestational hypertension and preeclampsia, which is a common complication (approximately 5%), and family of cardiovascular disease. By using data from the Japan Perinatal Registry Network database, we found a positive association between exposure to ozone during the first trimester (placental development stage) and hypertensive disorders in pregnancy (Fig. 5). Although the underlying mechanisms are unclear, systemic inflammation is likely to play a role in these hypertensive disorders. Therefore, our findings are understandable, because ozone is a strong oxidant, and exposure to ozone during pregnancy has been associated with systemic inflammation.

Fig. 5
Association between exposure to air pollution during the first trimester and hypertensive disorders in pregnancy

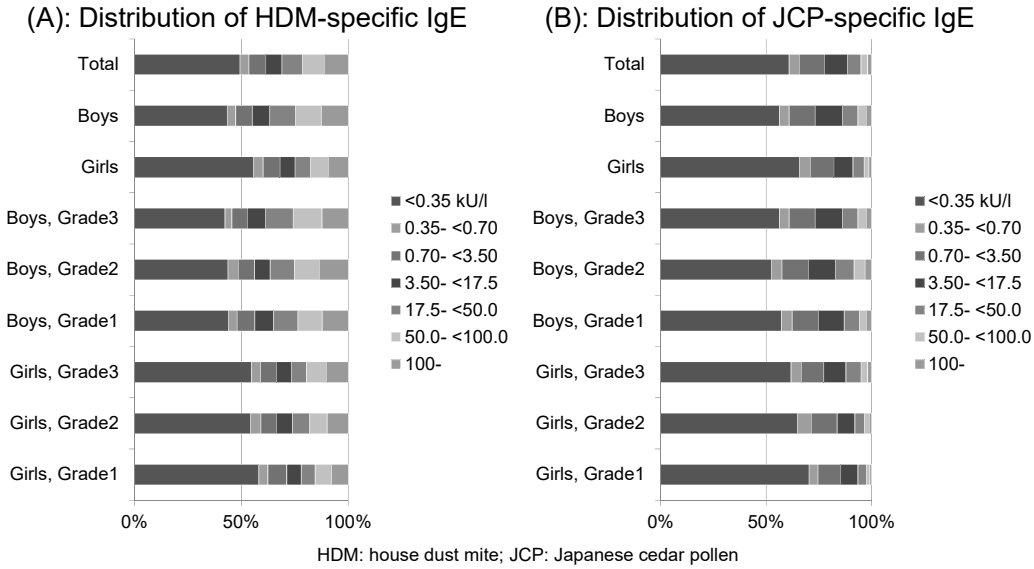


*Adjusted for maternal age, birth year, season of conception, parity, smoking, alcohol drinking, and BMI before pregnancy

**Suspended particulate matter. Particles that pass through a size-selective inlet with a 100% cut-off level of 10 μm in aerodynamic diameter

The prevalence of allergies is increasing worldwide, particularly among children, with unprecedented complexity and severity. A common hallmark of allergic disease is the production of serum-specific IgE against allergens, and sensitization to such allergens is a significant risk factor for the subsequent development of allergic diseases. We determined the distributions of IgE antibodies specific to two major inhalant allergens in Japan—serum house dust mite and Japanese cedar pollen—as markers of sensitization in schoolchildren in the lower school grades (Fig. 6).

Fig. 6
Distributions of IgE classes specific to house dust mite (a) and Japanese cedar pollen (b) among Japanese schoolchildren



HDM: house dust mite; JCP: Japanese cedar pollen

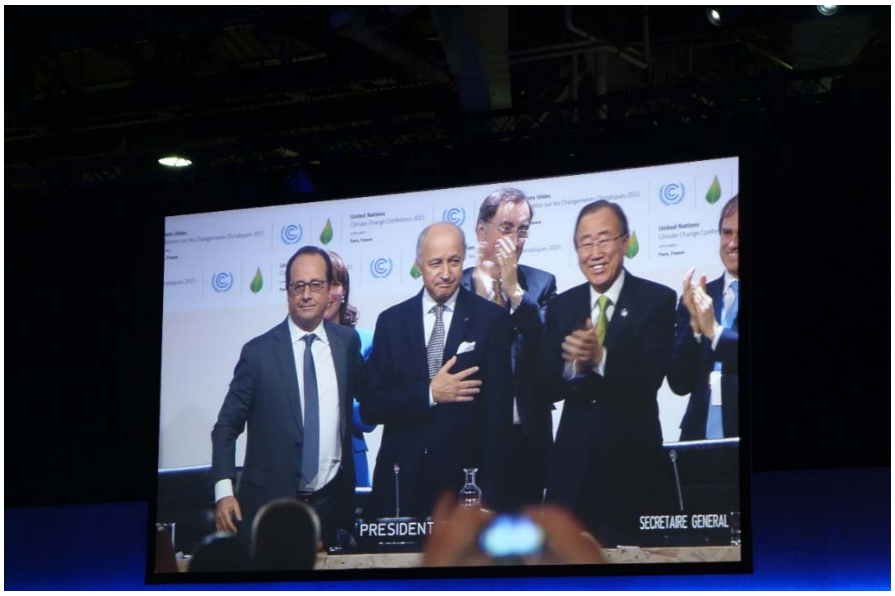
The **Integrated Health Risk Assessment Section** has developed high-throughput analytical methods for human biomonitoring. These methods were validated through rigorous quality assurance/quality control procedures and were tailored for use in large-scale birth cohort studies. We have been focusing on harmonizing

these human biomonitoring methodologies among international groups, including those in Germany and the US. The methods developed include online solid-phase extraction (SPE) liquid chromatography tandem mass spectrometry (LC–MS/MS) methods for monitoring nicotine metabolites, phthalate metabolites, and paraben metabolites in urine.

We also conducted exposure factor research. Samples of meals, feces, urine (24-h pooled), indoor air, house dust, and soil were collected from preschool children or their environments. Phthalates were analyzed in all the samples and then the children's intakes of house dust and soil were calculated by using a numeric model combining all the sources and exposure factors. We also gave women of childbearing age a questionnaire on their use of personal care products. We found that makeup and skincare, body care, bathing, and sanitary products were commonly used. An exposure model that we developed for radiological dose assessment is described in the Environmental Emergency Research Section of this report.

The **Programme Office of JECS** continued to play key roles in running the JECS. Our main study participants have reached the ages of 2 to 5 years. We administered questionnaires for these participants to collect a wide range of information on issues that included the children's health and development, socioeconomic status, social capital, and exposure to various environmental factors. We also stated a sub-cohort study involving 5000 participants selected from the main study. Home visits for the 1.5-year-old sub-cohort were performed to collect indoor and outdoor air samples and house dust samples. Volatile organic compounds, aldehydes, acidic gases, and particulate matter in these samples were measured. House dust samples were sieved with a 250-mm mesh and stored in freezers. We completed our analyses for metal elements (mercury, lead, cadmium, manganese, and selenium) in mothers' blood samples (60,000) and for nicotine metabolites in mothers' urine (35,000). In cooperation with Medical Support Center situated at the National Center for Child Health and Development and Regional Centers, the Programme Office also worked on a developmental test, examinations by pediatricians, and blood testing and collection in 2-year-old sub-cohort participants.

Center for Social and Environmental Systems Research



COP 21/CMP 11 President Laurent Fabius, then Foreign Minister of France, urges the Parties to agree on the current draft text and thanks them for their support at the last meeting of the Comité de Paris.

International Symposium on Eco City Bogor was held in March 2016 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; these proposals cover 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 technologies and climate change adaptation in cities.

Two research programs are conducted through 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 2015 were as follows.

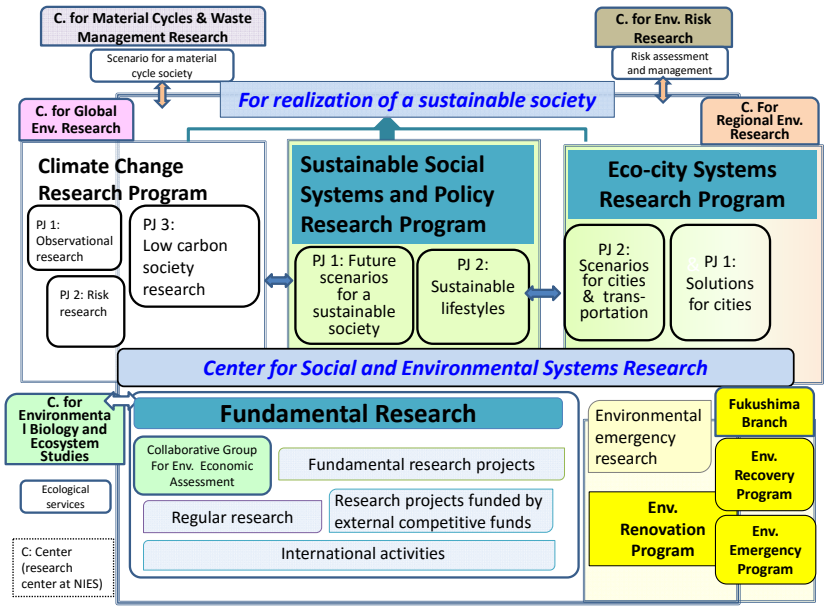


Fig. 1 Structure of research at the Center for Social and Environmental Systems Research

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 proposed scenarios.

From the perspective of sustainable lifestyles and consumption patterns, the Sustainable Lifestyle Scenario 2030 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 targeted at 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.

2. Eco-city Systems Research Program

The research focus at the Eco-city Systems Research Program is on developing theories and methodologies for fostering a planning and evaluation system to realize the development of effective environmental technologies and suitable 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 developed by verifying 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).

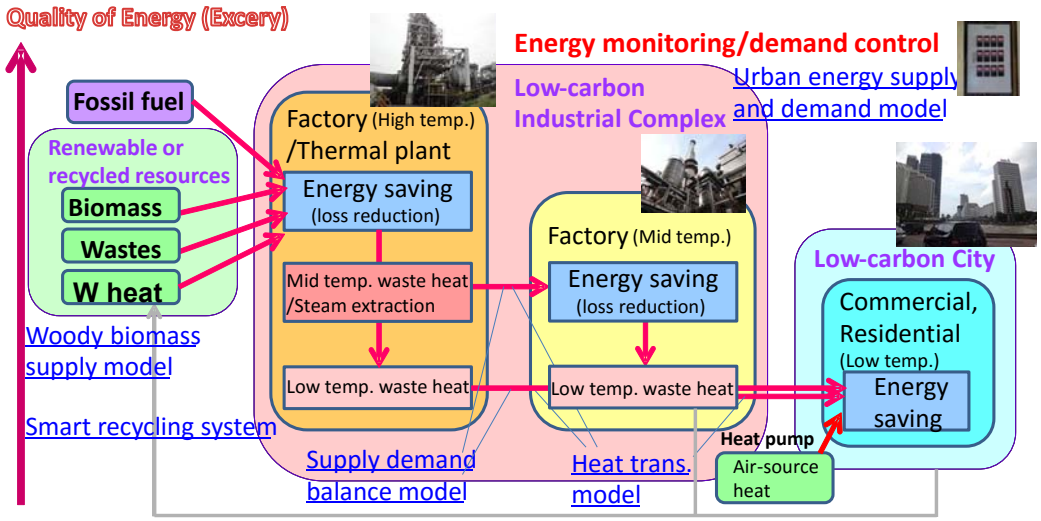


Fig. 2 Framework of a model for the planning and evaluation of co-benefit-type alternative technologies

In Project 1, to efficiently promote a reduction in emissions of CO_2 from spatially distributed emission sources in cities, we have developed a prototypic ICT (Information and Communication Technology) based monitoring tool that will facilitate the process of planning for low-carbon cities. The system will also verify the resulting CO_2-reduction effects through the monitoring of energy consumption. The system has been applied to buildings in the city of Bogor in Indonesia and to factories in 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) waste, waste heat, and renewable resources with upgraded energy quality (Fig. 2). We investigated the feasibility of building a hybrid system in cities such as Kitakyushu in Japan. An energy-saving sewage treatment system has been developed, and the associated technology has been demonstrated in

Thailand. Experiments are currently being conducted to develop an advanced trickle-filter system that will achieve satisfactory treated-effluent quality.

In Project 2, we used factorial analysis to map out changes in the spatial distribution of populations and to develop a method for creating feasible spatial distribution scenarios. By using data from a population census and road traffic census in 2010, we have modified the scenario for the spatial distribution of populations. On the basis of this modification, we have developed a method of estimating the energy demands of the household and business sectors. We have also evaluated the reasons why houses are becoming vacant, taking into account the numbers of households and people, the numbers of different types of buildings, and the floor area of each building. This type of bottom-up estimation method can be utilized by municipalities to estimate carbon dioxide emissions from each household and business sector; it can also be used to develop action plans for use by local governments in preventing global warming. Information on population distribution and building utilization status by region, as determined from our research products, was used in some workshops to develop comprehensive plans for municipalities.

3. Other research outcomes

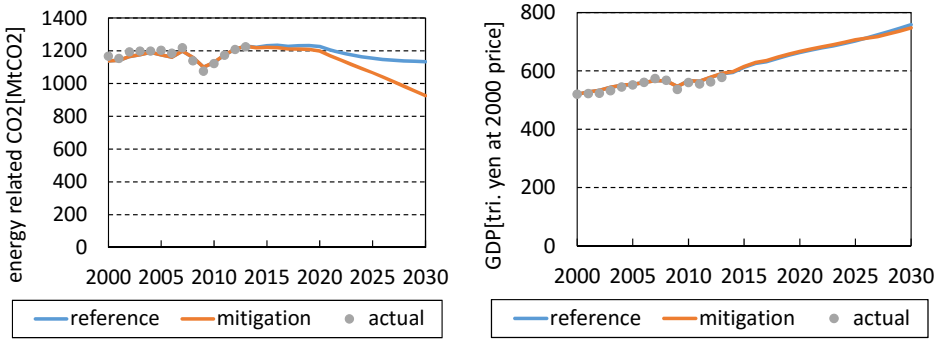
3.1 Quantification of long-term global scenario development

We used two economic measures to quantify the impacts of climate change on human health through undernourishment. First, taking changes in the labor force, population, and demand for healthcare into consideration, we used a computable general equilibrium (CGE) model to analyze changes in morbidity and mortality due to nine diseases caused by being underweight as a child. Second, we took changes in mortality from the CGE simulation and used them in an economic assessment of the value of lives lost and willingness to pay to reduce the risk. Model uncertainties in future crop yields and climate conditions were considered by using future projections from six global crop models and five global climate models. We found that the economic valuation of healthy lives lost due to undernourishment under climate change was equivalent to −0.4% to 0.0% of the global gross domestic product (GDP); this value was regionally heterogeneous, with the same predicted range of −4.0% to 0.0% of regional GDP in 2100. In contrast, at the global level, the actual economic losses associated with both the effects of additional health expenditure and the decrease in the labor force due to undernourishment resulting from climate change corresponded to a −0.1% to 0.0% change in GDP and a −0.2% to 0.0% change in household consumption.

3.2 Assessment of Japan's Intended Nationally Determined Contribution (INDC)

Before the COP21 of the United Nations Framework Convention on Climate

Change (UNFCCC) held in Paris in 2015, Intended Nationally Determined Contributions (INDCs), which include the intended national greenhouse gas (GHG) mitigation targets post-2020, were submitted by many countries. The Japanese Government submitted its target on 17 July 2015. It has committed to a 26% reduction in GHG emissions in 2030 compared with those in 2013. Unfortunately, the modeling teams including the Asia-Pacific Integrated Model (AIM) team did not contribute to the decision-making process. Nevertheless, we assessed this target by using our national CGE model (Fig. 3). The marginal cost of emission reduction in 2030 will be very high (more than 20,000 JPY/tCO_2), but the economic loss in 2030 will be 1.4% of GDP under the reference scenario. Even under the mitigation scenario, the annual GDP growth rate will be 1.6%. Because the marginal cost is the highest cost among all countermeasures and revenue from carbon taxes is used to mitigate the cost of contributing to GHG reduction, the GDP loss itself will not be severe. Moreover, by extending the mitigation capacity through penetration of mitigation options, the GDP loss in 2030 will be mitigated further. On the other hand, if tax revenue is not used to counterbalance the additional investment costs, the economic loss in 2030 will be 4.7% of GDP under the reference scenario.



(a) Emissions from energy-related CO_2 (b) GDP

Fig. 3 Assessment of Japan's INDC by using AIM/CGE

3.3 Economic impact of changes in energy demand for space heating and cooling systems

Space heating and cooling account for a significant proportion of overall energy use in the building sector, and the associated energy demand is affected by climate change. We projected the economic impacts of changes in energy demand for space heating and cooling under multiple climatic conditions. We used an economic model coupled with an end-use technology model to explicitly represent the investment costs of air-conditioning technologies, which influence the macro-economy.

According to the model analyses, the negative effects on the economy from increases in space cooling were sufficiently large to cancel out the positive effects from decreases in space heating under climate change, and this discrepancy was expected to cause significant economic loss. The economic loss under the highest emissions scenario (RCP8.5) was estimated as a −0.34% (−0.39% to −0.18%)

change in global GDP in 2100 as compared with global GDP without any climate change. On the other hand, under the lowest emissions scenario (RCP2.6), the impact was estimated as a −0.03% (−0.07% to −0.01%) change in global GDP in 2100 (Fig. 4). We also found that the economic losses would be generated mainly by incremental technological costs and not by changes in the energy demand itself. To reduce the negative impacts of climate change, measures for reducing the costs of air-conditioning will be important for the building sector in the future.

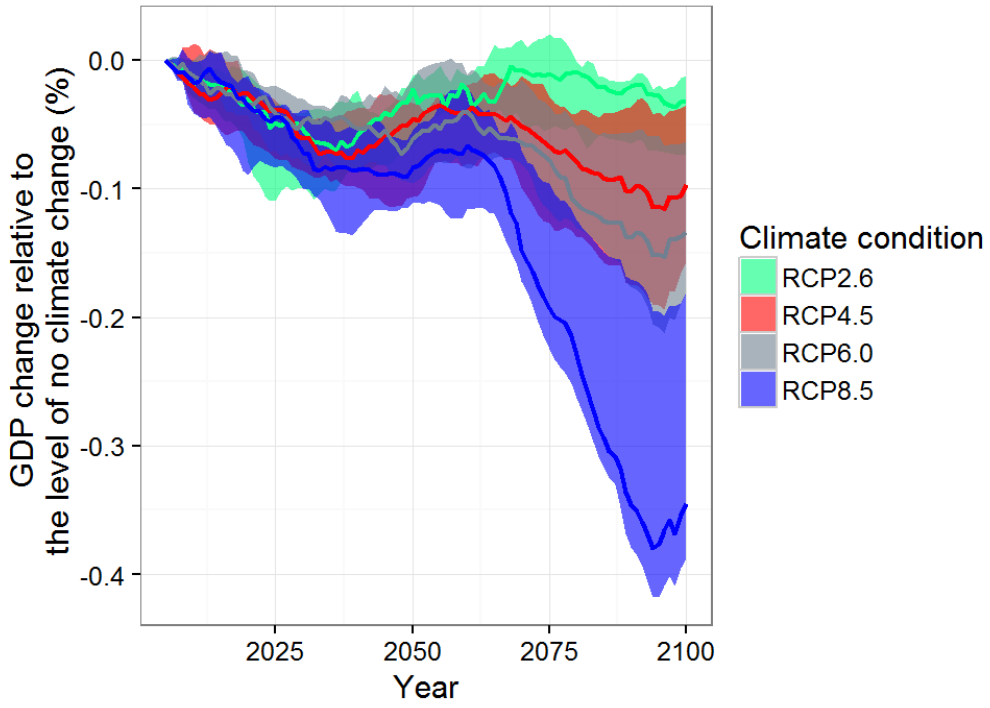


Fig. 4 Changes in global GDP due to changes in demand for space heating and cooling under different climatic conditions. (GDP changes are shown as changes compared with the levels without any climate change. Lines show median values, and ranges represent the uncertainty ranges of the general circulation models.)

3.4 Model and tool development under Climate Change Vulnerability, Impacts and Adaptation to support local municipalities' adaptation implementation and planning in Japan

This research is one of the themes of the SI-CAT (Social Implementation Program on Climate Change Adaptation Technology) program. The Ministry of Education, Culture, Sports, Science, and Technology began funding SI-CAT this fiscal year. The objectives of SI-CAT are 1) model and tool development to promote climate change adaptation investigation and planning by Japanese local governments, and 2) co-design and realization of local adaptation plans in Japan that take into account policymakers' needs and researcher's seeds. The role of the research is not only model development for climate change impact assessment but also the development of application tools to support local policymakers in utilizing the scientific information developed by the SI-CAT. The impact assessment model focuses on the essential sectors used to plan and implement local adaptation. The tool is equipped with functions for 1) extracting the map and numerical information used in climate change adaptation reports and pamphlets; 2)

displaying the results of comprehensive climate change impact assessment for use in prioritizing adaptation measures; and 3) supporting understanding of scientific uncertainty.

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 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 the Land Use and Scenario Integration, Transportation and Air Quality, Energy Systems, Solid Waste Management, and Socioeconomic sectors of both Malaysia and Japan, and the 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 simulate 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 at 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. The newly designed monitoring system is expected to serve as a support tool for users to promote energy-saving actions and to share information with others through the visualization of real-time energy consumption (Figs. 5 and 6). More than 160 sensors have been installed in residential houses, office buildings, commercial buildings (including a large shopping mall), and a hotel in Bogor. The monitoring data and knowledge database will provide enhanced local parameters for modeling approaches, further facilitating the transformation to a low-carbon society.

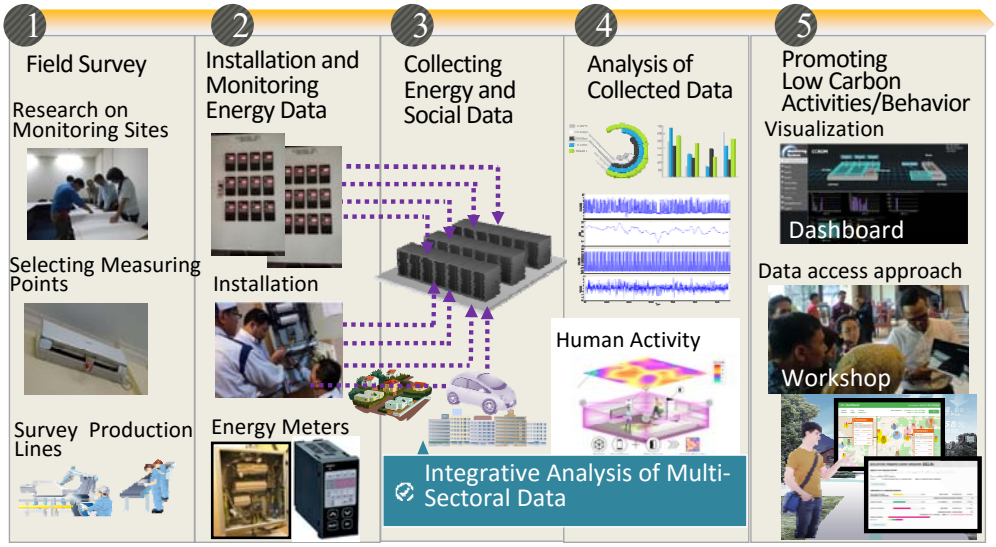


Fig. 5 ICT (information and communications technology) framework for an urban low-carbon monitoring system in Asia

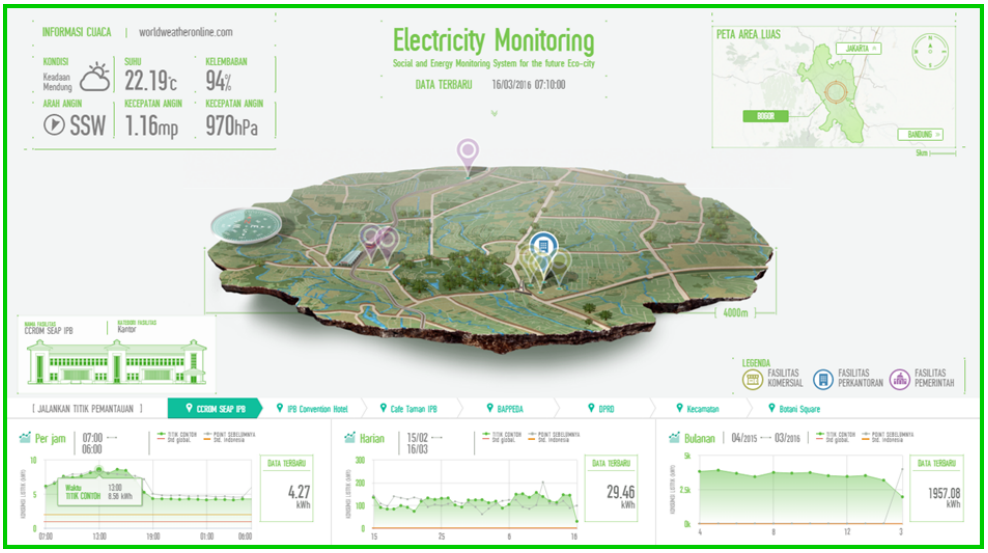


Fig. 6 Graphical display of the real-time data monitored by the system in the city hall of Bogor City Government, Indonesia

3.7 Urban structure and the numbers of seniors with poor access to transport

Elderly people without adequate access to public transportation suffer from a lack of mobility after they stop driving, as they mostly depend on urban structure. To

reduce the numbers of seniors with poor access to transport, it is important that we understand the relationship between urban structure and access to transportation. By applying spatial analysis to the greater Tokyo region, which may be severely affected by this issue in the near future, this study is estimating the past and future numbers of seniors facing a mobility crisis. In addition, we are using a cohort analysis to quantitatively clarify the relationship between urban structure and the number of seniors with poor access to transport. Data include those from national censuses from 1980 to 2010, future population projections up to 2040, railway station locations, and bus routes. We have estimated that the number of seniors with poor access to transport increased from 324,702 in 1980 to 758,336 in 2010 and will reach 1,394,074 in 2040 (Fig. 7). In addition, the percentages of the elderly without train access similarly increased from 43% in 1980 to 46% in 2010 and will reach 49% in 2040. The percentages without rail or bus access were 15% in 1980 and 10% in 2010 and will reach 12% in 2040. These changes are associated with choices made regarding residential distribution in preceding years.

Fig.7 Estimated numbers of seniors with poor access to transport in 2040

3.8 Future technology and policy system analysis for eco-cities: Sophistication of a system for energy recovery from municipal solid waste

Efficient energy recovery from municipal solid waste is an important solution for building a low-carbon and sustainable society. Among the wide variety of possible methods, upgrades in the use of waste will provide a clear direction for substantially improving the efficiency of energy recovery. The use of waste in industrial processes (e.g. as solid recycled fuel for furnaces or for the supply of steam from an incinerator to neighboring factories) is a typical method of

achieving direct and indirect upgrade use of waste.

We built an integrated model to evaluate the energy-recovery efficiencies and cost-benefits of different energy-recovery scenarios. Scenarios were designed by setting waste management options, including a combined system of methane fermentation and incineration with an individual superheating process, in addition to the above-mentioned options for the use of waste by industry.
We found that the upgrade use of waste in industries (e.g. steam supply to a factory) had around double the energy-recovery efficiency of conventional waste power generation in an incinerator (the power-generation efficiency of which is about 20%, at most, in Japan). The combined system can increase power-generation efficiency from waste and is effective in areas where the supply of steam to industry is difficult for geographic reasons.

3.9 Sustainable consumption and behavior research

This field of research consists of the following two parts:
1) Public opinion research, focusing on the role of mass media as a catalyst for social change. Public awareness is very much influenced by mass media coverage on specific issues, including environmental issues. International and domestic events are the main contents of media coverage. We track climate change issues, in terms of both public awareness and media coverage (in printed newspapers), every month. The results for 2015 showed that Paris COP21 received the most attention by mass media coverage and the public; it was also seen as the most important issue among all global events related to climate change.
2) To disseminate the results of research into Sustainable Lifestyle Scenario 2030, we published both Japanese and English versions of brief reports introducing our project, team, aim, methodology, results, and comments from experts. Also, we conducted focus group interviews of people in the northern Kanto region for comparison with residents of the Tokyo metropolitan area. We found that, in contrast to people in the metropolitan area, people in the Kanto region live in a society that is more family oriented and in which traditional gender roles predominate. People’s happiness seems to not be tightly related to their incomes, but to family and local community relationships.

3.10 Institutional dimension of environmental policy research

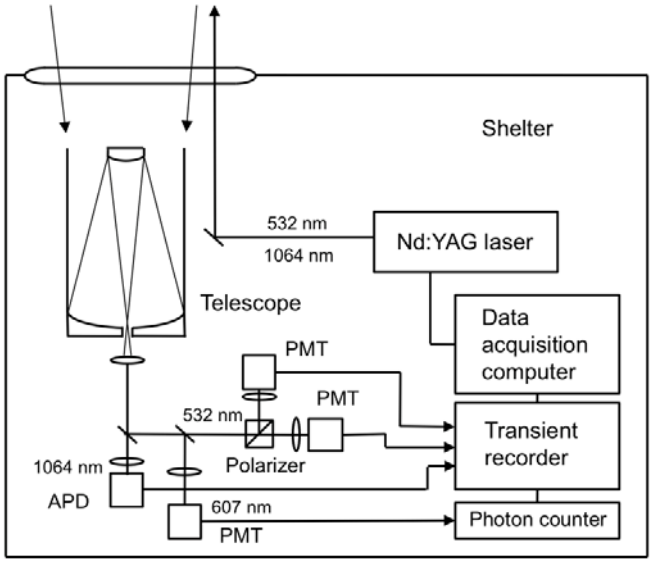
We have been using legal and political science–based knowledge to conduct research into the institutional aspects of environmental policies. This research topic covers five to 10 different themes and research projects, three of which are explained below:
1) Study of an Agreeable and Effective International Institution Concerning Climate Change for the Years after 2020: This study drafted a proposal for a plausible agreement to be reached at COP21. Many features in common were found between our proposal and the Paris Agreement.

2) Qualitative Analysis of Various Funding Schemes Targeting Climate Change Adaptations: This study reviewed several types of funding mechanisms for adaptation. It suggested that there ought to be more coordination among these various funding sources.

3) Study of Sustainable Development Indicators (SDIs): Here, we developed a set of indicators to measure Japan's progress in a trajectory towards a sustainable future. The report was published in Japanese and English and can be downloaded.
http://www.nies.go.jp/program/psocial/pj1/ (Japanese)
http://www.nies.go.jp/program/psocial-e/pj1/index.html (English)

Center for Environmental Measurement and Analysis

Cold-vapor generator coupled to a multi-collector inductively coupled plasma mass spectrometer, used to measure Hg isotopic ratios



Polarization-sensitive (wavelength 532 nm) Mie-scattering (532 and 1064 nm) and Raman-scattering (607 nm) lidar system installed in Phimai, Thailand

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 Radioactive Materials and Environmental Disaster Research 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 developing 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 important results of our research in FY 2015.

Isotopic composition of Hg in NIES CRM No. 13, Human Hair

NIES has been preparing and distributing environmental and biological Certified Reference Materials (CRMs) since 1980. Over the past 20 years, we have provided 52 countries with thousands of bottles.

To meet the growing demand for a better understanding of Hg exposure routes, we analyzed the Hg isotopic ratios of NIES CRM No. 13 (Human Hair) by using cold- vapor generation multi-collector inductively coupled plasma mass spectrometer (CV-MC-ICP-MS).

Within- and between-bottle variations in Hg isotopic measurements of NIES CRM No. 13 were found to be sufficiently small for the CRM to be used for its intended purpose (Table 1). The CRM can be used to confirm analytical results and to manage analytical data precisely. The results of an interlaboratory

comparison of the CRM, performed at the University of Pau and Pays de l'Adour in France, showed good agreement with the values obtained at NIES.

Table 1 Hg isotopic composition of NIES CRM No. 13, Human Hair

	δ^{199}Hg	δ^{200}Hg	δ^{201}Hg	δ^{202}Hg	δ^{204}Hg	Δ^{199}Hg	Δ^{200}Hg	Δ^{201}Hg	Δ^{204}Hg
(n = 11)	‰	‰	‰	‰	‰	‰	‰	‰	‰
Mean	2.13	0.98	2.77	1.89	2.76	1.65	0.04	1.36	–0.04
2SD	0.07	0.08	0.10	0.10	0.16	0.06	0.04	0.07	0.11

Because mass independent fractionation of the odd-mass isotopes (Δ^{199}Hg and Δ^{201}Hg) in human hair varies with the type and quantity of food (particularly seafood) consumed, it can be used to estimate the sources of exposure (Fig. 1). We showed that absorption of mercury (mostly in the form of methylmercury) by the human body induced mass dependent fractionation of about +2% in the case of δ^{202}Hg, implying that the isotopic composition of Hg in human hair was as expected following its ingestion and distribution in the body.

Isotopic compositions are reported in the delta (δ) notation relative to Hg standard solution: δ^{***}Hg (‰) = $\{[(^{***}Hg/^{198}Hg)_{sample}/(^{***}Hg/^{198}Hg)_{NIST\ SRM\ 3133}] - 1\} \times 1000$, where *** represents isotopic mass numbers 199, 200, 201, 202, and 204. Mass-independent fractionation is reported in capital delta (Δ) notation as the difference between the measured and the theoretical δ^{***}Hg value: Δ^{***}Hg (‰) = $\delta^{***}Hg - (\beta \times \delta^{202}Hg)$, where β equal to 0.252, 0.502, 0.752, and 1.493 for ^{199}Hg, ^{200}Hg, ^{201}Hg, and ^{204}Hg, respectively.

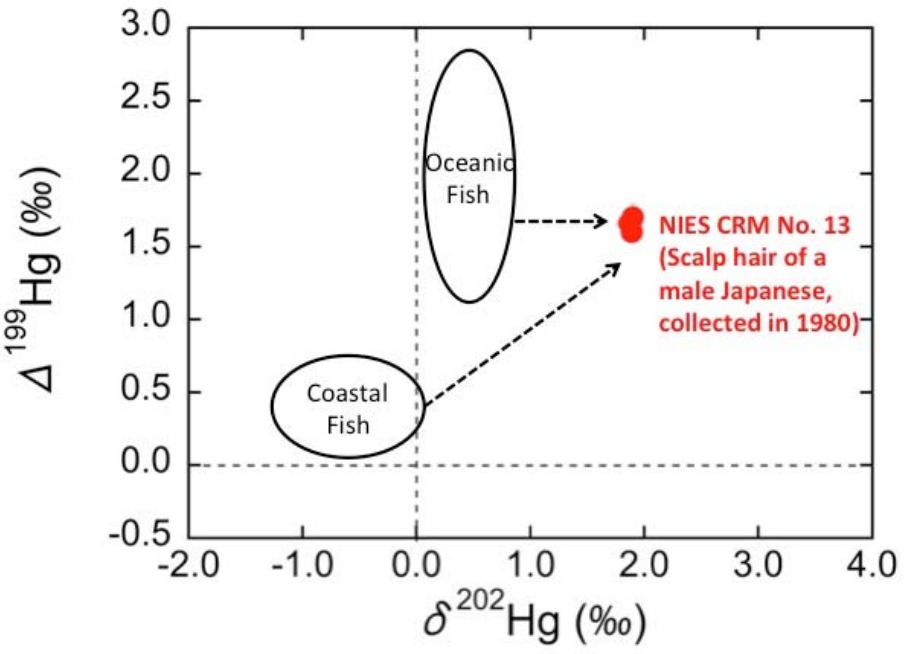


Fig. 1 δ^{202}Hg versus Δ^{199}Hg for NIES CRM No. 13, Human Hair. Ovals represent the plot range of Hg isotopic compositions of oceanic and coastal fish.

High-resolution mapping of biomass-burning emissions in three tropical regions

In tropical regions, biomass burning plays an important role in atmospheric pollution and the carbon cycle. We developed a comprehensive monthly biomass-burning emissions inventory with a high spatial resolution (1 km). It includes the burning of vegetation, human waste, and fuelwood in 2010 in three tropical regions: Africa, Central and South America, and South and South East Asia. The estimations were based on the burned area product derived from satellite data [NASA's Moderate-resolution Imaging Spectroradiometer (MODIS)] and statistical data. Vegetation burning was distributed extensively, with larger amounts in Africa than in the Americas and Asia (Fig. 2). Human waste combustion presented patterns different from those of vegetation burning. Fuelwood combustion displayed spatial patterns similar to those of human waste burning. The total emissions of all gases and aerosols were 17,382 Tg of CO_2, 719 Tg of CO, 30 Tg of CH_4, 29 Tg of NOx, 114 Tg of NMOC (non-methane organic compounds), 7 Tg of SO_2, 10 Tg of NH_3, 79 Tg of $PM_{2.5}$ (small particulate matter), 45 Tg of OC (organic carbon), and 6 Tg of BC (black carbon). Taking CO as an example, vegetation burning accounted for 74% of total CO emissions, followed by fuelwood combustion and human waste burning. Africa was the biggest emitter (440 Tg)—larger than Central and South America (113 Tg) and South and South East Asia (166 Tg). The dominant types of vegetation fire were woody savanna/shrubland (Africa), savanna/grassland (Central and South America), and forest (South and South East Asia). Although there were some slight overestimations, our results are supported by previously published data such as EDGAR (Emissions Database for Global Atmospheric Research).

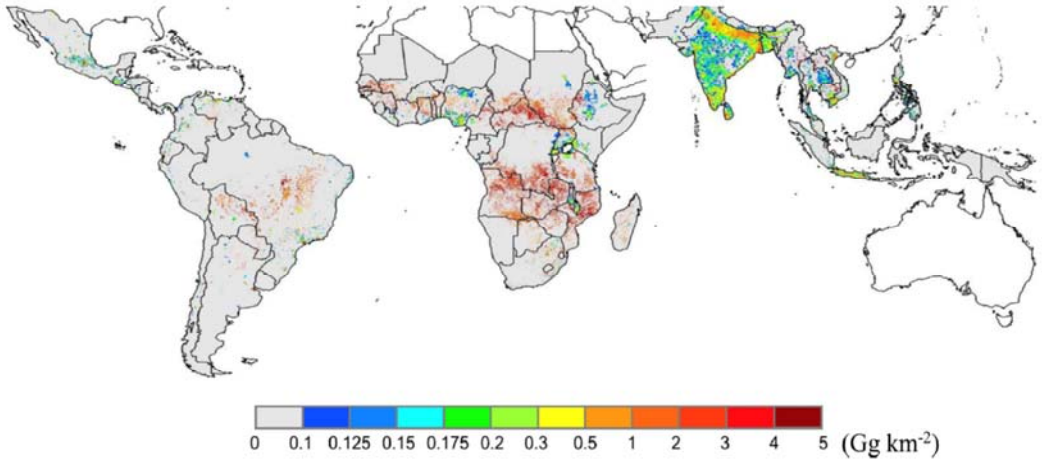


Fig. 2 Spatial distribution of total amounts of burned vegetation, human waste, and fuelwood in 2010 (1-km grid), derived from satellite data

Aerosol characteristics in Phimai, Thailand, as determined by continuous observation using a polarization-sensitive Mie-Raman lidar and a sky radiometer

In Phimai, Thailand (102.57°E, 15.18°N, 212 m above sea level), we continuously observed the distributions and optical characteristics of aerosols by using a polarization-sensitive (wavelength 532 nm) Mie-scattering (532 nm and 1064 nm) and Raman-scattering (607 nm) lidar and a sky radiometer. The Phimai observatory is one of the lidar sites of the Asian Dust and aerosol lidar observation Network (AD-Net) (http://www-lidar.nies.go.jp/AD-Net/). It is also a SKYNET sky radiometer site (http://www-lidar.nies.go.jp/skynet/).

Figure 3 shows examples of extinction coefficient estimates for non-spherical and spherical aerosols, obtained by using the AD-Net data-processing algorithm. Polarization lidar measurements indicated that high-concentration plumes of spherical aerosols, considered to be smoke from biomass burning, were often present in the dry season. Plumes of non-spherical aerosols—considered to be long-range-transported soil dust from Africa, the Middle East, or Northeast Asia—were occasionally observed. For example, a dust event on 15 June 2012 is apparent in the non-spherical aerosol plot in Figure 3. Diurnal variations in the extinction coefficients of non-spherical and spherical aerosols in both the dry season and the wet season in 2013 are shown in Figure 4. In both seasons, low-concentration non-spherical aerosols were almost always observed in the atmospheric mixing layer. The extinction coefficient profiles of spherical aerosols and non-spherical dust exhibited different diurnal variations, and spherical aerosols (including smoke) were distributed at higher altitudes in the mixing layer and residual layer. This difference can be explained by the hygroscopic growth of the smoke particles and the buoyancy of the smoke. The lidar spherical-aerosol extinction coefficient in the wet season, when the number of biomass-burning fires was very small, suggested that there were contributions from other emission sources.

Seasonal variations in aerosol optical depth (AOD) between 2005 and 2013, obtained from Mie-lidar extinction coefficient profiles from 120 m to 6 km, are depicted in the top panel of Figure 5. AODs derived from the Raman-lidar extinction coefficient profiles are also indicated for 2012 and 2013 in the same panel. Sky radiometer AODs, Angstrom exponents, and single scattering albedos (SSAs) are indicated in the remaining panels of the figure. Analysis of seasonal variations in optical properties, as derived from the Raman lidar and the sky radiometer, confirmed that the lidar ratio, AOD, and Angstrom exponent were higher in the dry season (October to May) and lower in the wet season (June to September). The SSA was ranged lower in the dry season. These seasonal variations are explained by frequent biomass burning in the dry season, consistent with the results of previous studies in the South East Asian region.

Our work also confirmed that soil dust was a major aerosol component at Phimai. This result is consistent with previously reported sampling analyses of the chemical and element compositions of aerosols at the Phimai site. The previously reported $PM_{2.5}$ to PM_{10} ratio of soil dust was 0.4 to 0.5, indicating that the concentration of fine dust particles is high. Our current results suggest the importance of low-concentration long-range-transported dust and the deposition–resuspension of this transported dust.

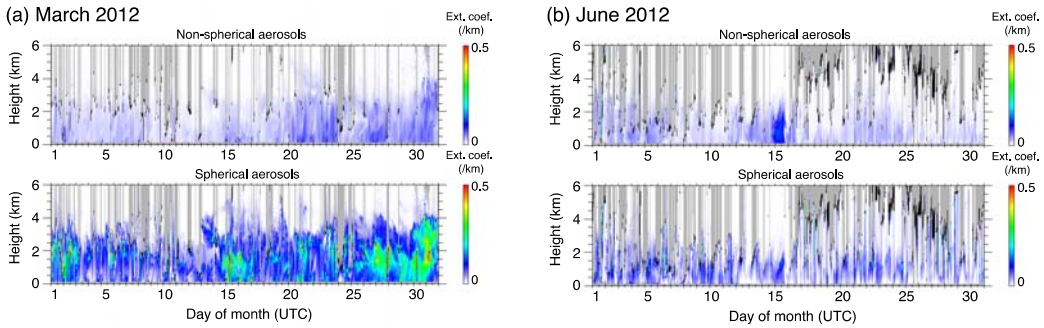


Fig.3 Time-height indications of the extinction coefficients at a wavelength of 532 nm for non-spherical (upper) and spherical (lower) aerosols in March 2012 (left) and June 2012 (right), Phimai, Thailand

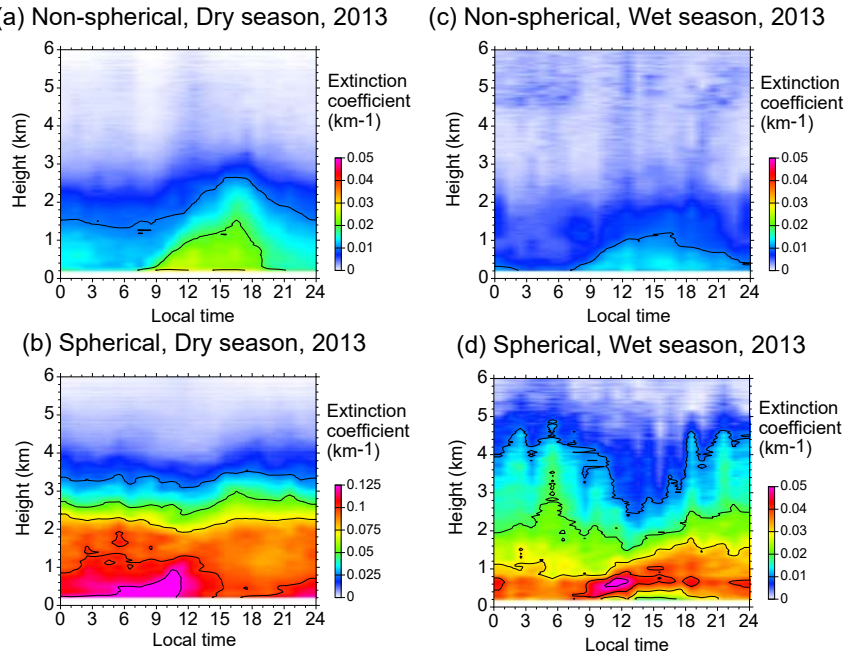


Fig. 4 Composite diurnal variations in the extinction coefficients of non-spherical (dust) particles (upper) and spherical particles (lower) at a wavelength of 532 nm for (a) and (b) the dry season (March to May), and (c) and (d) the wet season (July to September) in 2013, Phimai, Thailand

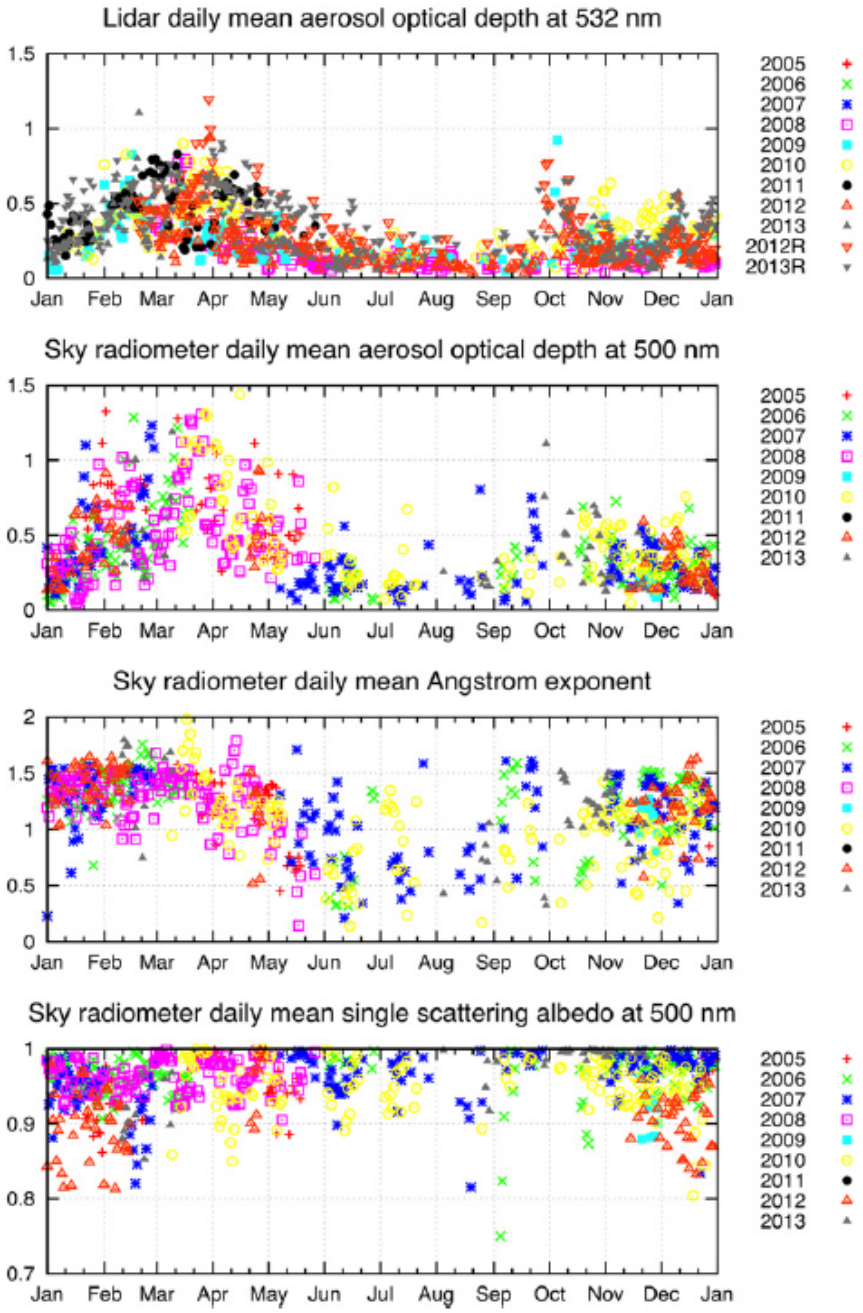


Fig. 5 Seasonal variations in aerosol optical properties, as determined by lidar and sky radiometer, in Phimai, Thailand

Chemical composition and source of fine particles and nanoparticles from recent direct-injection gasoline passenger cars

We measured the particle number, mass, and chemical compositions [i.e., elemental carbon (EC), organic carbon (OC), elements, ions, and organic species] of fine particles emitted from four recently-manufactured direct-injection spark ignition (DISI) gasoline passenger cars and a port fuel injection (PFI) gasoline passenger car. Measurements were taken in the Japanese official transient mode (JC08 mode). Total carbon (TC = EC + OC) dominated the particulate mass (90% on average). EC dominated the TC under both hot and cold start conditions. The EC/TC ratios were 0.72 for PFI vehicles and 0.88–1.0 (average = 0.92) for DISI vehicles. A size-resolved chemical analysis of a DISI car revealed that the major organic components were C_{20}–C_{28} hydrocarbons in the case of both accumulation-mode particles and nanoparticles (Fig. 6). The contribution of engine oil was estimated to be 10–30% in the case of organics and the sum of the measured elements. The remaining major fraction likely originated from the gasoline. Therefore, it was likely thatthe soot (EC) also originated mainly from the gasoline. In experiments using four fuels at three ambient temperatures, the emission factors of particulate mass were consistently higher with regular gasoline than with premium gasoline. These results suggest that a high content of less-volatile compounds in fuel increases particulate emissions. These results suggest that focusing on reducing fuel-derived EC in the production process of new cars would effectively reduce particulate emissions from DISI cars.

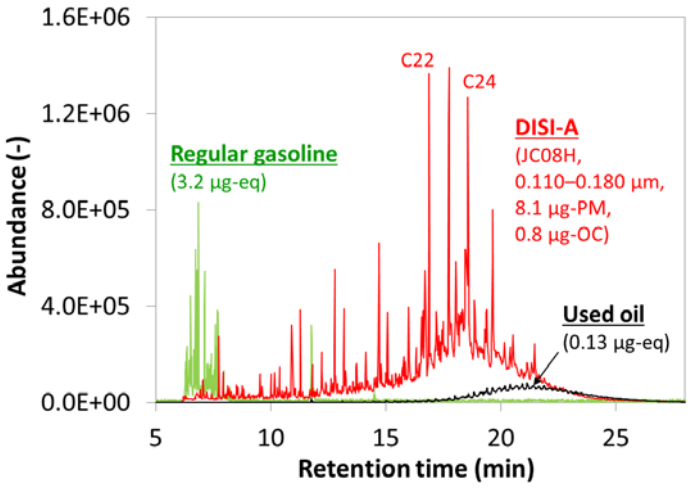


Fig.6 Mass chromatograms (*m/z* 85, hydrocarbon) of the accumulation-mode particles (diameter = 0.110–0.180 μm) from a recent DISI gasoline passenger car (JC08-hot mode), as analyzed by using thermal desorption gas chromatography/mass spectrometry (GC/MS), and from regular gasoline and used engine oil, as analyzed by GC/MS.

Development of a post-processing method for improvement of sensitivity and peak resolution of metabolites in the human brain *in vivo*

Glutamate (Glu) and γ–amino butyric acid (GABA) are major neurotransmitters in the human brain. Measuring the concentrations of Glu and GABA *in vivo* may be useful for finding biomarkers of environmental risk to the human brain. We have reported *in vivo* simultaneous detection of the peaks of these metabolites in the human brain using the localized 2D constant-time correlation spectroscopy (CT–COSY) method at 4.7 T. Furthermore, we developed a quantitation method on 2D CT–COSY spectra and thereby demonstrated the quantitation of Glu and GABA in the human brain. However, this method required at least two sets of spectra with different constant time delays. As a result, long measurement time of 40 min for each spectrum was needed. In those works, we have developed an appropriate Gaussian window function to resolve the diagonal peaks of those metabolites that overlap on conventional CT spectra. On the basis of these techniques, for higher sensitivity we have developed a CT point resolved spectroscopy (CT–PRESS) method by which only diagonal peaks can be measured, without cross peaks. In this work, we have also developed a phasing method for CT-PRESS spectra to improve the resolution of metabolite peaks, along with a curve-fitting method for quantitation. Figure 7a shows a phased CT-PRESS spectrum of the human brain. The diagonal peaks of Glu, GABA, and glutamine (Gln) can be resolved on this spectrum. The peaks are clearly resolved on a surface plot of the spectrum, as viewed from the F_1 axis (Fig. 7b). Figure 7c shows the result of curve fitting. The fit residual was small (Fig. 7d). In conclusion, 2D CT–PRESS spectra were successfully phased by our method, and the peak volumes of Glu C4H, GABA C2H and Gln C4H were curve-fitted well by the spectral analysis. These are useful for quantifying Glu, GABA, and Gln and will help us to find biomarkers of environmental risk to the human brain.

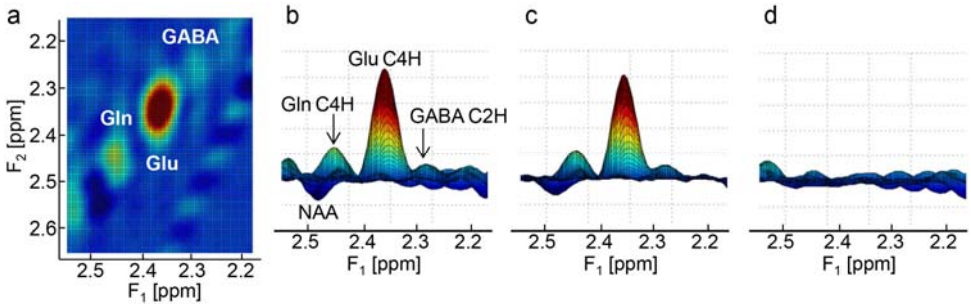


Fig. 7 Phased 2D CT-PRESS spectrum of the human brain (a); view from the F_1 axis (b); the result of curve fitting (c); and the residual after curve fitting (d)

Environmental Emergency Research

Lectures on a Regional ICT (Information and Communication Technology) System in the town of Shinchi in Fukushima Prefecture

Sampling of indoor particulates for endotoxin assay in the city of Joso after the 2015 Kanto–Tohoku heavy rain disaster

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, on behalf of central and local governments we are performing various types of urgent research into appropriate waste management.

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 in ash during the incineration of contaminated vegetation waste

Large volumes of radioactively contaminated vegetation waste (CVW) from off-site decontamination processes in Fukushima have been incinerated since 2015. We investigated the behavior of radioactive cesium (r-Cs) during the incineration of CVW at a working incineration plant. CVW incineration discharged bottom ash and fly ash with similar levels of r-Cs. Furthermore, we measured the leachability of r-Cs from both types of ash (Fig. 1). The r-Cs leachability was very low. These results differ significantly from those reported for incineration of contaminated municipal solid waste (CMSW) in earlier studies: in the case of CMSW, the r-Cs concentration in fly ash was higher and the leachability from fly ash was much higher, than those for bottom ash (Fig. 1). To understand the differences, we analyzed the elemental compositions and mineral phases. We considered that, in the case of CVW incineration, the source of r-Cs in the fly ash was mainly small particles originating from bottom ash blown into the flue gas, not the deposition of gaseous r-Cs chemicals on the surface of ash particles in the flue gas, as is observed in CMSW incineration.

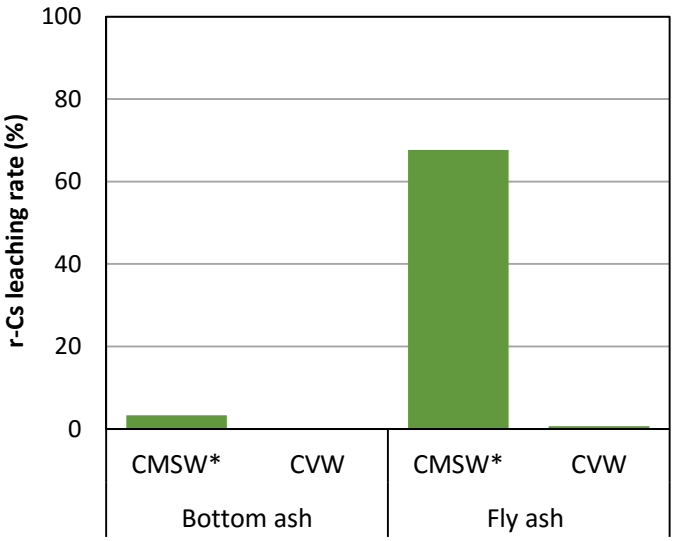


Fig. 1.
Results of leaching tests of fly ash and bottom ash. CMSW, contaminated municipal solid waste; CVW, contaminated vegetation waste. * Our previous data

2) Leachability of r-Cs from fly ash

Column leaching tests were conducted to evaluate the long-term leaching behavior of inorganic chemicals from incineration fly ash contaminated with r-Cs. The fly ash was packed into an acrylic cylindrical column 100 mm in diameter and 300 mm high. Distilled water was injected from the bottom of the column at a flow rate of 0.05 mL/min. The inorganic concentrations of the effluent were measured over time. Figure 2 shows the relationship between the liquid to solid ratio (L/S) and the effluent relative concentrations of solute. L/S was obtained by dividing the accumulated volume of effluent by the total mass of fly ash in the column. Monovalent cations in the fly ash were flushed more rapidly than divalent cations, and the leaching of cesium terminated faster than that of any other monovalent cation. The leaching behavior of r-Cs when L/S was <1 is important in evaluating r-Cs emissions.

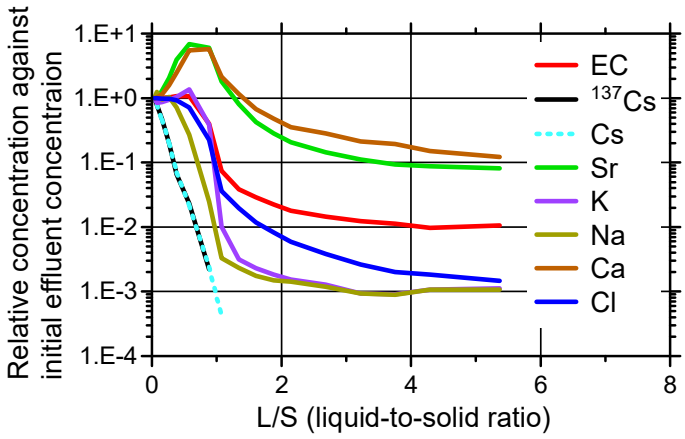


Fig. 2 Column leaching test results for radioactively contaminated fly ash

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

1) Air dose rate, accumulation, and penetration of radioactive Cs in refractory bricks in a waste incineration plant

We have been continuously surveying the air dose rates inside an incinerator plant treating radioactively CVW from off-site decontamination activities since the start-up of the plant (Fig. 3a). The dose rates at all measurement points increased with increasing operation time. Dose rates in the secondary combustion chamber and the upper part of the gas cooling tower were relatively high, whereas those in the combustion chamber were lowest. Therefore, we measured the concentration of r-Cs in the surface layers of refractory bricks at the same plant (Fig. 3b). r-Cs concentrations did not follow the same as the air dose levels. Hence we consider that another important factor—such as the deposition of radioactive materials on the inner walls of the plant—influences the air dose rates. In addition, the concentration profiles—namely the accumulation of r-Cs—up to 60 days differed from those between 60 and 180 days. The type of waste incinerated was changed after day 60. This indicates that the r-Cs accumulation rate depends on the type of waste.

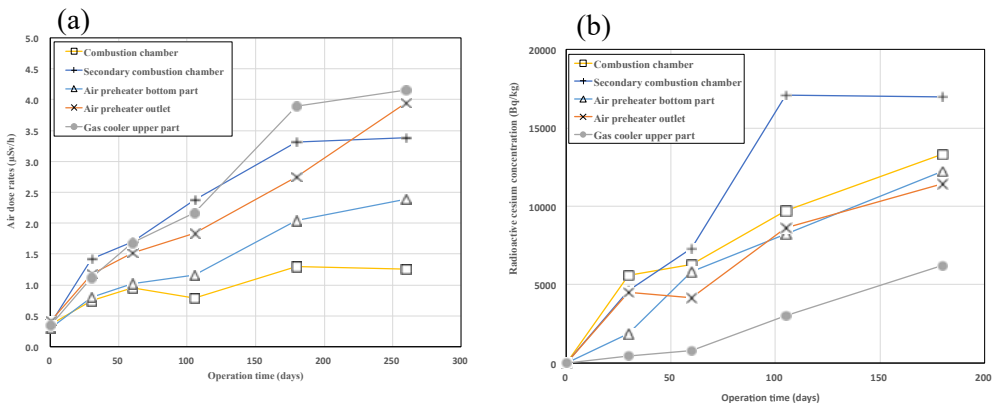


Fig. 3
Inside air dose rates (a) and r-Cs concentrations in the surfaces layer of refractory bricks (b) in an incineration plant treating contaminated vegetation waste

Furthermore, we investigated the penetration behavior of r-Cs into, and the leaching behavior of r-Cs from, the bricks. We concluded that most of the r-Cs could not penetrate deeply into the bricks and that leachability was low. These results differed from those of our previous investigation of the incineration of CMSW. Type of waste thus also affects r-Cs leaching and penetration behaviors.

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

In FY 2013 we developed a technology for removing r-Cs from fly ash. The r-Cs was removed from the fly ash and dissolved in water. Dissolved r-Cs was then concentrated by the adsorbent in a bench-scale test plant. In FY 2014 and 2015, we conducted radioactive contamination monitoring of the bench-scale plant during dismantlement of the plant. All equipment, including tanks and filters, was intensively monitored. The radiation dose rate and surface density were very low at all survey points. Our results indicated that all equipment could be transported from this plant, and disposed of, safely. We also used survey-meter and smear testing to confirm the contamination levels of the warehouse used for the

bench-scale test. No contamination was observed on the floor, wall panels, or ceiling of the warehouse (Table 1). Warehouses used for fly-ash washing can therefore be used for other purposes. To our knowledge, this is the first intensive 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.

Table 1 Contamination levels of the warehouse used for the bench-scale experiment

Survey point	Contamination level		Standard*
	GM survey meter	Smear test	
Floor	Max: 0.86 Bq/m^2	Less than 0.04 Bq/m^2	Not exceeding 4.0 Bq/m^2
Wall panels	Max: 0.86 Bq/m^2	Less than 0.04 Bq/m^2	
Ceiling	Less than 0.2 Bq/m^2	Less than 0.04 Bq/m^2	

*Ordinance on Prevention of Ionizing Radiation Hazards, Ministry of Labor Ordinance No. 41

3) Application of concrete technologies

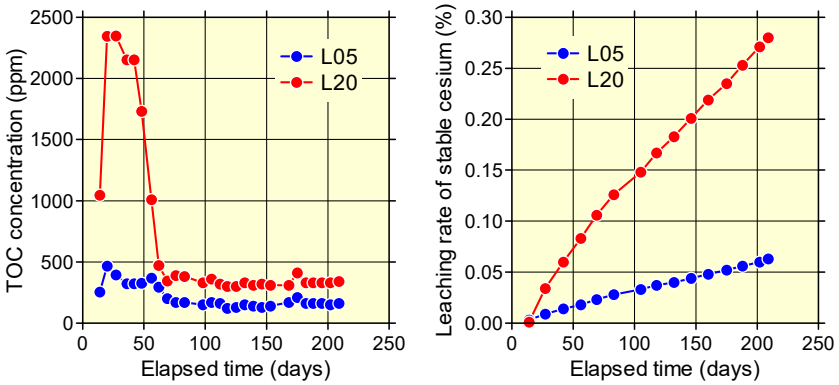
We have been investigating the depths of contamination of concrete waste with r-Cs with the ultimate aim of reducing the amounts of such contaminated waste. In the case of concrete products used in road construction, such as the concrete covers of girders, contamination is limited to the surface, regardless of the contamination level. Therefore, it is possible to decontaminate these products by removing most of the surface (e.g. with a water jet), and it is also possible to estimate the overall radiation levels of intact, thick concrete structures that are to be demolished. In contrast, in the case of some of the concrete buildings that collapsed as a result of the 2011 tsunami, r-Cs penetrated as deeply as a few millimeters. Moreover, r-Cs has penetrated through the cracks (Fig. 4). Increased concentrations of r-Cs can be seen in the β-radiograph at the far right in the figure, along a crack in the core sample. In these cases, there are no simple methods for decontamination or for the estimation of overall contamination levels.

Fig. 4
Radioactive cesium contamination of concrete (diameter of plug: 5 cm)

4) Landfill and storage technology for contaminated wastes and soils

We used two lysimeters (50 cm diameter, 200 cm high) in an experiment to clarify the influence of the organic content of removed soils on the effluent concentrations of pollutants and stable cesium in the interim storage facilities.

Each lysimeter was filled with volcanic cohesive soil mixed with 5% or 20% plants (organic materials). (The lysimeters are hereafter referred to as L05 and L20.) Stable cesium was added at 800 ppm to both soils. Tap water was added as artificial precipitation from the top surface of the lysimeters, at a constant flow rate of 20 mm/week. The measured changes in total organic carbon (TOC) concentration of the effluent and the leaching rates of stable cesium are plotted in Figure 5. The TOC concentration of L20 was greater than that of L05 during the first 50 days, whereas that of L05 was almost stable, ranging from 150 to 400 ppm over a 200- day period. Leaching rates of stable cesium increased gradually with time. The leaching rate depended on the organic content; in the case of L20, it reached 0.27% after 200 days.



(a) TOC concentration results

(b) Stable cesium leaching rate retults

Fig. 5
Changes in effluent TOC concentration and stable cesium leaching rate

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

We investigated the deposition behavior of r-Cs in the city of Fukushima in order to determine the emission sources of the r-Cs. From February 2013 to March 2015, we collected wet and dry fallout by using deposit gauges or dust jars at five sites in Fukushima city and one site in Tsukuba city in about one-month preiod in each season. The insoluble content of the collected matter was separated from the soluble content by filtration with membrane filters (pore size 0.45 μm). Surface soil samples were also collected from around these sites in September 2013. The soil samples were dried and sieved (<2 mm). The activity of r-Cs in fallout (insoluble and soluble contents) and soil samples was determined by gamma spectrometry. Elemental analysis of the insoluble content of the fallout and soil samples was performed by inductively coupled plasma optical emission spectrometry.

Our analysis of the activity in fallout samples collected in February–March 2013 revealed that 96% to 98% of the total activity was derived from the insoluble content. The temporal trends in activity in the fallout samples are illustrated in Figure 6. Deposition of r-Cs increased in the windy season (February–March).

Throughout the investigation period, deposition of r-Cs decreased to one-tenth of the value in Feb/Mar 2013. Only 50% of this decrease can be explained by the decay of radiocesium nuclei.

r-Cs activity was high in soil samples collected from around the sites where rates of deposition of r-Cs were high. The elemental composition of the insoluble content of fallout samples was the same as that of the surface soil samples. These results indicated that surface soil was an important source of r-Cs from fallout**.**

We also used imaging plates to visualize the distribution of radioactivity in the insoluble content of fallout samples (Fig. 7). The image of filters was shown as photo stimulated luminescence(PSL) intensity with brightness and value. r-Cs in the insoluble content of fallout was not distributed uniformly on the filters but was detected as highly active particles. This trend did not change with sampling site. It seemed that the more contaminated fallout samples contained more active particles.

The results suggest that a decrease in r-Cs activity in fallout can be caused by the loss of highly active particles from surface soils through erosion (weathering) or through decontamination activities.

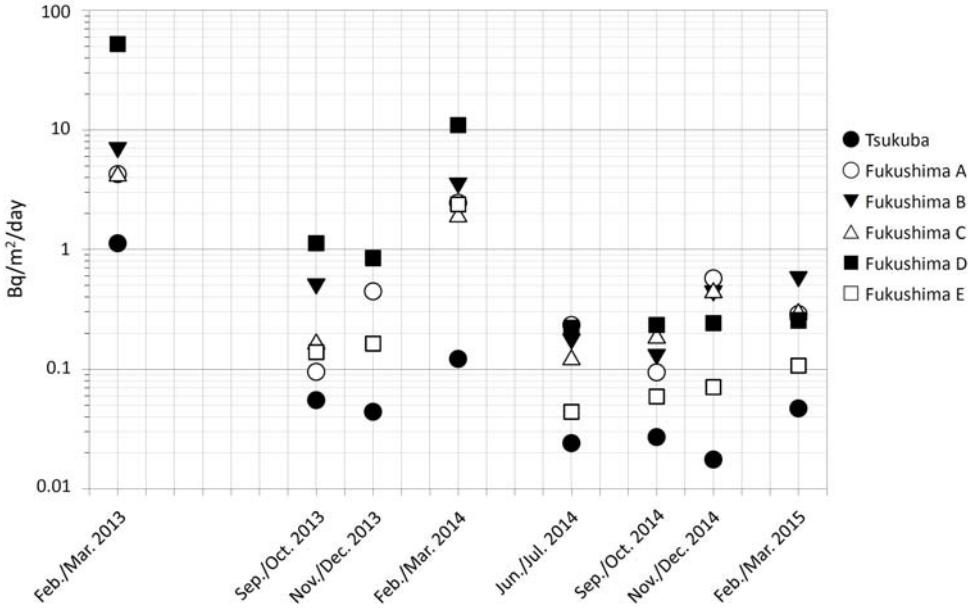


Fig. 6
Temporal trends in the deposition of r-Cs in Fukushima and Tsukuba

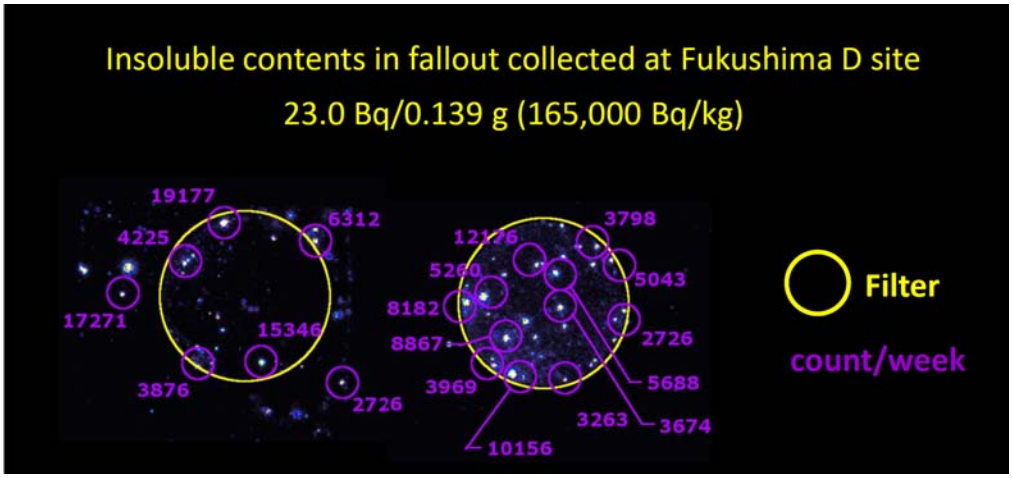


Fig.7
Distribution of r-Cs in the insoluble content of fallout. White dots show the accumulation of radioactivity.

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

We developed a Microsoft Excel–based calculation tool for analyzing macro flows of r-Cs accompanying the treatment and recycling of waste and recyclable materials (Fig. 8). The tool has a process data table that contains the input–output coefficients of waste or recyclable materials and r-Cs in each process and the rate of allocation of the outputs to the next process or use application. On the basis of the given values for the generation of, or demand for, waste or recyclable material and the amount of r-Cs contained in each material, the tool calculates the flows of waste and recyclable materials and the r-Cs flows present in them and then summarizes the results in the format of an input–output table. Users can easily modify the process data table (e.g. they can add new processes and waste or recyclable materials or modify the existing process data) by using the user-friendly interface; thus the analyzed system can reflect the actual processes. The tool can be used to conduct case studies of r-Cs flows through the treatment and recycling of waste and recyclable materials in Fukushima Prefecture.

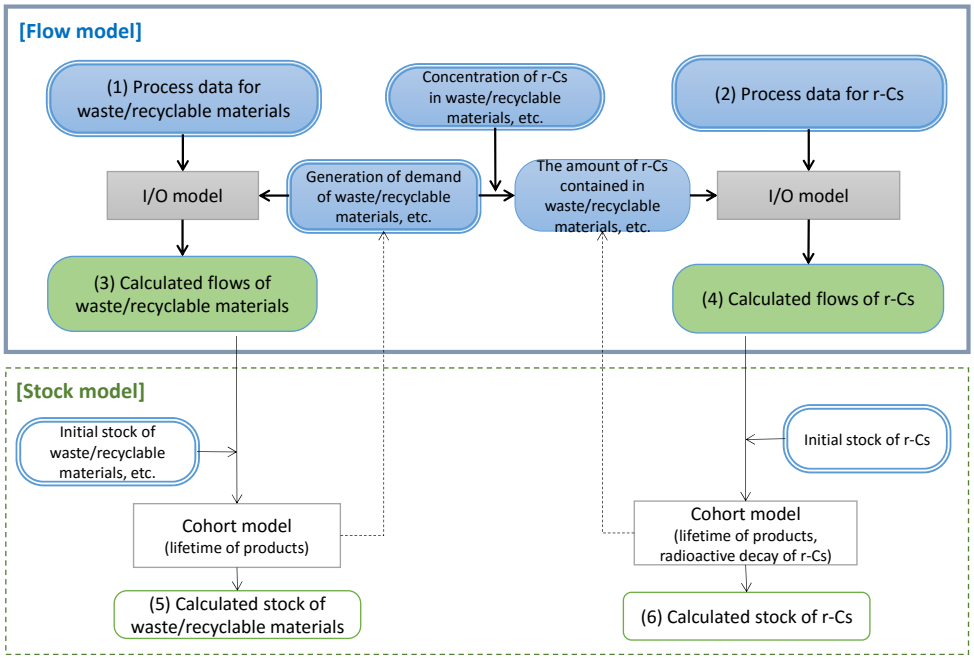


Fig. 8
Structure of the tool we developed for analyzing r-Cs flows in the treatment and recycling of waste and recyclable materials

1.5 Risk communication

1) Web questionnaire

We have been studying risk communication in the wake of the accident at the Tokyo Electric Company's Fukushima Dai-ichi nuclear power plant. This year marks 5 years since the earthquake disaster and the accident.

Last year, we performed a web questionnaire survey to investigate the relationship between the reliability of information sources and people's impressions of this reliability. This year, we performed a web questionnaire survey of reliability and people's general impressions and expectations of it.

We asked respondents to select answers from 30 adjectives in a multi-answer format. The adjectives described the impressions they would usually have, and those they would like to have, from 15 information sources (TV, radio, newspapers, books and magazines, Internet, social networking sites, family members, colleagues, parents of friends of their children, neighbors, friends, teachers, specialists/researchers, central government, local government). We collected 4215 samples from five age groups (<20, 30s, 40s, 50s, 60+). We then analyzed the relationships between reliability and people's impressions of it by using a correspondence analysis.

In all age groups, the reliability of information sources was considered highest in the case of [family]. Combination of the percentages of "highly reliable" and "reliable" gave a score of 74.4% for [family]. In terms of age group, people in their 50s or 60+ tended to believe [local government] or [central government]. Interestingly, confidence in [TV] was highest in those in their 50s or 60+.

The trustability of [experts] or [central] and [local government] was lost after the accident. However, we consider that their reliability had recovered in the 5 years since the accident.

Whereas [experts] and [central government] were categorized as "authoritative" and "academic," [local government] was classified similar to [newspapers], and keywords such as "representativeness," "quality of preservation," "fairness," and "utility" were closely related. [Family] was closely related to categories such as "same viewpoint," "being healed," "camaraderie," and "empathy." We had expected "accuracy," "rapidity," or "academic" to be high, but they were low.

From these results, we surmised that sources of impartial news and news that is close at hand are easier to trust than breaking reports or information provided by specialists.

In the case of those impressions that the respondents would like to have, the categories of "bi-directionality," "made-to-order," "conscience," "same viewpoint," and "no cost" were all equally high scoring. People did not want impressions such as "authoritative" or "academic." We interpreted this as a tendency for people to expect to obtain information close at hand and as easily as possible, and to ask for others' judgments.

2) Decision-making process in the selection of landfill sites for specified radioactively contaminated waste

Since March 2013, one council ("Yushikisya Kaigi"), which is organized by relevant experts, and another council ("Shicho-Soncho Kaigi"), which is organized by all city mayors, have been held to select and determine the only landfill site in each prefecture to receive specified radioactively contaminated waste. We investigated the decision-making process for landfill site selection by performing a content analysis of council records. In our results, we pointed out that a lack of flexibility and understanding of risk management in discussions between each stakeholder could cause difficulties in the decision-making process.

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

2.1 Behavior of dissolved radiocesium in river water in a forested watershed

We investigated the concentrations of dissolved r-Cs concentrations in river water in a high-dose-rate forest watershed in Fukushima Prefecture under base flow and storm flow conditions. Under base flow conditions, dissolved ^{137}Cs concentrations in the water [Bq/L] were higher in summer than in winter, and these levels in both seasons were higher than particulate ^{137}Cs concentrations in the same seasons [Bq/L]. On the other hand, under storm flow, the particulate

^{137}Cs concentration became dominant as the suspended solids concentration increased. Throughout the monitoring period, dissolved ^{137}Cs concentrations in the water [Bq/L] were higher under storm flow than base flow conditions and were positively correlated with runoff intensity (Fig. 9).

We also investigated the factors influencing changes in dissolved ^{137}Cs concentrations by measuring the ^{137}Cs concentration of suspended solids [Bq/kg] and the dissolved ^{137}Cs concentrations in unsaturated soil water, throughfall, and rainfall, together with other main solute concentrations. The ^{137}Cs concentration per unit weight of suspended solids in river water was not strongly correlated with runoff intensity. Additionally, dissolved ^{137}Cs concentrations were not detected in soil water, groundwater, and rainfall, whereas higher dissolved ^{137}Cs concentrations were detected in throughfall than in river water. K^+ concentrations were higher under storm flow than base flow, and dissolved organic carbon concentrations increased toward the peak flow rate. These findings suggested that one major factor influencing the generation of dissolved ^{137}Cs in the river water was leaching from organic material in flooded areas.

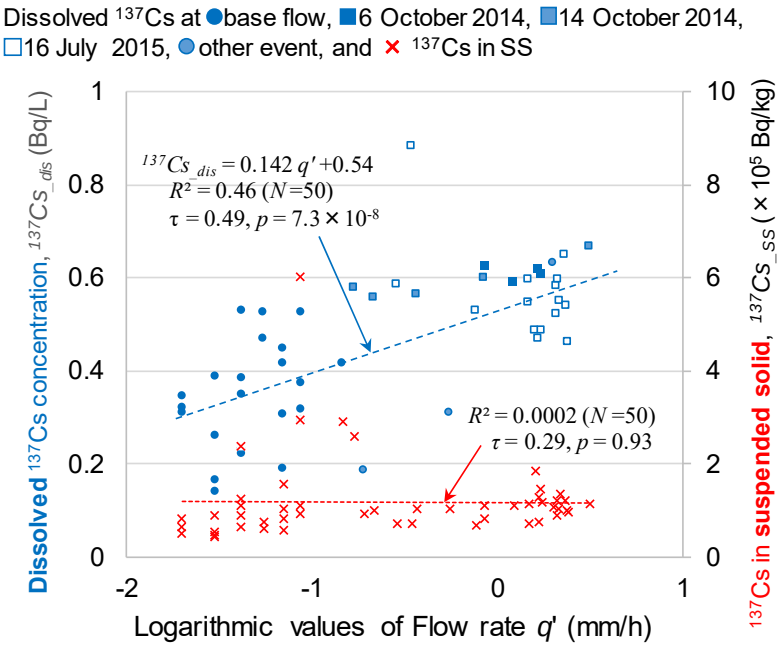


Fig. 9 Relationships between specific runoff rate (mm/h) and dissolved ^{137}Cs (Bq/L) or ^{137}Cs in suspended solids (Bq/kg)

2.2 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 fates of radioactive substances by combining the three models using appropriate geographic resolutions.

In our atmospheric modeling, we evaluated the model performance for atmospheric ^{137}Cs concentrations during March 2011 by using observational data sampled at operational air pollution monitoring stations. In addition, we made sensitivity simulations of our resuspension model. When we chose an appropriate resuspension factor, the model successfully simulated atmospheric ^{137}Cs concentrations over the 2 years after the Fukushima accident. We found that resuspension was the dominant source of atmospheric ^{137}Cs several months after the accident.

In our terrestrial modeling, we analyzed temporal changes in the relationship between depth distributions of ^{137}Cs in surface soils and air dose rates. We found that downward penetration of ^{137}Cs could contribute greatly to a decrease in the air dose rate. We also developed a 1-D model to predict the fate of ^{137}Cs in forest soils. The model predicted the distribution of ^{137}Cs in each soil component, as well as the ^{137}Cs depth profile, taking into consideration different tree species. In addition, we simulated daily changes in environmental conditions and the related fates of ^{137}Cs in the Abukuma River basin and other basins in the Hamadori region of Fukushima Prefecture. We obtained good agreement between the simulated flux of ^{137}Cs and field observations.

In our oceanic modeling, we simulated oceanic ^{137}Cs behavior in and around the shelf off Fukushima and adjacent prefectures for about 4 years after the Fukushima accident. This simulation also evaluated the sensitivities of sedimentary ^{137}Cs to the following three inflows: atmospheric deposition, direct discharge from the accident, and river runoff. The atmospheric deposition and river runoff data were obtained from the results of simulations using the above-mentioned atmospheric and terrestrial models. The sensitivity analysis indicated that 68% of the total sedimentary ^{137}Cs as of the end of 2011 was derived from direct discharge, whereas 32% was derived from atmospheric deposition. The influence of river runoff was negligible. A long-term simulation revealed that the rate of decrease in the sedimentary ^{137}Cs in and around the shelf was very slow (3.2% per year)—only 1.4 times the physical decay rate.

2.3 Monitoring terrestrial biodiversity, and a preliminary report on a data analysis of flying insects in the Fukushima area

Terrestrial biodiversity monitoring by NIES started in 2014 and aims to yield information on the biodiversity and ecosystem effects of large-scale and long-term evacuation of the Fukushima area. The obtained information can support the return of residents, who enjoyed multiple ecosystem services before the nuclear accident. To conduct relatively long-term monitoring effectively with limited effort, we decided to focus on mammals, birds, frogs, insects, vegetation, and land cover/land-use change. Below we give a preliminary report on our analysis of insect data.

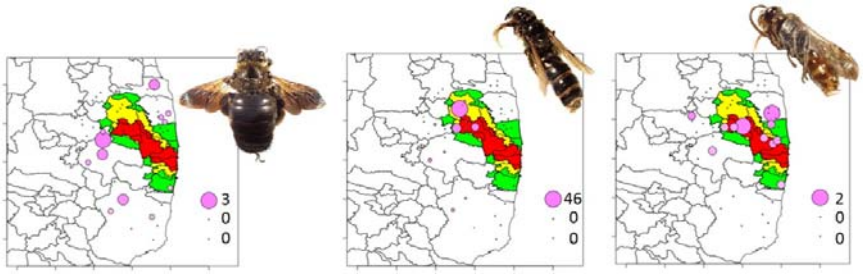
From mid-May to early July in 2014, we conducted sampling using Malaise traps (Fig. 10) at 52 sites inside and outside the evacuation zone. A Malaise trap is a tent-like trap targeting a broad range of flying insects. It can be used to investigate the numbers of important pollinators such as the Apidae and of medically important pests such as flies. However, at five sites we found that the traps had fallen over and the sampled insects had spilled out of the bottles. Therefore, only the samples from the remaining 47 sites were used in the analyses.

A total of 48,081 insects and spiders were sampled from the 47 sampling sites. Most were Hymenoptera and Diptera (16,583 and 20,082 individuals, respectively). In total, 46 taxonomic and caste groups (6 orders and 10 families of butterflies and moths; 12 species and 5 genera of bees and wasps; total winged ants, total worker ants, workers of 8 ant species [including a polygynous species], and queens of 1 ant species) were found at more than 5 sites and were used in the subsequent analyses. In the analysis, we used a Bayesian statistics technique to examine the association between the evacuation zone and the abundance of these taxa.

Fig. 10 Malaise trap for sampling flying insects

We found that the abundance of carpenter bees, *Xylocopa appendiculata*, was lower within the evacuation zone than outside, whereas those of most of the other collected taxa, including pollinators, were higher or not different. Considering previous studies of insects and radiation levels (in which radiation levels were less than several dozen microgray per hour) in the evacuation zone, it is unlikely that the radiation has acutely damaged the bee population. Alternatively, a potential cause of the reduced population density of the carpenter bee in the evacuation zone (Fig. 11) might be a reduction in the numbers of flowers of garden plants following the evacuation. *Xylocopa appendiculata* favor large and conspicuous flowers such as wisteria, orchids, and passionfruit. On the other hand, the higher density of small bees and other insect groups inside the evacuation zone may be due to “release of resources”—that is, the cessation of farming,

which was previously dominant in the lowland areas of the evacuation zone, may have increased the abundance of wild plants that provide food and nesting materials for these species.



Xylocopa appendiculata *Ceratina flavipes* *Nomada spp.*

Fig. 11 Examples of abundance of insects collected at each sampling site. Sizes of the pink circles correspond to the abundance of taxa. Green, yellow, and red zones correspond to the subzone preparing for the lifting of the evacuation order, restricted residential areas, and the subzone to which it was difficult to return, respectively.

Although these results suggest that flying insects and their ecosystem services (e.g. ecosystem benefits such as pollination) 3 years after the disaster (i.e. in 2014 at the start of monitoring) were not critically affected, it is important that we monitor the long-term effects of the evacuation. In 2015, to make the monitoring more efficient, we introduced flight-intercept traps (Fig. 12) at all the monitoring sites. In addition, the Malaise traps have remained. Furthermore, we are considering developing other sampling techniques that will use digital devices to cover insect groups that cannot be detected by either malaise traps or flight-intercept traps.

Fig. 12 Flight-intercept traps for sampling pollinators efficiently

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

To estimate additional radiation doses from the Fukushima incident and exposure sources, we are using a combination of environmental measurements and exposure models.

(1) We measured r-Cs concentrations in house dust samples collected from

Fukushima and Tsukuba to estimate the radiation exposure from each source (Fig. 13a). The concentration of r-Cs has gradually decreased from soon after the accident to the present day; however, concentrations of several hundred Bq/kg of r-Cs were detected even 5 years after the accident. The majority of the ambient air samples from two sites in Iitate in 2015 did not exceed 0.001 Bq/m^3, meaning that the estimated inhalation dose is less than 0.001 mSv/year (Fig. 13b).

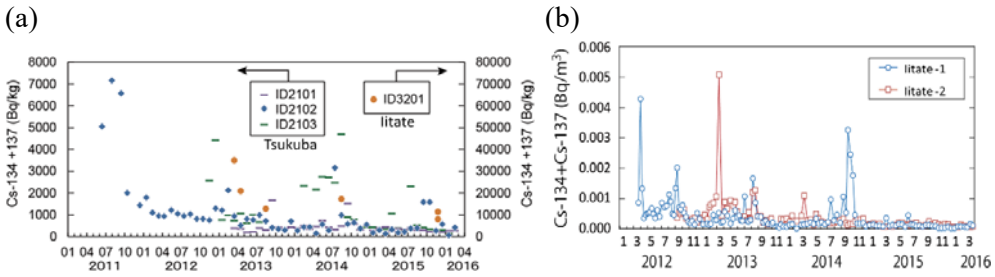


Fig. 13
Temporal changes in radioactive cesium concentrations in house dust collected from residences in Tsukuba and Iitate (a) and in ambient air collected in Iitate (b).

(2) We have developed numerical exposure models for both external and internal exposure to estimate the radiation doses of residents in eastern Japan. Diet, indoor air, indoor dust, outdoor air, and soil were considered as potential sources of internal radiation doses. The models were built by using a set of data that we collected, as well as datasets provided by other institutions. To refine the model, we measured the effects of decontamination and snow shielding. Snow shielding was calculated from the relationship between depth of snowfall and the decrease in the air dose rate in winter (Fig. 14). The provisional shielding factor was determined to be −0.07/10 cm snowfall.

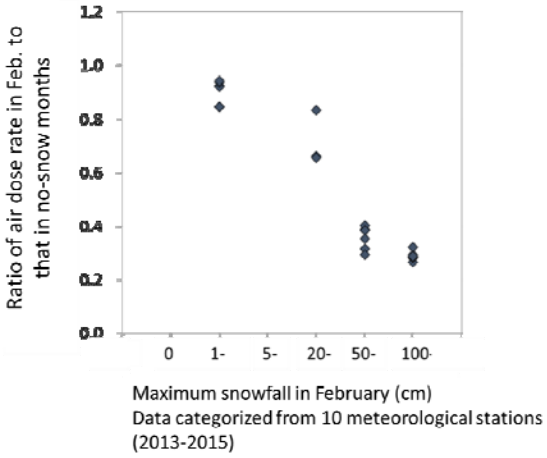


Fig.14 Relationship between depth of snowfall and shielding factor

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

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

On the basis of real energy-consumption data from regional information and

communication technology (ICT) systems implemented in the town of Shinchi, in Fukushima Prefecture, we have developed a time-space disaggregated database reflecting regional characteristics. We are creating a basic framework for an "energy and environmental technology design-support system," which can identify a suitable technology combination for energy supply–demand characteristics at a district scale (Fig. 15). We are applying it to energy infrastructure planning as part of the Shinchi-station District Redevelopment Project, which is expected to start next year.

The energy cost-saving and CO_2 emission reduction effects obtained by using the design support system were evaluated quantitatively (Fig. 16). These result data were utilized in a preparatory analysis as part of applications for research funding for a project feasibility analysis; such funds are supplied by the Green Plan Partnership project of the Ministry of Environment and the Smart Community Planning project of the Ministry of Economy, Trade, and Industry. Having developed a regime for the joint study of distributed energy systems in collaboration with municipalities and energy-related companies, we have sophisticated the design-support system and prepared an inventory database based on actual technology information. Furthermore, we have improved a system for handling the reutilization of waste heat from industry and biomass energy and demand side management.

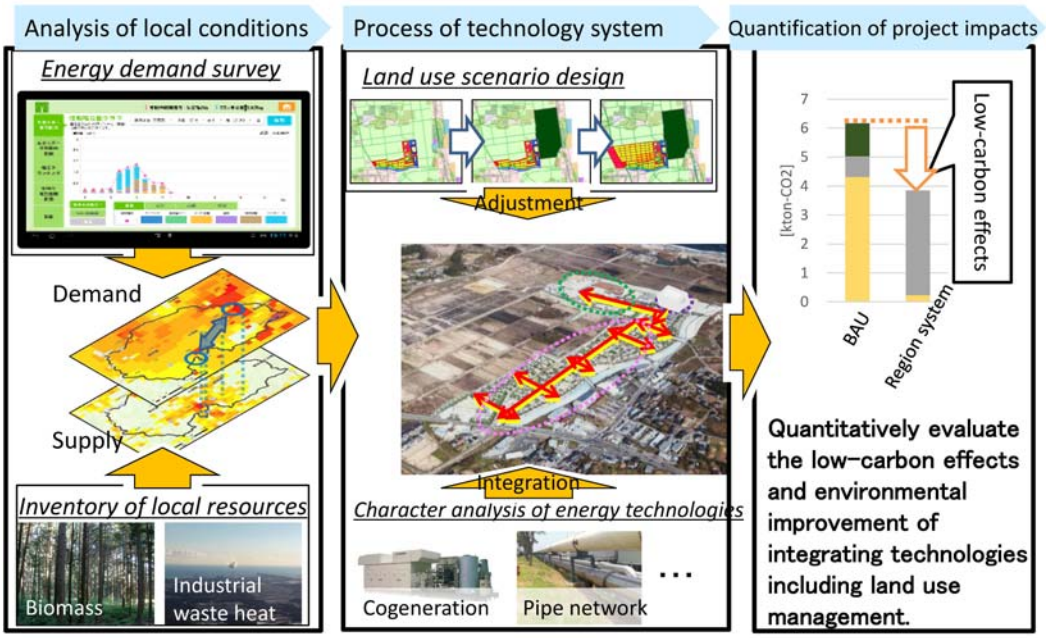


Fig. 15 Basic framework of the environmental and energy technology design-support system

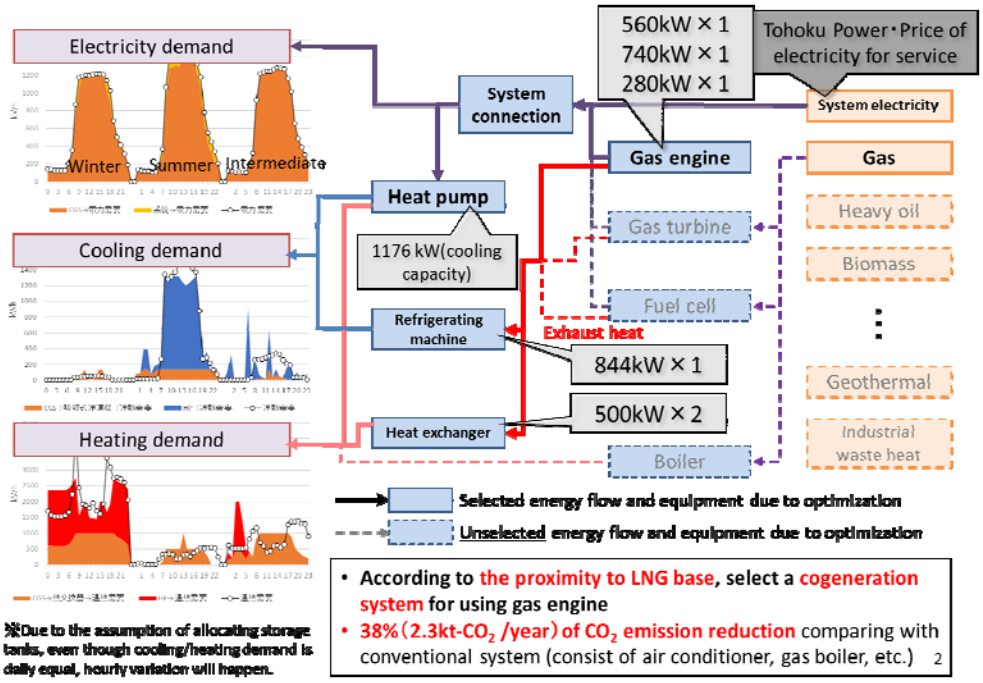


Fig. 16 Pilot design analysis for the Shinchi-station area

3.2 Integrated modeling for long-term development after recovery from the Fukushima disaster

We have improved the ExSS (extended snapshot tool) for Fukushima Prefecture, so that we can see the contribution of each policy to population increase and a low-carbon society. The improved tool describes demographic variables (birth rate, death rate, immigration, and emigration), employment structure, employment opportunities in the surrounding area, and constraints of supply of residential buildings. Through scenario studies with given assumptions, the model can identify a scenario that achieves a given population target and can then quantify the target levels and contributions of policy programs such as industrial policy, residential policy, and childcare policy needed to achieve that target. We used the AIM/Enduse model to analyze contributions to low-carbon effects. The model uses population and industrial activity, as projected by ExSS, at given levels, and it then introduces economically reasonable energy technologies to achieve a low-carbon target. By coupling the results of AIM/Enduse and a decomposition analysis, we can project the GHG emission reduction of each technology or policy. We have developed a framework to find the relationships between policy programs and the opinions of residents, taking into account the targets of the policies, the time needed to implement them, and the main bodies that implement them. These methods were applied to the town of Shinchi, in Fukushima Prefecture. Several scenarios were developed to support the formulation of a population vision and comprehensive development plan for the town.

For analyses using an energy system model, we have developed a decomposition

methodology to estimate power demand by appliance usage from the total power demand of a household to estimate power demand by time and appliance usage. We combined an engineering approach and a statistical approach and developed a hybrid method. The engineering approach estimates the power demand of each appliance by considering the behavior of the household member at each time of day and use of the equipment. The statistical approach applies a multiple regression analysis of total power demand, ownership of equipment, and other factors. The hybrid method can be used to estimate total energy demand and its seasonal variations with increased precision, including details of appliance usage. The method was applied by using household power consumption data obtained by the local ICT system (a tablet device and power monitoring system, see 3.3) . Power demand by time and appliance usage in the region was revealed. In addition, we estimated the potential for households to save energy by using energy-saving-information services.

3.3 Local planning support system through multi-stakeholder communication development

We conducted a continuing verification test of the local ICT system, which was developed in Shinchi in 2014. Seventy-five households are now participating in the test. With this system, users can view various types of local information via a tablet. We improved the functionality of the system by analyzing feedback from the participants. For example, the system is now also available from sources other than the tablets that were distributed. In addition, we continued a questionnaire survey on quality of life using the system, and we clarified issues related to function and operation of the system.

We collated the results of a workshop that was held in 2014. The workshop participants were 88 second-grade students from Shoei junior high school. The theme of the workshop was “Let’s think about Shinchi in 2050.” We prepared a pamphlet about this workshop and distributed it to teachers and students.

We conducted interviews of woody biomass stakeholders and used the results to classify the flows of wood, costs, and money. We also gave some thought to optimum allocation of the use of electricity and heat from timber obtained from forest thinning. In addition, we conducted a web-based questionnaire survey intended to determine and analyze the current status of woody biomass use in households.

4. Environmental Emergency Management Research Program on “Establishment of an environmental management system in preparation for future disasters”

Our Environmental Emergency Management Research Program aims to establish practical management systems and technologies for handling disaster debris

during and after disasters. It also aims to develop a strategy for environmental and health risk management in times of emergency in order to create more resilient social environmental systems and foster the associated communities.

4.1 Quantitative and qualitative disaster debris management systems

We previously developed a prototypic Web GIS system for quantitative disaster debris management. With this system, the amount of disaster debris can be estimated and displayed on a map by using an estimation procedure based on per-unit generation of disaster debris, building fragility curves, hazard data, and census data. The system also enables us to simulate disaster debris disposal progress within predetermined disaster debris management scenarios.

Through the development and initial testing of this prototypic Web GIS system, we were able to analyze the system's ideal overall structure. It was suggested that some subsystems (including a progress management system, information sharing system, debris transportation simulation system, and disaster response tasks management system) should be embedded in the main system that enables us to estimate the amount of disaster debris.

4.2 Establishment of disaster waste management technologies and systems

1) Evaluation of an intermediate treatment technology for disaster waste
We conducted an experiment to identify the major factors affecting the speed and accuracy of hand-sorting of mixed disaster waste and construction and demolition waste. Artificial plastic and cement cubes waste samples were arranged on a 1 × 1m field on a desk. We recorded the speed, order, and motion of hand-sorting, and the items sorted, by several subjects during a given period of time. No apparent relationship between the properties of the samples (such as visual attractiveness, weight, and size) and the speed of recovery was observed under the conditions in this experiment. During the hand-sorting operation, subjects tended to search for and pick up samples near the recovery box or boxes. When they were directed to sort a larger number of items, the speed of hand-sorting increased. These findings indicated that the range of operation and the number of items to be recovered affected the efficiency of hand-sorting.

2) Studies of the proper management of asbestos in disaster waste treatment
From December 2015 to March 2016, we conducted a series of air-monitoring studies using airborne fibers at a disaster waste depot located in a "zone in preparation for lifting of the evacuation order." Air samples were collected on membrane filters by using low-volume air samplers near a dump of concrete debris at the depot and also on the boundary of the site. Fibers deposited on the filters were counted under phase contrast microscopy. Total fiber concentrations were <0.056 to 0.73/L and increased in dry and windy conditions. We found that the scattering of asbestos and other fibrous materials as a result of disaster waste

treatment was small, because the total fiber concentrations were as small as the background levels obtained in the Ministry of the Environment's air-monitoring campaign.

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

Demonstration embankments 3 m high were constructed by using tsunami deposits. We monitored the physical properties of the deposits and the environmental impact of the contaminants released from them in order to acquire basic information for utilizing the secondary soils. Use of the new ignition-loss test method was proposed to estimate the wood content. Furthermore, we investigated tsunami deposits utilized at construction sites in the Tohoku area.

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

To develop and standardize earthquake-resilient construction and installation techniques for *johkasou* domestic wastewater treatment plants, we analyzed the stress on *johkasou* during earthquakes by use of a finite element model. We also conducted interview surveys of seven local governments to clarify the problems related to human waste and sludge collection, transportation, and treatment in emergency situations. According to the interviews and local disaster management plans, setup of temporary toilets was planned in all local government areas, but human waste collection and treatment were not mentioned in detail. Therefore, it is important that we establish ways of estimating human waste generation and the required numbers of vacuum trucks. The mathematical model that we developed in a previous study for human waste and sludge transportation to sludge treatment facilities would be of practical use.

4.3 Disaster waste management methods

On the basis of theories of policy implementation and emergency management, we analyzed past and current practices of disaster waste management and disaster waste preparedness planning. The results suggested that preparedness planning for disaster waste management will enhance smooth and appropriate disaster waste management. This will be done through the prescribing of basic pre- and post-disaster waste-management actions, through the assembly of information useful in post-disaster actions (such as per-unit data on debris generation), and through learning of disaster waste management skills by officers. We also studied the public perception of environmental issues during disasters, including those related to disaster waste management, by conducting a series of interview surveys and focus group interviews. The results indicated that the public were concerned about various environmental risks during disasters, including odor, pests, asbestos dispersion, and loss of places in which to enjoy nature. The results also highlighted a variety of factors related to the perception of such risks.

4.4 Networking of disaster and environmental emergency research

We improved our online information platform for disaster waste management. The new content includes flash reports on disaster waste management cases (e.g. the 2015 Kanto–Tohoku heavy rain disaster), reports on past disaster-waste management cases (e.g. the 2014 Hiroshima landslides), and some new learning materials, including an introductory video clip for those who are new to disaster waste management.

We held a workshop and a table-top exercise in collaboration with Hyogo Prefecture to develop participatory training methods for disaster waste management. We analyzed the effectiveness of the workshop in developing ownership and positive attitudes among the public officers responsible for disaster waste management. The results showed that workshops in which issues and their solutions are discussed in small groups are effective in enhancing positive attitudes towards preparedness actions for disaster waste management. However, no impact on ownership was observed. The findings highlighted the significance of designing participatory training methods according to their aims and the characteristics of the participants.

All of these practical research activities helped to enhance the practical and academic network that will potentially contribute to future disaster responses. This was demonstrated partially in the response to the 2015 Kanto–Tohoku heavy rain disaster, where experts on disaster waste management (including those at NIES) helped the city of Joso to tackle issues related to flood waste management.

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

1. IT support for research and related activities at NIES

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

1.1 Management and operation of computers and related systems

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

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

Fig. 1 The NEC SX-ACE supercomputer

1.2 Use of IT to improve work efficiency at NIES

The department provides IT support to the administration and planning divisions of NIES with the aim of increasing work efficiency. It also provides NIES researchers with processed research data and helps them to disseminate their data through the NIES website. In FY 2015, 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 services

As of March 2016, the NIES library (Fig. 2) held 64,526 books, 316 journals (including electronic resources), and various other technical reports and reference materials. These materials can be searched by using OPAC (Online Public Access Catalog) and a link resolver via the Intranet.

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

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

Fig. 2 The NIES library

2. NIES public relations activities

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

2.1 Management of the NIES website

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

Fig. 3 The NIES website

2.2 Editing and publication of NIES reports

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

3. Other activities

3.1 Collection, processing, and dissemination of environmental information

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

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 such things as environmental issues in Japan and throughout the globe; descriptions of key environmental technologies; information on policies and laws in environmental fields; environmental information via GIS; and other content to aid environmental learning.

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

3.2 Tasks commissioned by the Ministry of the Environment

In FY 2015 the department performed the following task, as commissioned by the MOE:

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

Inquiries:
International Coordination Office
Telephone:＋81-29-850-2827
Facsimile:＋81-29-851-2854
E-mail:international@nies.go.jp

National Institute for Environmental Studies
16-2 Onogawa, Tsukuba, Ibaraki 305-8506, JAPAN
http://www.nies.go.jp/

NIES Publications
http://www.nies.go.jp/kanko/index-e.html

Editorial assistance: MAEDA Printing Co., Ltd.